SAVA

WHITE BOOK

THE RIVER SAVA:
THREATS AND RESTORATION POTENTIAL

save the blue heart of europe

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Cover photo in SAVA: Sava upstream Rugvica in Croatia (© Goran Šafarek)
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PREFACE

The future of the Sava

The Sava is one of the most interesting and complex rivers in Europe. It originates in the Slovenian mountains and flows into the Danube in Belgrade. In between – along its course of 926 kilometres – the Sava features the entire spectrum of different rivers habitats. Together with tributaries such as the Ljubljanica, Kupa, Una, Vrbas, Bosna, and Drina, the Sava basin constitutes one of the best preserved and most diverse river systems in Europe: from narrow gorges, to areas with extensive gravel banks, to huge alluvial forests with oxbows and species-rich alluvial meadows. Accordingly varied is its biodiversity: from the huchen to the white-tailed eagle, from little tern to spoonbills and white storks – all of them can be found in the Lonjsko Polje Nature Park.

Unfortunately, like so many other European rivers, the Sava stands at a crossroad. The challenges are immense: on the one hand improving the ecological condition of water bodies is a clearly defined goal of the European Union. On the other hand, flood protection, recreational use and transport capacities, etc. are to be increased as well. How can these conflicting commitments be reconciled? Any changes to the river in the upper reach have implication for the middle and even the lower course. A Slovenian hydropower plant trapping gravel and sand, for instance, leads to river incision downstream in Croatia. Large-scale gravel extraction at the tributaries Drina or Vrbas result in negative effects on the Sava. Constructing flood dikes automatically aggravates flood risks downstream.

In which direction is the Sava going? This is the very question we asked ourselves within the context of the "Save the Blue Heart of Europe" campaign. Our answer is this White Book. It shall serve as an extensive and comprehensive overview of the situation of the Sava. However, what makes this White Book truly unique is that it is the first study offering suggestions for area-specific ecological flood control and river restoration projects. In other words, we show where former alluvial areas could be naturally flooded once again and in which sections the Sava's river bed should be given more space.

Huge floods on Rhine, Oder, Elbe, Danube and Sava in recent years clearly revealed the necessity to work in accordance with nature instead of against it. This White Book shows how it could be done.

On a final note, we want to express our thanks to Dr. Ulrich Schwarz for the preparation of this extraordinary document.

Ulrich Eichelmann

Gabriel Schwaderer

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ACRONYMS AND ABBREVIATIONS

BA	Bosnia and Herzegovina
CEN	European Committee for Standardisation
ECE	UN Economic Commission for Europe, Inland Water Transport
FD	EU Floods Directive
FFH	EU Habitat Directive
HMWB	Heavily Modified Water Body after WFD
HPP	Hydropower plant
HQ_{max}	Maximum discharge
HQ100	100-year discharge
HR	Croatia
HYMO	Hydromorphology
IBA	Important Bird Areas (designated by BirdLife International)
ICPDR	International Commission for the Protection of the Danube River
ISRBC	International Sava River Basin Commission
MQ	Mean discharge
m^3/a	m^3 per year (for sediment transport in rivers)
m^3/s	m^3 per second (for discharges in rivers)
PA	Protected Area
RS	Serbia
SI	Slovenia
SPA	Special Protected Areas
WFD	EU Water Framework Directive

EXECUTIVE SUMMARY

The Sava White Book gives an extensive and comprehensive overview of the current situation of the Sava river and is intended as a resource for building a vision for the future. However, what makes this White Book truly unique is that it offers suggestions for area-specific restoration projects of great potential value for flora and fauna as well as for the people that live along the river.

The river Sava is the largest tributary of the Danube by discharge. It has a catchment area of over 97,800 km² and a length of 926 km (if considering the longer of two source branches, the Sava Dolinka; see Figure A). Its average discharge at the confluence with the Danube is 1,570 m³/s. The middle and lower Sava is internationally recognised for its huge hardwood forests, the large near-natural flood retention system around the famous Lonjsko Polje Nature Park in Croatia, and the Obedska Bara Nature Reserve in Serbia. The river attracted international attention due to a historic flood in 2014.

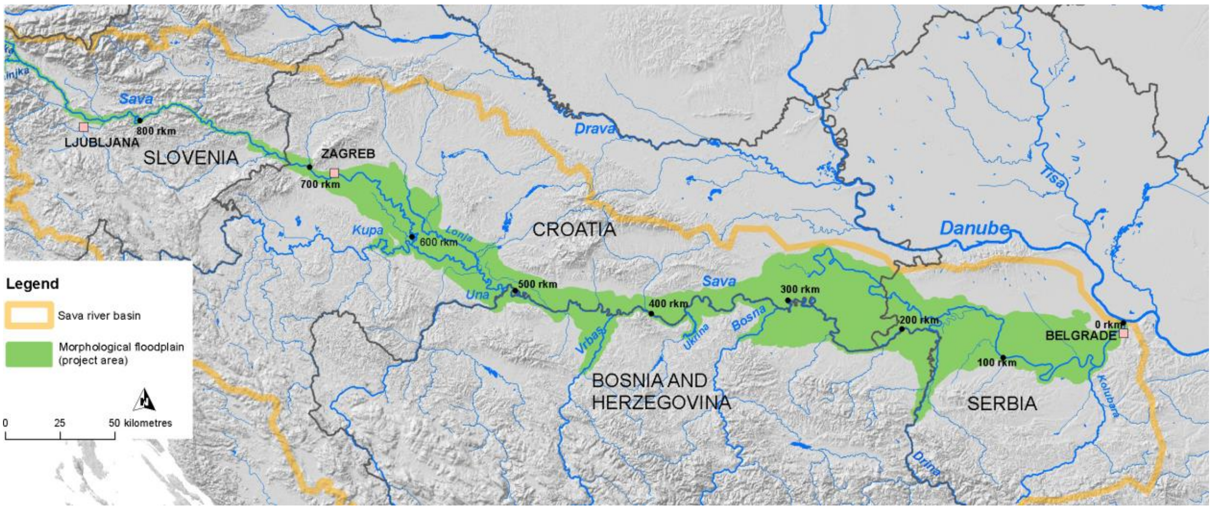


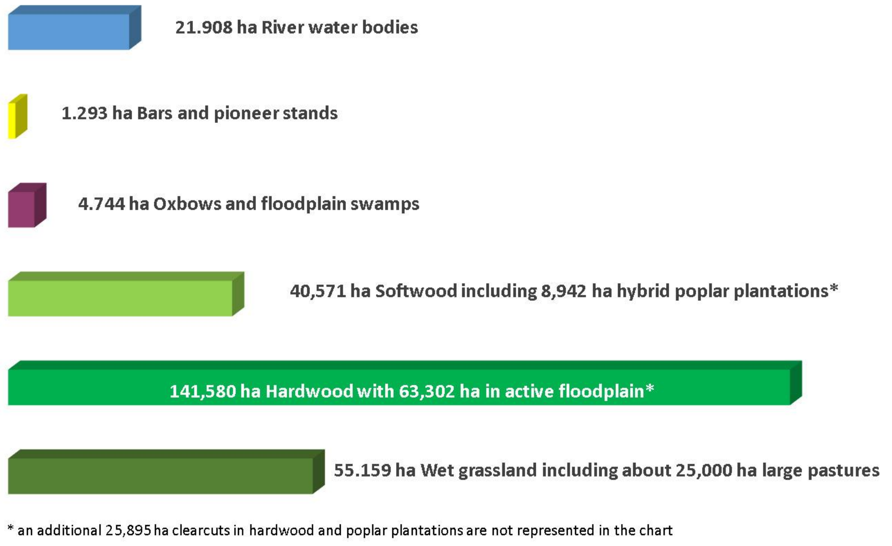
Figure A. The morphological floodplain of Sava river with the Sava and its tributaries.

The alpine upper Sava in Slovenia crosses several breakthrough stretches and small basins, and today is partially impounded by hydropower dams. Below Zagreb, the Sava valley is broad and the river continues with a small gradient all the way to the confluence with the Danube in Belgrade. The character of this meandering lowland river reach is influenced by the southern tributaries, which include the Kupa, Una, Vrbas, Bosna and Drina. At its lowest course, starting about 100 km upstream the confluence with the Danube, the Sava is influenced by the backwater of the Danube dam Iron Gate I.

1. Current situation

Land structure: The lower Sava valley hosts large alluvial ash, oak and poplar forests, mainly managed by state forestry companies. In addition, willow softwood galleries prevail along all banks. Numerous oxbows, floodplain swamps and wet grasslands characterize the river system. Together with faster flowing southern tributaries featuring numerous gravel bars, these rivers build a unique riparian corridor with rich landscapes and diverse habitats for many species.

The outstanding number of hardwood forests, totalling 63,300 ha in the active floodplain and another approximately 78,000 ha outside the flood dikes, as well as the large intact wet pastures within the active floodplain (about 25,000 ha) are of particular importance. In addition, pioneer stands on gravel bars cover up to 1,300 ha (mainly along southern tributaries) and are important for the whole river landscape, but particularly for the lower Sava.



Figures B. Areas of riparian land structure types with high ecological value (in total about 265,000 ha).

Hydromorphology: The hydromorphological assessment describes how human activities have altered the natural shape and flow of the river and document the modifications of the riverine landscape. Since some hydromorphological processes, such as incision of the riverbed, have very gradual effects on the river ecosystems, it is important to know about modifications of the past. Many large European river stretches fall in the range *moderately modified* to *extensively modified* (classes 3 and 4, respectively) of a five class assessment system developed for the EU Water Framework Directive (WFD). Impoundments have the lowest scores and fall into class 5. The Sava performs much better in the classification: 53% of it falls into class 2 (*slightly modified)*, predominantly in its long free-flowing middle stretch and some in its free-flowing upper stretches. A total of 4% is rated as class 1, *near-natural* (Figure C): this comprises a long gorge stretch on the upper Sava and some very short stretches in the meandering middle river reach.

This study's findings for the middle and lower Sava and its large southern tributaries contradict the official intention of the countries (International Sava River Basin Commission) to designate all of these stretches as *heavily modified water bodies (HMWB)*, a classification that could potentially justify further significant alteration (e.g. hydropower, navigation).

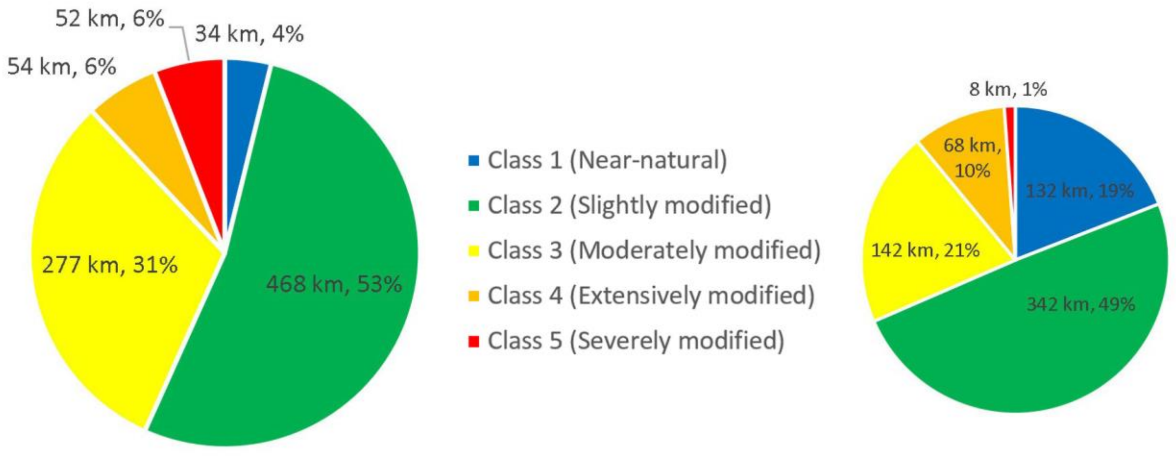


Figure C. Overall hydromorphological assessment of the Sava (left) and its tributaries (right).

Protected areas and biodiversity: The ecological importance of the Sava and its floodplains is reflected by the significant number and size of protected areas; about 36% of the morphological floodplain[1] (322,875 ha) and 64% of the Sava river course (excluding headwaters) are designated as protected areas. The most prominent are the Lonjsko Polje Nature Park in Croatia and the Obedska Bara Nature Reserve in Serbia, both of which are Ramsar sites. In addition, large stretches of the Sava and tributaries in Croatia as well as some stretches in Slovenia are Natura 2000 sites. Furthermore, the Sava basin is a pan-European biodiversity hotspot, hosting about 250 breeding bird species (e.g. little tern, spoonbill) or endangered fish species such as the huchen, the Cactus roach and the sterlet.

Floodplain loss: Along the Sava and its tributaries an area of merely 2,067 km² can still be flooded (active floodplain), while originally, the morphological floodplain area was as large as 8,943 km². This reveals a total loss of 77%. This ratio is comparable with that for the Danube or any other large river in the region. However, there are significant local differences along the Sava. In the middle Sava in Croatia, more than 60% of former floodplains are still active, allowing for a significant capacity for water retention during floods. This part of the Sava represents a unique example of large-scale natural flood mitigation and could function as a blueprint for other river stretches. However, downstream the Bosna confluence, almost 85% of the original floodplains are cut off from the active floodplain. This was the area where the historic flood wreaked so much damage in 2014.

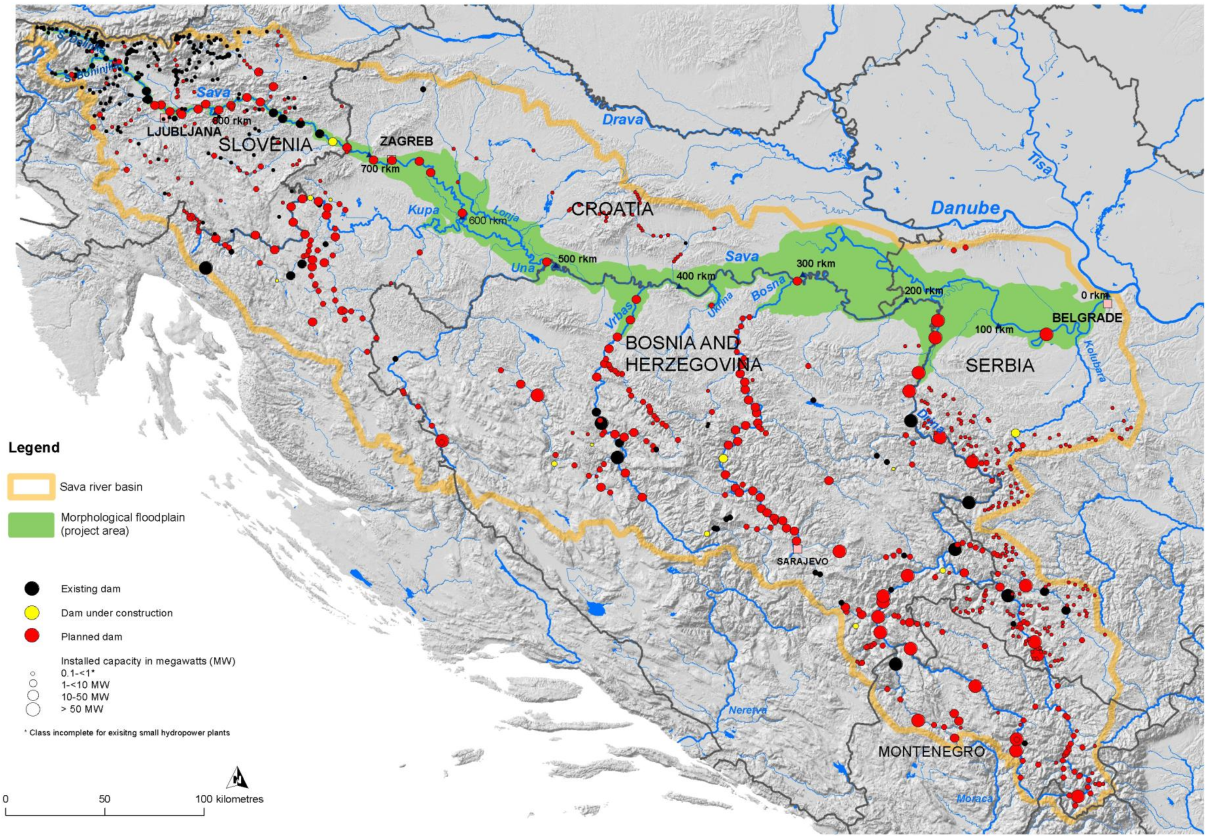
Natural flood mitigation: Flood defences became a heightened priority after the 2014 historic flood along the middle and lower Sava. Seven major dike breaches between the Bosna and Drina confluences flooded large areas in Bosnia and Herzegovina and areas south of the Bosut forest on the Croatian side of the river. This highlights the absence of retention capacity and the negative effects of the disconnected floodplains in this reach of the Sava. The flooding of Obrenovac in Serbia, caused mainly by dike failure on the Kolubara tributary and low retention capacities in the adjacent Sava, must be seen in the same light. In strong contrast stands the Upper Posavina flood system (Croatia) with a retention capacity of 1.6 billion m³ which is sufficient to protect the towns of Zagreb (bypass into Odransko polje), Sisak and Jasenovac. This retention system is capable of topping off the peak discharges in the Sava at up to 1,500 m³/s, significantly lowering peak water levels downstream. Unfortunately, all countries affected by the 2014 flood event are now focussing on the reconstruction and reinforcement of existing flood defence dikes and have not formulated ambitions to reconnect retention areas to the flood regime, with the exception of an area close to the Bosut mouth that is intended as flood storage polder.

2. Threats

The many **hydropower** projects in the Sava river basin constitute one of the greatest sources of pressure on the river. Proposals for a total of up to 582 new dam projects have been identified (Figure D). Dams on the tributaries would have a severely negative impact on the Sava, where they would cause river bed incision by holding back sediments. A total of 88 hydropower projects are planned within huchen stretches. If implemented, this would lead to a decline of the Balkan population by at least 70%.

Twenty new hydropower projects are envisaged for the Sava alone, adding to the seven already existing (and one under construction). Most projects are located in Slovenia, however there are also dams projected in the almost entirely free-flowing middle and lower Sava and in all major tributaries.

[1] The morphological floodplain is defined as maximum area originally influenced by floods.



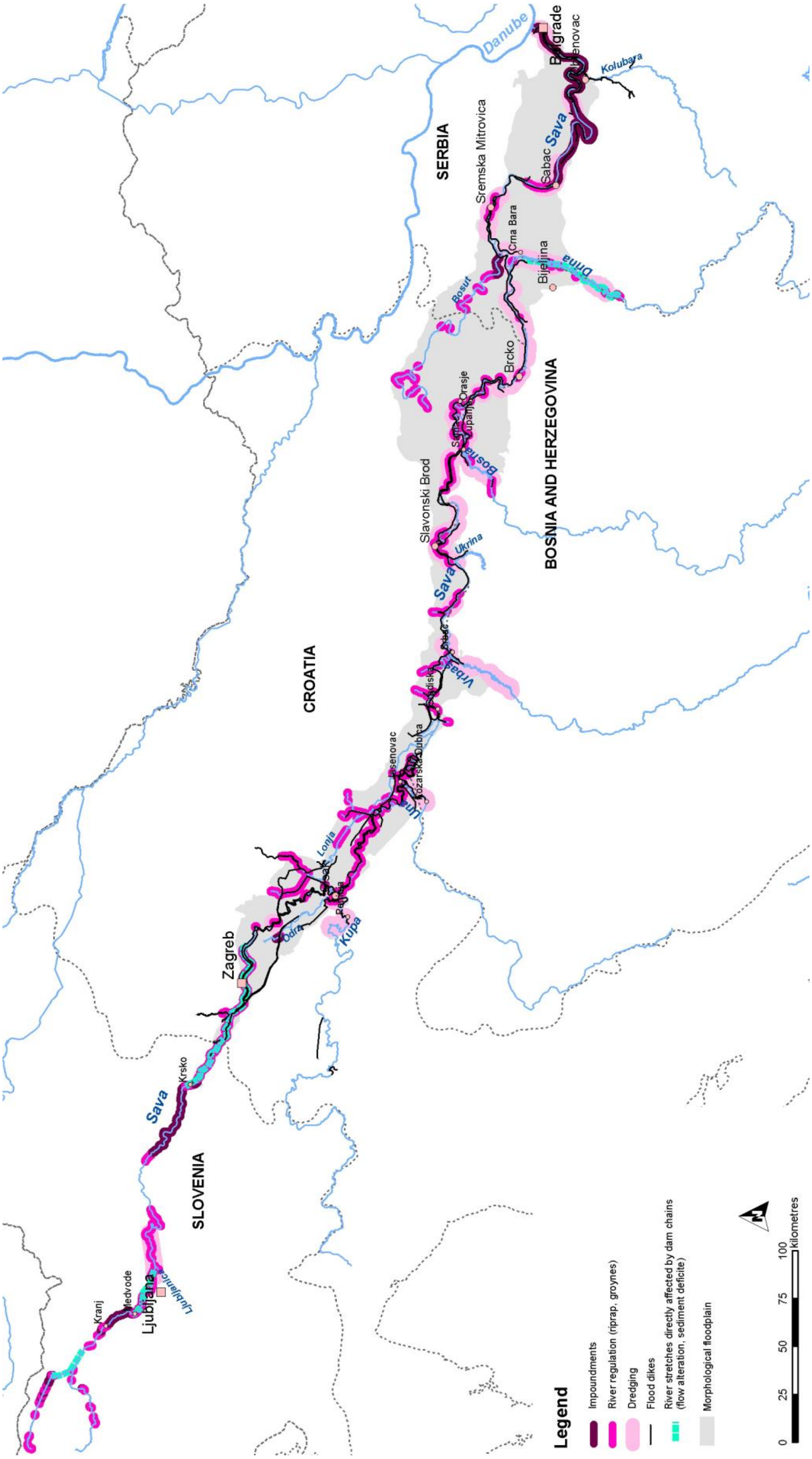
☐ *Figure D. 582 hydropower plants are foreseen in the Sava basin.*

Dredging and sediment exploitation from the river channels is widespread; over the last decades significant amounts were extracted: on average 950,000 m³/year (m³/a) from Sava channel and 1.29 million m³/a from tributaries. Estimates based on the available dredging data show that the material extracted from the river per year is up to ten times higher than the natural transport capacity for the Sava and more than four times higher for the tributaries. The impact of dredging on the sediment balances cannot be examined separately from the effects of trapping coarse material in the dam chains. The combination of dredging and trapping can lead to channel incision even in stretches that are not under serious pressure from dredging, particular between the Sisak and Drina confluences. A preliminary legal decision in Croatia will hopefully drastically reduce the dredging amounts within the Natura 2000 sites. This law will require part of the material to be given back to the river, as is practised in Germany and Austria, where sediment management has become an important tool for successfully stabilising river incisions. More attention and monitoring should be given to potentially self-sustaining solutions in river stretches, such as the lower Drina along the Serbian-Bosnian border. This river is strongly impacted by dams in the upper and middle catchment, but just 20 km downstream of the last dam (hydropower plant (HPP) Zvornik) one of the most exciting and ecologically important river landscapes within the entire Danube basin can be found: the lower Drina. This river stretch is mostly free of riverbed fixation measures allowing for strong lateral erosion and a consequent loss of land, but the lateral movement of the river reduces the risks of dangerously big river bed incisions and as a consequence maintains natural groundwater tables in this fruitful landscape.

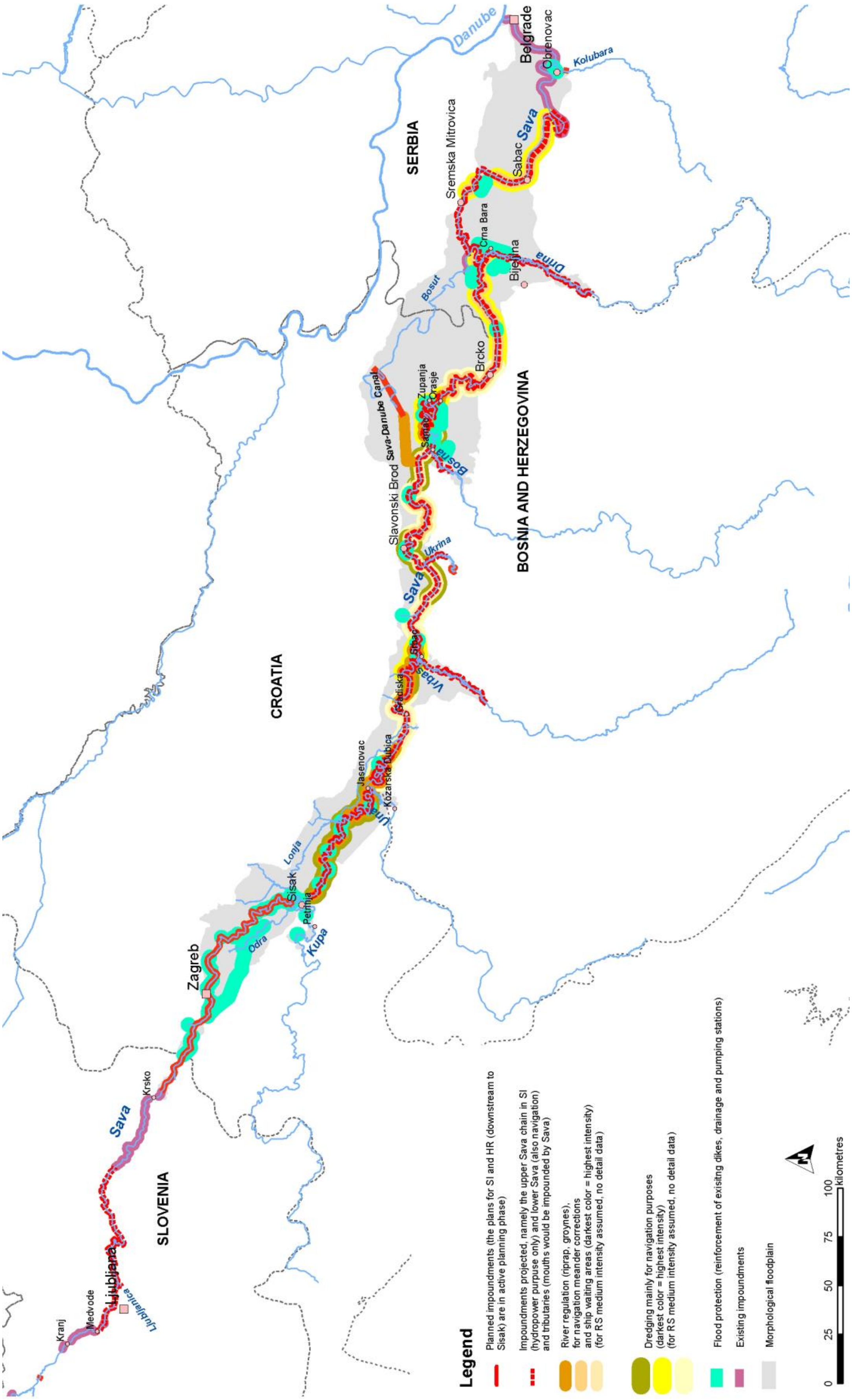
At the moment, **navigation** does not play a significant role in the economic development of the Sava river basin, but the topic is on the political agenda at the national and European level. Navigation development, including the projected Sava-Danube canal through the Bosut-Spačva forest area, could cause serious changes to the river system. Regular maintenance dredging has a more severe impact if the extracted material is sold on the market – a common practice in the Sava river basin – as opposed to feeding the material back to the river. Proposals to improve the low water situation for navigation river regulations include the construction of three ground sills, bank reinforcements (riprap and groynes) and further disconnection of river and floodplain (e.g. traverses to close side-channels). These constructions constitute the main impact on the river system by navigation. Major threats are new plans to raise the ECE (UN Economic Commission for Europe, Inland Water Transport) waterway class for the 594 km stretch between Belgrade and Sisak from III to IV (and on the Serbian part, from IV to Va). This requires many significant river regulations, including 24 meander bend corrections and the stopping of nearly all lateral erosion by riprap and stabilising of the shipping channel. Necessary dredging is estimated at least at an initial 1.7 million m³ for the Croatian stretch, followed by continuous maintenance dredging. Another threat is the construction of new infrastructure, such as the proposed new harbour at Sisak, planned in an active floodplain area outside the town. These plans would have a huge deteriorating impact on the river and adjacent environment.

The following two maps (Figures E & F) summarise the current and potential future threats. Current threats (Figure E) cover nearly all activities that are threatening the ecological functionality of the river system: hydropower (impoundments, hydropeaking and sediment deficit), river regulation, frequent dredging and flood defence constructions. The second map (Figure F), showing projected alterations, indicates that almost the entire length of all rivers in the morphological floodplain would be affected if hydropower and navigation projects were fully implemented.

☐ *Figure I. The Sava river and its floodplains are a European lifeline and a natural flood prevention system (© Goran Šafarek).*



□ *Figure E. Current alterations and threats (impoundments, river regulation, dredging, flow alterations/sediment deficits and dikes) along the Sava and assessed tributaries.*



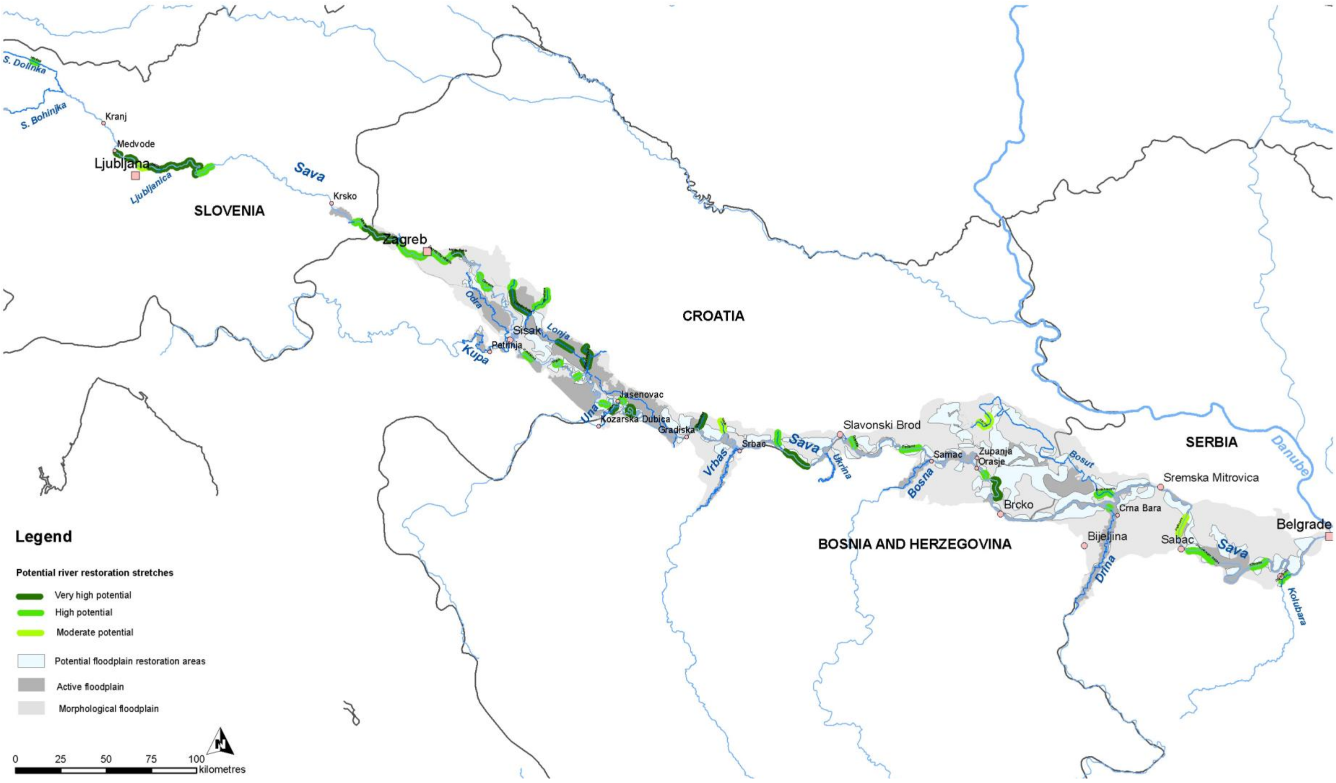
☐ *Figure F. Projected alterations and threats (impoundments, river regulation, dredging, and technical flood protection). The entire Sava is at risk.*

3. Restoration potentials

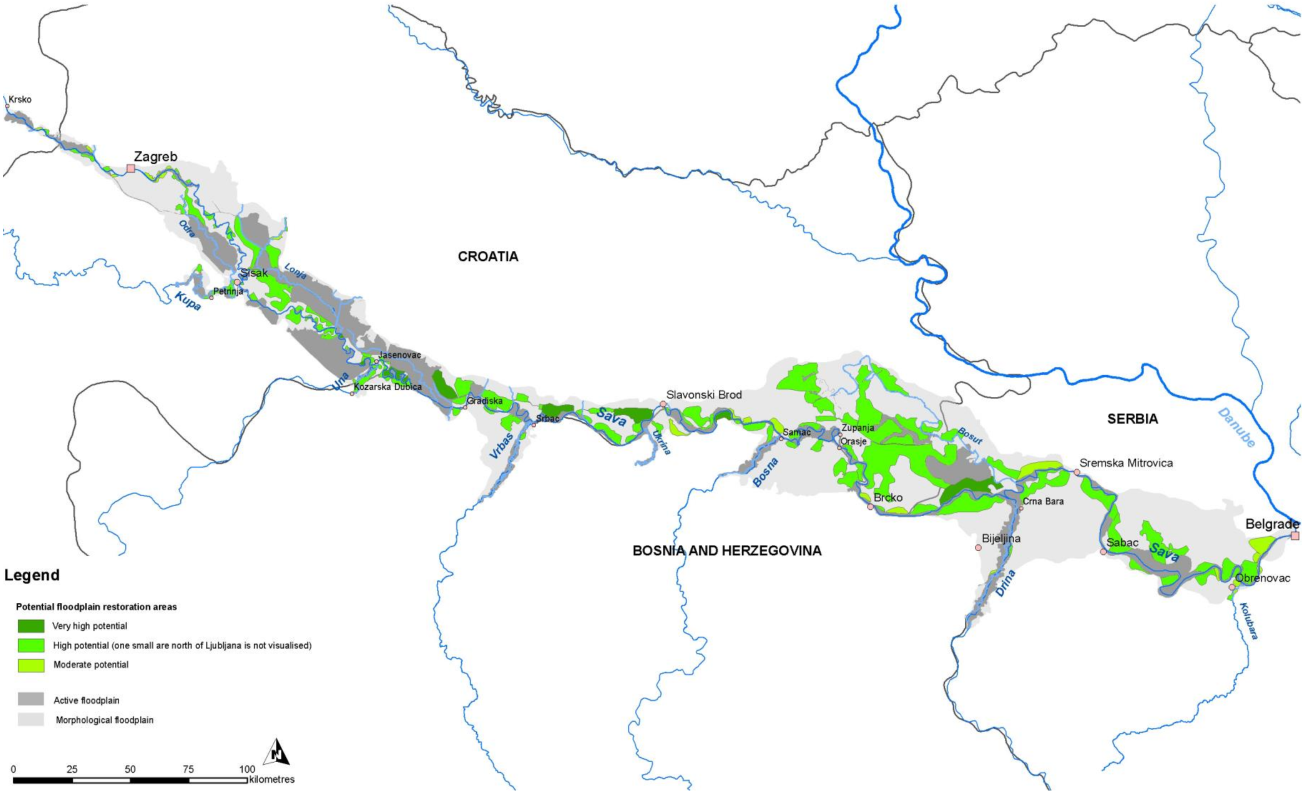
This study has attempted to identify the potentials for river and floodplain restoration along Sava river and the lower reaches of its tributaries. While river restoration means “giving more space to the river itself”, the goal of floodplain restoration is “giving more space to floods”.

With a view to achieving *good* ecological status as defined in the WFD, **river restoration** (Figure G) aims to prevent further deterioration and to improve the hydromorphological conditions. Altogether, 41 different river stretches with a length of 251 km have been identified (15 classified as *highest*, 22 *high* and four *low* priorities).

In terms of **floodplain restoration** (Figure H), an additional 143 potential areas have been delineated, covering a total area of 184,289 ha and reconnecting about 22% of the floodplain area with the river. This would increase the overall flood retention capacity by approximately 3.1 billion m³. These areas have been evaluated and prioritised according to land structure, hydromorphology, protected area status, retention capacity and land ownership structure. Ten areas have come out with very *high* priority, 108 with *high* priority and 26 with *moderate* priority. The study also includes detailed proposals for several pilot restoration sites and areas.



☐ *Figure G. Potential river restoration stretches and their prioritisation. 41 river stretches with a total length of 251 km could be restored.*



☐ *Figure H. Floodplain areas with potential for restoration and their relative priority.1,843 km² of former floodplain area with a retention capacity of 3.1 billion m³ could be reconnected.*

Conclusions

- The Sava is an outstanding river of pan-European importance.
- The entire river network of Sava river basin is threatened, mainly by hydropower projects, navigation schemes and sediment extraction. If the official projects are implemented as planned, all rivers would deteriorate severely with negative impact on protected areas, biodiversity and flood control.
- This study offers an alternative concept to improve the Sava ecosystem for the benefit of nature and people. In total, 41 potential river restoration stretches and 143 floodplain restoration areas have been identified. The latter has the potential to increase the flood retention capacity by about 3.1 billion m³. Moreover, this restoration projects are in line with the requirements of the Water Framework Directive, the Floods Directive and the Habitats Directive.

1 INTRODUCTION

The Sava White Book aspires to be a guiding document for the nature protection and water management along the Sava river. The White Book is also designed as a foundation on which plans to restore the river basin shall be based, as it contains detailed assessments and prioritisation of river stretches and floodplain areas in terms of their restoration potential.

Chapter 2 gives an evaluation of the ecological character of the Sava and all of the major tributaries in its catchment area. This evaluation is followed by three chapters of presenting spatial analyses regarding land structure (Chapter 3), hydromorphology (Chapter 4) and protected areas (Chapter 5), offering concise base data for each. These analyses make extensive use of GIS techniques and result in detailed maps for all river stretches and floodplain areas in the project area (see map annex[2]). These unique data sets are marked as a result in themselves, and serve as crucial input for the main assessments of the White Book in Chapters 6 and 7.

Chapter 6 (Threats) presents a thorough evaluation of the riparian habitats and ecology under impact from human activities, including planned activities. Threats covered in this chapter are the constructions of hydropower plants, navigation, dredging and flood defence.

Chapter 7 (Restoration potential) offers guiding principles for the selection and prioritisation of potential restoration of river stretches and floodplain areas along the Sava river. Finally, Chapter 8 sets out the recommendations of the study.

The Sava White Book is constructed around the evaluation of new data sets uniquely prepared for the Sava river and a critical review of official documentation. The study highlights several problematic environmental impact studies. Its evaluation of the river's condition is compared to the assessments under the WFD and the Floods Directive.

☐ *Figure 1: The white-tailed eagle is one of the most prominent species of middle and lower Sava and its floodplains (© Goran Šafarek).*

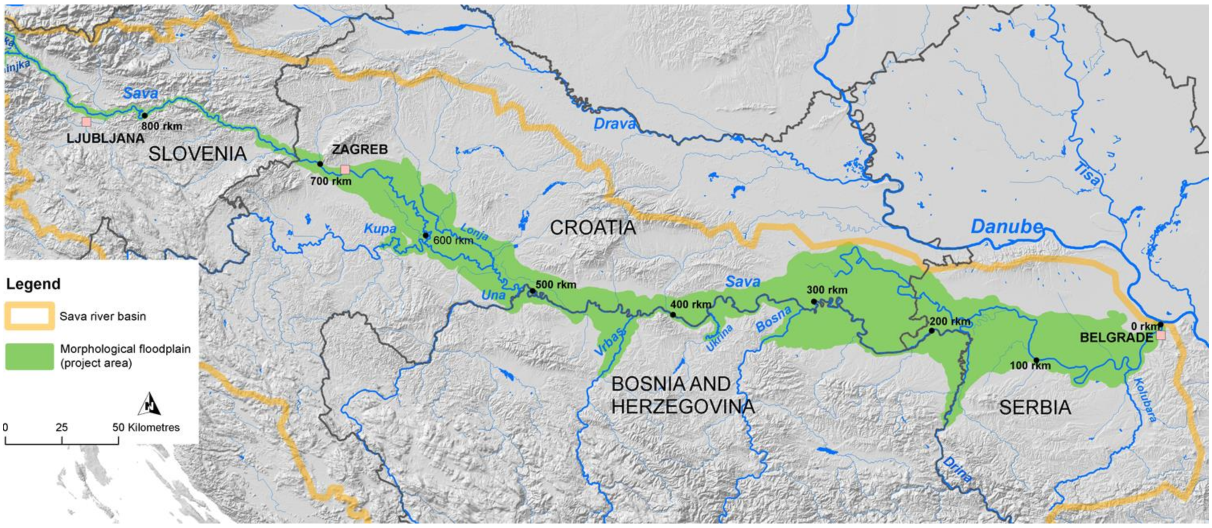
[2] The Map Annex to this study is provided in an additional document titled „Sava White Book – Map Annex

2 THE ECOLOGICAL CHARACTER OF THE SAVA RIVER

The varied landscape and climate along the Sava and the influences of tributaries make it unique among European rivers. It is still free-flowing in its middle and lower courses and features long stretches that are relatively intact. Urbanisation of parts of the floodplains, the extension of agriculture to previously uncultivated areas and the construction of flood defence, mostly in the 20th century, have all impaired the river system. However, many stretches retain an ecological importance that is without par in Europe.

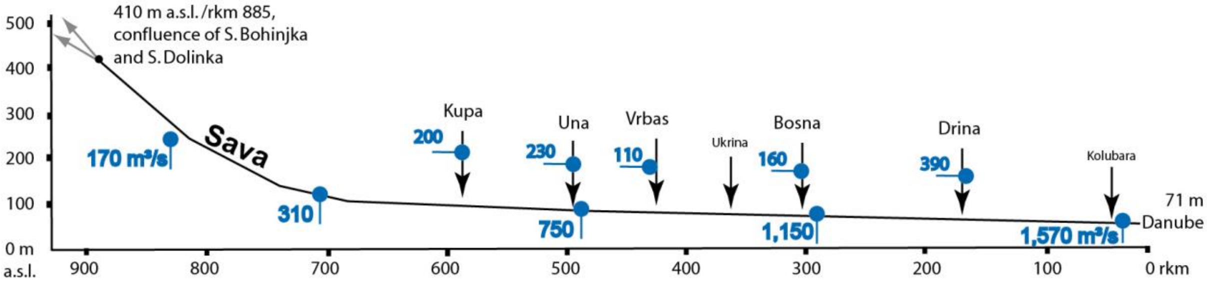
This assessment comprises the Sava river corridor with a total length of 926 river kilometres (rkm) as well as the main lowland stretches of the Sava tributaries: 50 km of the Kupa, 80 km of the Lonja, 20 km of the Una, 25 km of the Ukrina, 35 km of the Vrbas, 30 km of the Bosna, the entire 120 km of the Bosut (a special case as a backwater floodplain river of the Sava floodplains), 56 km of Drina and 10 km of the Kolubara. The study also includes the spring branches Sava Dolinka (41 km, included in the total Sava length of 926 km) and Sava Bohinjka (32 km). The total river length covered by this study is 1,384 km. The project area is congruent with the morphological floodplain (the formerly maximum area influenced by floods), which covers an area of 8,943 km².

Figure 2 shows the entire Sava river. Its catchment boundary is marked by an orange line, and the morphological floodplain is shown in green shading.



☐ *Figure 2: The Sava river and its morphological floodplain within the Sava river basin.*

Figure 3 represents the longitudinal profile of the Sava excluding the spring branches Sava Dolinka and Sava Bohinjka. Downstream of Zagreb, from rkm 660 onwards, the Sava continues with a very small gradient and starts to meander widely within the plain. This means most of the altitude difference is overcome in the upper reach.



☐ *Figure 3: Longitudinal profile of Sava showing rkm, tributary confluences and their mean discharges [in m³/s].*

The Sava flows through two European Union (EU) countries, Slovenia (SI) and Croatia (HR), and two non-EU but candidate countries, Bosnia and Herzegovina (BA) and Serbia (RS). For much of its length, it marks the border between HR and BA. Much of the upper catchment area of the Drina, the largest tributary of the Sava, lies in Montenegro (ME) (not illustrated on map).

The river Sava is divided into upper, middle and lower reaches, but this classification is not applied consistently. The upper Sava is distinguished most clearly, ending approximately at Zagreb. In this study, the middle Sava defines the stretch from Zagreb down to the mouth of the Drina, the last major gravel-born tributary at rkm 180. The lower Sava therefore consists of the Serbian stretch of the river down to its confluence with Danube.

Geographical description

The Sava basin, with an area of about 97,800 km², is the second largest tributary basin of the Danube (second only to the Tisa basin), but has the largest discharge – as much as 1,570 m³/s, whereas the Tisa discharges merely 810 m³/s. Measured from downstream the confluence of its spring branches Sava Dolinka and Sava Bohinjka, the Sava is nowadays only 885 km long (926 km if measured with its longer branch Sava Dolinka) and thus significantly shorter than indicated in many sources [1]. The main reason is the significant straightening of the river between Krško and Zagreb.

The highest elevation in the catchment is the mountain peak of Triglav in SI with a height of 2,864 m a.s.l., while the river discharges into the Danube at 71 m a.s.l. The river originates from two alpine branches, the Sava Dolinka in the north and the Sava Bohinjka in the south. The Sava Dolinka valley is broad and straight, while the Sava Bohinjka flows out of Lake Bohinj, the starting point of the famous Seven Lake Trail to Triglav. The two spring branches flow through an alpine environment, however after their confluence the landscape has a subalpine character, with the exception of the Ljubljana basin (Notranjski Karst). In this subalpine stretch, the Sava flows through the area where the Eastern Alps merge with the Western Dinarides and is joined by the Ljubljanica – a typical karst river that flows through several poljes and intermittent karst lakes. Another southern tributary, the Krka, is also a karst river (not illustrated on map).

☐ *Figure 4: Sava Bohinjka, SI (© Miha Ivanc)*

The Sava breaks through the alpine foothills downstream of the Ljubljanica confluence in an impressive gorge with some rock passages and short cataracts before leaving the mountain area near Krško (rkm 730), followed by a short braided and a long anabranching stretch. The first significant floodplains are located just upstream of Zagreb.

The altitude difference over the remaining 660 km downstream course is only 35 m (see Figure 3), an average gradient of only 5 - 6 cm/km. Consequently, the Sava is one of the two longest meander rivers in the Danube basin, the other being the Tisa. It flows along the margin of the region influenced by the Pannonian lowland. After being joined by the Kupa, the Sava huddles against the Dinarides foothills in a west-eastern direction. The river finally loses its subalpine influence once the major tributaries from the south (Una, Vrbas, Bosna and Drina) join the Sava, making the river the largest Danube tributary by discharge.

With the exception of the Kupa, all of the southern tributaries flow through narrow, mountainous valleys. On their very lowest courses, they develop anabranches and even some meandering stretches with floodplains. The Drina − the largest tributary − originates in mountainous ME. Its two spring branches, the Tara and Piva, are known for having the deepest Balkan gorges. The Piva has been significantly altered by hydropower in its upper and middle courses, while the Tara still remains near-natural.

☐ *Figure 5: Middle Sava close to Lonjsko polje near Puska, HR (© Goran Šafarek).*

Climate conditions: The climate in the upper Sava valley is close to subalpine. The lowlands downstream of Zagreb have a somewhat humid Pannonian climate (illyric forming). The average temperatures increase slightly with decreasing altitude: 10.4 °C in Ljubljana, 11.3 in Zagreb and 11.6 °C in Belgrade. Precipitation is more markedly differentiated: 1,140 l/m², 883 l/m² and 657 l/m² respectively) [2].

Ecoregions: The ecoregions through which the Sava passes comprise the Alpine ecoregion in its upper courses, followed by the Western Dinaric Balkan ecoregion, through which all of its major southern tributaries flow, and finally the Continental Pannonic ecoregion.

Geology and lithography: The area has diverse geology and lithography, with magmatic and metamorphic rocks (granite, diabas, dacite, andesite, feldspars and peridotites), sedimentary formations such as limestone and dolomites, and clastic sedimentary rocks (conglomerates). These diversities have yielded a complex composition of gravel and sediment, terrace building and soil development [2].

Soil: The soil close to the river along its upper stretch is undeveloped skeleton soil. The first larger floodplains also contain poorly developed brown floodplain soil characterised by sesquioxide translocation. The lowland floodplains are mainly dominated by gley and semigley fluvisoils, which have developed huge oxidation horizons corresponding to the water level fluctuations, formed by the settling out of manganic and iron concretions. Intact floodplain soils developed by overbank deposition are important carbon sinks, which are generated through carbon sequestration (the process of carbon capture within the long-term storage of atmospheric carbon dioxide).

Hydrographical description

With a mean discharge of 1,570 m³/s at its mouth, the Sava is by far the biggest tributary of the Danube. It significantly influences the hydrographical regime of whole lower Danube.

Table 1 lists the mean discharge and the 100-year discharge at selected gauging stations along its length. It exhibits high discharges in the Alpine upper river basin caused by snow melt in late spring. The middle and lower river basin is influenced by rainfall in autumn and winter (Mediterranean influence) and particularly by flow regimes of large southern tributaries, namely the Una, Vrbas, Bosna and Drina. Sometimes floods of different origins are superimposed, leading to long-lasting flood events. The 2014 flood in the lower Sava − the biggest for a century − was primarily fed by the Bosna and the Vrbas, but not by the other two large tributaries.

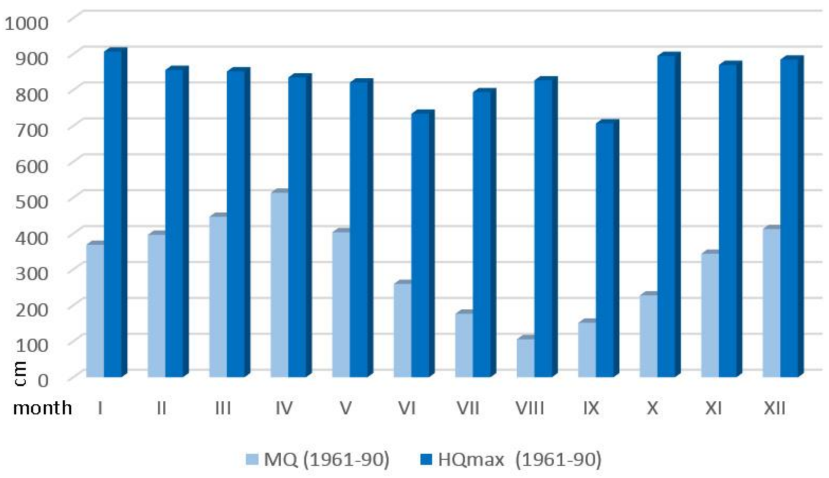
☐ *Table 1: Mean discharge (MQ) and 100-year discharge (HQ100) for selected gauges of Sava and tributaries*

River and Station	**MQ in m³/s**	**HQ100 in m³/s**
Sava, Litija (rkm 801)	178	1,965
Sava, Zagreb (rkm 685)	327	3,143
Sava, Crnac (upstream Kupa, rkm 595)	557	2,540[3]
Sava, Jasenovac (upstream Una, rkm 516)	750	2,864[2]
Sava, Slavonski Brod (rkm 371)	1,020	3,905
Sava, Županja (rkm 267)	1,209	4,527
Sava, Sremska Mitrovica (rkm 137)	1,572	6,753
Tributaries (at most downstream gauges):		
Ljubljanica, Ljubljana Most	60	320
Savinja, Veliko Širje	110	1,490
Krka, Podbočje	50	460
Kupa, Crnac	190	2,510
Una, Kostajnica	210	1,521
Vrbas, Delibašino Selo	100	1,479
Bosna, Doboj	140	3,087
Drina, Radalj	350	6,000
Kolubara, Beli Brod	18	784

The Sava water level can fluctuate by up to 9 m. Due to the size of its catchment, flood events on the Sava characteristically have a long duration. During a flood event, the water level can exceed the average annual water level by more than 5 m for a continuous period of up to two months. These long-lasting and slow-flowing natural floods set the Sava apart from other European rivers. They influence broad areas of the hinterland by raising groundwater levels and obstructing inflow from tributaries.

[3] Two gauges, Crnak and Jasenovac, have significantly lower peak flows due to the "Upper Posavina flood retention system", including the Odransko polje bypass on the south bank and the Lonjsko polje - Mokro polje system on north bank.

Figure 6 shows the discharge regime of the middle Sava using the mean monthly values – the mean discharge (MQ), and maximum discharge (HQ_{max}) – at the Jasenovac gauge for the period 1960 - 1990. The southern Sava basin experiences the Mediterranean influence of heavy rainfall in autumn and winter resulting in a typical annual flow regime with two discharge peaks: one in April due to the snow melt in the Alps and Dinarides, and a smaller peak in December induced by heavy winter rains. The winter peak is more pronounced in the major southern tributaries. Figure 6 also shows that floods and extreme discharges on the middle Sava – and consequently also on the lower Sava – can occur in every season. Floods are more frequent in winter but not uncommon in spring or even in summer. The historic flood in 2014 occurred in May.



☐ *Figure 6: The discharge regime of the Sava at Jasenovac between 1961 and 1990 (water levels in cm; mean discharge (MQ); maximum discharge (HQ_{max})), based on [3]. Floods can occur all year round.*

Biodiversity

Riparian vegetation

The aquatic and wetland vegetation along the Sava, including its forests, is well documented [4, 5]. Aquatic vegetation is not widely spread in the fast-flowing upper reaches, with the exception of the slow-flowing karst tributaries of Ljubljanica and Krka with their floating vegetation carpets (e.g. river water-crowfoot (*Ranunculus fluitans*). The fast-flowing alpine and sub-alpine river banks are mainly lined by Elaeagnus willow (*Salix eleagnos*). Downstream of the Krka confluence, these habitats give way to white willow (*Salix alba*) woods.

The middle and lower Sava is very rich in aquatic vegetation. Swampy vegetation is widespread and richly developed in side-channels, smaller tributaries, and particularly in oxbows and backwaters. Frequently occurring protected species in the morphological floodplain include floating watermoss (*Salvinia natans*), water caltrop (*Trapa natans*), water soldier (Stratiotes aloides) and fringed water-lily (Nymphoides peltata). The littoral zone of the river, consisting of bars and banks, is colonised by annual pioneer species like the mudwort (*Limosella aquatica*). The woody vegetation consists of riparian gallery forests of willows and white and black poplars (*Populus alba and Populus nigra*). Low-lying and frequently flooded forests are characterised by narrow-leafed ash (*Fraxinus angustifolia*) and – on small elevated stands – oak (*Quercus robur*) with European white elm (*Ulmus laevis*). Black alder woods (*Alnus glutinosa*) can be found in depressions and fringes of the floodplain. An occurring specific flood-tolerant wet grassland type known as Cnidion meadows/pastures may be partially natural, shaped by large herbivores.

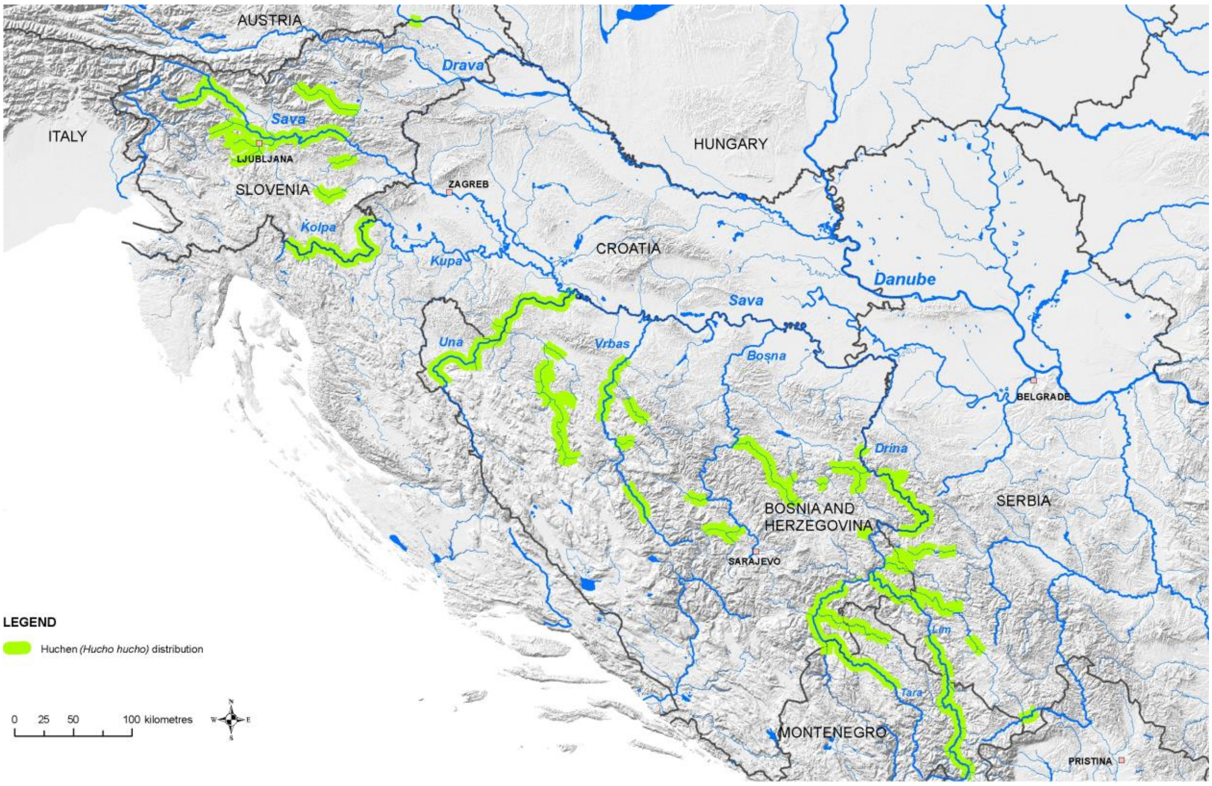
The southern tributaries host many more typical pioneer habitats and softwood patches than the Sava itself. These are typically located up to several kilometres upstream of the confluences; however their vegetation has not been properly investigated. It is safe to assume that these habitats also host typical pioneer species as already mentioned for the Sava. Furthermore, gravel islands allow for the succession towards softwood or dryer poplar forests.

The Danube salmon (*Hucho hucho*) in the Sava and its basin

The Danube salmon or huchen (*Hucho hucho*) is one of the most appealing freshwater fish species in Europe, and one of its rarest. It can grow up to 1.5 m in length and occurs naturally only in the Danube basin. It settles in free-flowing, gravel- and oxygen-rich river sections. Damming and river regulations have deprived the species of much of its former territory, especially in Germany, Austria, Slovakia, Romania and Bulgaria.

□ *Figure 7: Young, male huchen (Hucho hucho) – the tiger of the Danube basin (© A. Hartl).*

A recent assessment [6] has concluded that the Sava basin is a hotspot for this threatened species. Experts found self-sustaining populations on 43 rivers in the area, with a total length of about 1,820 km (as the huchen study covers the entire Balkan region, about 30 km of huchen stretches are located outside the Sava basin). This corresponds to 65% of all known huchen stretches in Europe. The most important rivers for huchen populations are the Sava in SI and the Sava tributaries Kupa, Una, Sana, Drina and Lim. Each of these rivers support huchen populations on stretches of more than 100 km in length.

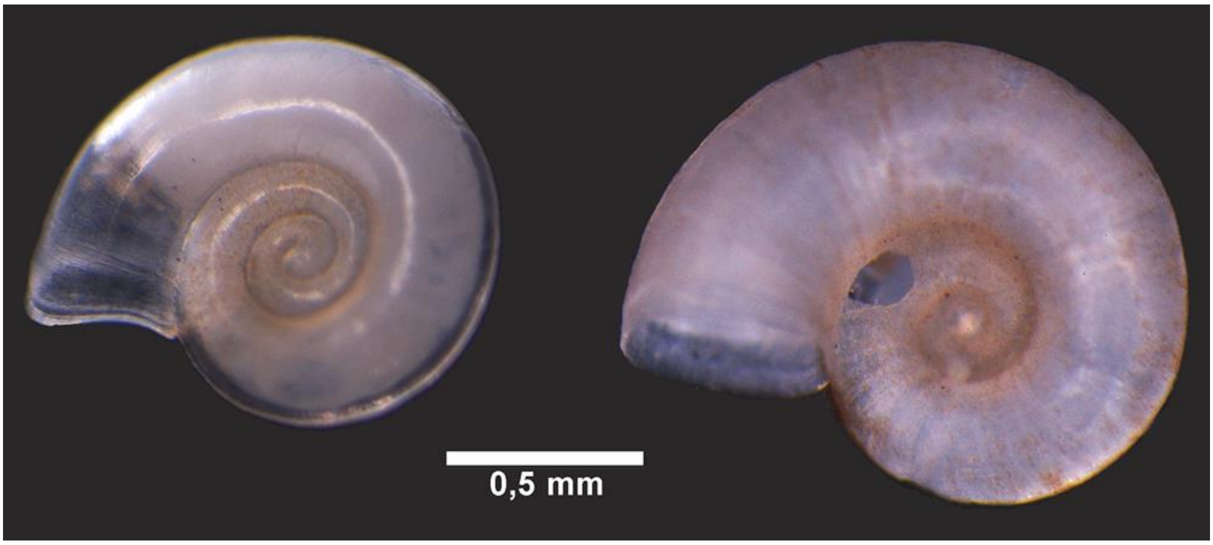


□ *Figure 8: The Balkan rivers host the densest huchen populations in Europe, over a total length of 1,822 km.*

Mayflies and snails - interstitial fauna in the Sava

The interstitial fauna – fauna that lives in the river bed – consists of species of snails, crustaceans and other aquatic species that are barely visible to the naked eye. Due to the extreme environment, they are often endemic and therefore more vulnerable to extinction than bird or fish species. So far, very little is known about the interstitial fauna of the Sava.

In 2015, a group of researchers from the University of Ljubljana surveyed stretches of the Sava threatened by hydropower plants in SI, particularly those around Brežice and Mokrice. Although the study is not yet completed, preliminary results clearly indicate that these Sava stretches host a rich interstitial fauna. About 30 species found at these locations are included on Red Lists or are protected by national nature conservation laws and the European Groundwater Directive. Examples are the mayfly *Potamanthus luteus* and the vulnerable snail *Hauffenia michleri*.



□ *Figure 9: The snail Hauffenia michleri. (© Simona Prevorčnik)*

Birds of the Sava and its floodplains

Birds are excellent indicators for the quality of natural habitats and the health of fundamental ecological processes. Their occurrence can also be linked to the hydromorphological situation of rivers and streams, reflecting the presence of sand bars, gravel islands and steep banks, which form important nesting and breeding habitats.

The alpine and subalpine parts of the upper Sava have a stable population of breeding golden eagle (*Aquila chrysaetos*), the largest raptor species in the region [7]. Fast flowing rocky streams host such typical species as dipper (*Cinclus cinclus*) and grey wagtail (*Motacilla cinerea*), which forage on the nymphs or larvae of mayflies, blackflies, stoneflies and caddisflies, as well as on small fish and fish eggs.

Downstream of Zagreb to the Una confluence the river is firstly rich in sediment bars and islands and host further downstream meander bends with steep banks that are home to several flagship bird species. Figure 11 shows the distribution of characteristic species in this section as well as for the whole middle and lower Sava. Gravel bars and islands downstream to Rugvica (660 rkm) support breeding of up to 150 pairs of common terns (*Sterna hirundo*). They also represent the only breeding site along the whole Sava for the threatened little tern (*Sterna albifrons*), which has a population of up to 20 pairs [8, 9], as well as for the little ringed plovers (*Charadrius dubius*) with up to 14 pairs. A few pairs of common sandpipers (*Actitis hypoleucos*) [10] can also be found there. The first steep banks, resulting from dynamic hydromorphological processes, appear downstream of the Slovenian-Croatian border. Freshly eroded steep banks provide home for another indicator species, the sand martin (*Riparia riparia*). The total breeding population along the Sava is estimated at 3,000 pairs, but the section upstream of the Una confluence hosts two thirds of the total breeding population. Particularly important sites are located downstream of Zagreb and upstream of Sisak, with colonies holding up to 270 pairs. Another charismatic species that lives in steep sand banks is a solitary nesting kingfisher (*Alcedo atthis*). The Sava downstream of the Una confluence holds 75 - 90 breeding pairs and the density of 2.4 pairs/km is one of the highest in the whole Danube basin. Other important locations for this species are the sections downstream of the river Lonja in the Lonjsko Polje Nature Park.

The middle Sava (the part downstream of Jasenovac) and lower Sava to Belgrade is characterised by a lack of sand bars and islands; the silty banks are vegetated and often flooded. This Sava stretch is characterised by large and fairly intact floodplains called poljes. Vast areas of shallow water, rich in fish and amphibians, provide perfect conditions for spoonbills, herons, storks and cormorants. The Eurasian spoonbill (*Platalea leucorodia*) is a well-known flagship species that currently breeds in four colonies (Krapje đol and Obedska bara oxbow, Vrbovljani and Jasinje fishponds) with a total of 160 - 220 pairs. Herons breed in single or mixed colonies all along the Sava. The grey heron (*Ardea cinerea*) is the most abundant, with an estimated population of 2,000 breeding pairs in 20 colonies. There are 180 pairs of great egrets (*Ardea alba*) and up to 160 pairs of purple herons (*Ardea purpurea*) that breed on willow trees or reed beds on fishponds and oxbows (Obedska bara and Krapje đol). Eight colonies situated on oxbows and fishponds contain 470 pairs of little egrets (*Egretta garzetta*) and there is an estimated breeding population of 1,180 pairs of black-crowned night herons (*Nycticorax nycticorax*). The threatened squacco heron (*Ardeola ralloides*) breeds in four sites with a total population of 94 pairs, its most important sites being the Jasinje fishponds and Obedska bara. The latest addition to this rich heron fauna is the cattle egret (*Bubulcus ibis*), which started to breed in Krapje đol in 2015 [11]. Another group of birds closely related to rivers and floodplains that are rich in fish are cormorants. The great cormorant (*Phalacrocorax carbo*) has now established two colonies in the Lonjsko Polje Nature Park, with a total of 1,100 pairs [12]. Undiscovered colonies are very likely to exist in BA downstream of Slavonski Brod. Obedska bara is the stronghold for the breeding pygmy cormorants (*Microcarbo pygmeus*) with 50 nesting pairs, and occasional breeding has been recorded at the Jasinje fishponds and Krapje đol.

□ *Figure 10: Spoonbill and little egret colony in Lonjsko Polje Nature Park, HR (© Nenad Šetina).*

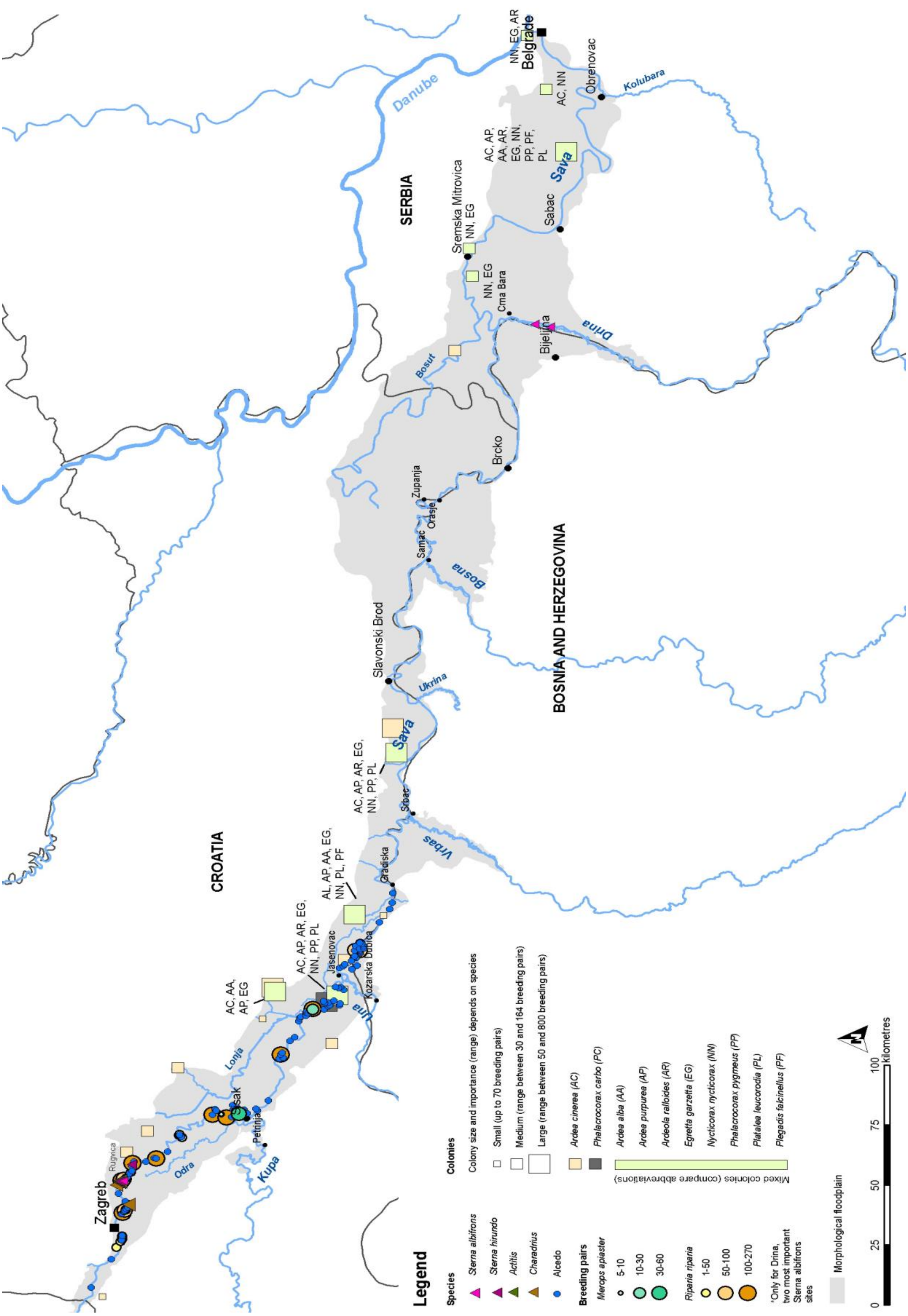
The value of large pastures and extensive agricultural areas is well represented by white storks. There are over 900 breeding pairs in the villages along the Sava and its floodplains. The most important site is Lonjsko Polje Nature Park, where as many as 35 breeding pairs can be found in a single village (i.e. Čigoć – European Stork Village). The third important habitat type of the Sava floodplains is the large alluvial forests. They host two fascinating species: the white-tailed eagle (*Haliaeetus albicilla*) and the lesser spotted eagle (Aquila pomarina). Along the Sava, the white-tailed eagle has a total estimated breeding population of 78 - 88 pairs. Lonjsko Polje Nature Park is the long-established stronghold for this species and the starting point for its recent recolonisation of the rest of the floodplains. The Sava floodplains are also a major breeding site for the very rare and special lesser spotted eagle. About 20 pairs are estimated to nest especially in Lonjsko polje and Mokro polje. The breeding population has declined in recent years, most likely due to intensive forestry and the loss of feeding grounds (e.g. invasion of *Amorpha fruticosa*). The breeding pair furthest upstream has its nest west of Zagreb.

By contrast, there is little information on breeding of the black stork (*Ciconia nigra*). This secretive species is also widely distributed along the Sava floodplain, but the size of its breeding population remains unknown. There is still a lack of data on the distribution of flagship bird species along the tributaries, but current research efforts led by EuroNatur is expected to fill this gap soon.

The distribution of breeding birds closely reflects the protected area network (see Chapter 5). The importance of the river corridor for breeding and migratory birds is internationally recognised. Birdlife International has designated numerous Important Bird Areas (IBA). In SI and HR those areas are today partially within Natura 2000 sites including Special Protected Areas (SPA) under the EU Birds Directive. Table 2 lists all those internationally important natural sites for birds along the Sava and its lower tributaries.

☐ *Table 2: Important Bird Areas along the river Sava*

No.	Country	Name of the site	Size (ha)
1	SI	Julijci	88,645
2	SI	Jelovica	9,767
3	SI	Ljubljansko barje	12,961
4	SI	Posavsko hribovje	3,516
5	SI	Kozjansko	8,042
6	SI	Krakovski Gozd - Šentjernejsko polje	8,347
7	SI	Dobrava-Jovsi	2,849
8	HR	Sava kod Hrušćice	1,528
9	HR	Turopolje	20,003
10	HR	Donja Posavina	121,075
11	HR	Jelas polje	38,834
12	HR	Spačvanski bazen	43,519
13	BA	Bardača fishponds	3,500
14	RS	Bosutske šume	25,931
15	RS	Donje Podrinje	4,706
16	RS	Zasavica	4,670
17	RS	Obedska bara	29,913
18	RS	Ušće Save u Dunav	9,808
		TOTAL	**437,614**



□ *Figure 11: Distribution of selected indicator species of breeding birds and colonies along the middle and lower Sava in HR and RS (no data for BA and for the tributaries except on little tern along the Drina).*

The ecological and chemical status according to the EU Water Framework Directive (WFD)

The ecological classification of European rivers is based on a harmonised methodology developed for the WFD. The ecological status recognises five categories based on the concept of "Reference Conditions": *high*, *good*, *moderate*, *poor* and *bad*. The WFD defines the target conditions for European rivers as the classes *high* (natural state or "reference conditions") and *good*. These conditions are type specific, which means that they vary according to the sizes and geographical distribution of rivers, from high mountains to lowlands. The other classes indicate significant alterations and deficits in the ecological status.
The ecological status is attributed to river segments known as "water bodies": individually defined sections of rivers with a length of anywhere between a few km and 100 km, or even more for large rivers such as the Sava. Each water body is subjected to a separate assessment of ecological status, while ecological quality is assessed by monitoring and describing certain biological groups like fish, macrophytes and – particularly for the Sava – macroinvertebrates.

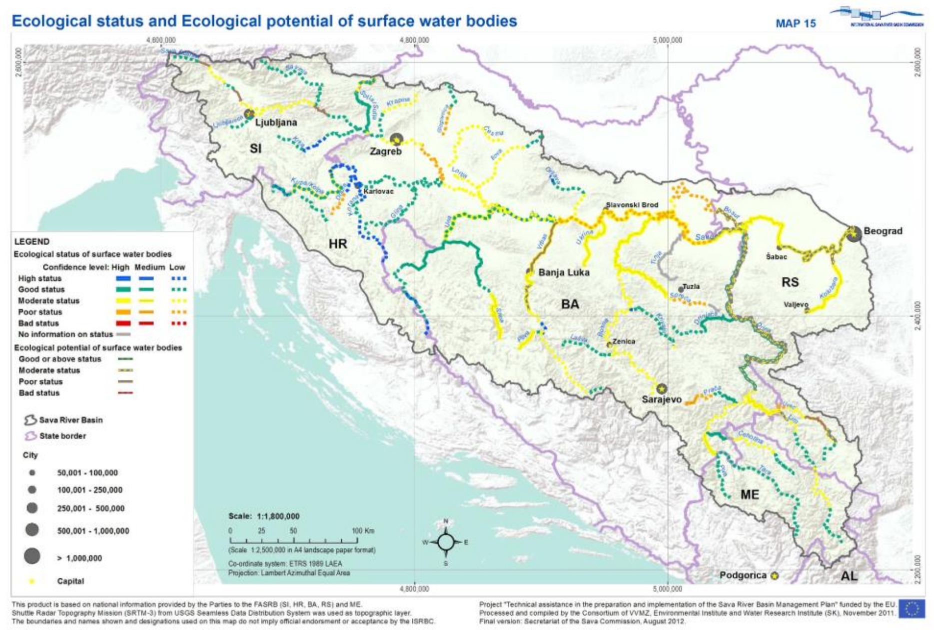


Figure 12: Ecological status and ecological potential for Sava river water bodies, incl. heavily modified water bodies (HMWB) in the Sava basin [1].

Evaluation of ecological status has been carried out on a total of 182 water bodies on the Sava [1, 2]. These also include all Heavily Modified Water Bodies (HMWB) and all water bodies in EU candidate member states. Ten were assessed as class 1 (high), 82 as class 2 (good), 73 as class 3 (moderate) and 17 as class 4 (poor). None of the Sava water bodies can be found in class 5 (bad). These are much better values as for e.g. Germany, where 85% of all water bodies fall currently in the classes 3, 4 and 5 [13].

According to the official map (Figure 12), the middle and lower Sava appears to have rather low ecological status or potential (moderate and poor), but the benthic fauna – a core indicator of ecological status in the WFD – has been subject to a systematic comparison and scientific analysis based on several European and national metrics, and this has found that the stretch is prevalently in "good" status [2]. According to the WFD, ecological status for a water body is assessed by the worst case for all biological quality elements (benthic fauna, fish and phytobenthos/macrophytes), but a better evaluation, possibly based on rich and intact fish habitats, is clearly needed [14]. The scientific analysis and multi-method assessment [2] yields the following characterisation of the Sava: the upper fast-flowing reaches are good; some stretches would probably even fall in class 1. The middle Sava (from the Slovenian-Croatian border to Drina confluence) falls predominantly into class 2, but has lower status in short stretches downstream of major agglomerations and polluted tributaries, mainly due to organic pollution. The lowest 50 - 100 km Serbian stretch is influenced by backwater and falls into class 3 (considering muddy habitats with smaller amounts of dissolved oxygen).

Chemical status: Only 20% of water bodies fail the criteria of good chemical status, and water quality is particularly good in the upper Sava. Local pollution is primarily present downstream of agglomerations, however, there is an accumulation of this in the lower Sava in RS, underlining the pure potamic character and backwater situation that the Danube dam Iron Gate I causes on the last 100 km. Implementing wastewater plans and improving water quality are among the main targets of WFD policies for the next decade and are therefore not further discussed in this study.

Conclusions

- The Sava is one of the largest tributaries of the Danube (with a length of 926 km if including Sava Dolinka and a catchment of 97,800 km²). With 1,570 m³/s, the Sava is the biggest tributary of the Danube by discharge.
- The Sava catchment spreads over several ecoregions and comprises a large variety of landscapes and climatological units. Regular floods on the Sava usually occur in spring and winter. Over more than two thirds of its length, the Sava is a slow-flowing meandering lowland river influenced by large mountainous tributaries from the Balkans.
- The Sava is very important for the huchen species. 65% of all known huchen stretches are located in the Sava basin.
- About 3,000 breeding pairs of sand martin, up to 220 pairs of spoonbills, up to 90 pairs of white-tailed eagle and 900 pairs of white stork are strong indicators for the ecological integrity of larger river stretches and floodplain areas.
- The official and integrative “ecological status” according to the WFD classed the Sava mainly in class 3 (moderate). However, scientific analysis for macroinvertebrates indicates mostly good conditions along the entire course.

☐ *Figure 13: Sand martin colony, typical for natural sandy steep banks. About 3,000 pairs are nesting along the middle Sava (© Anton Vorauer)*

3 LAND STRUCTURE

This is the first comprehensive land structure analysis of its kind for the Sava river corridor. Until now, the available data lacked adequate scale and thematic resolution. For some land use types, such as river banks, bars, pioneer sites and wetlands, no data was available at all. There was no proper distinction between softwood and hardwood forests. Major changes in the landscape have been revealed by analysing the shift between the active and former floodplain boundaries. Local information on river engineering structures such as riprap reinforcements, groynes, concrete banks, weirs and sluices, the distribution of extraction and deposition sites for gravel and sand, and forestry clear-cuts provide a good basis for a detailed quantitative analysis of specific threats and impacts on the riparian corridor.

Identifying and describing the land structure in riverine landscapes in the Sava valley is an essential part of this study. This analysis assesses where and how the land structure of the Sava floodplain depends on the river dynamic, taking into account the impact of changes in land use and vegetation on the landscape. This knowledge will then support the spatial analysis of the threats (Chapter 6) and an evaluation of the restoration potential of the river (Chapter 7).

For this exercise, the project area is defined as the extent of the morphological floodplain, the maximum area originally influenced by floods. Since flood defence dikes have been erected along the Sava and its tributaries, it is important to differentiate between active floodplain and former floodplain when evaluating land use and habitat types. The active floodplain is defined as the area of the morphological floodplain that is still regularly flooded. The former floodplain is defined as the area of the morphological floodplain that lies outside the active floodplain and is no longer under direct influence of the river, in most cases due to the erection of flood dikes.

A map of land structure types with data on land use and habitat has been produced from high resolution satellite images, publicly available aerial images, topographical maps and previous habitat mapping projects.

☐ *Figure 14: Odransko polje, a huge near-natural retention area opposite from Lonjsko polje on the southern Sava bank, HR (© Goran Šafarek).*

Land use and habitat types

The land structure map compiled for the project area covers 8,943 km² (894,350 ha) split into still active floodplain (206,725 ha) as well as former floodplain (687,625 ha) and includes 1,384 rkm of the Sava and the lower courses of its major tributaries. The map has been prepared in three different scales, 1:10,000 for the river system, including features such as islands and gravel bars; 1:25,000 for the active floodplain; and 1:50,000 for the former floodplain.

A total of 35 different land structure types were categorized in eight main groups, as shown in Table 3. The mapping process identified more than 50,000 polygons and features. The maps are prepared in the European ETRS89 LAEA projection system, allowing for effortless data exchange. The Sava White Book contains a map annex with a land structure map of the entire project area. In the following section, the different land use and habitat types are presented in their main groups.

Water bodies

- *River*
- *Impoundment* – backwater of hydropower dams along main rivers, further canals and ditches forming part of the drainage system and usually connected to the river by pumping stations
- *Lake* – very limited size and number in the project area
- *Oxbow* – disconnected former river bends and backwater side-channels
- *Filled gravel and sand pit* – mainly filled with groundwater during or after exploitation
- *Fish pond*
- *Tailing pond and ash dump* – a category containing only three sites. One can be found near Jesenice steel plant on upper Slovenian Sava, a second is related to the chemical industry in Kutina (HR) and the last is near Obrenovace coal power plant in RS

Pioneer stands are defined by their bed material, which can be bedrock, gravel, sand or mud. Bars and islands already connected to forest sites are included in the type *Bar with pioneer vegetation*.

Forest

- *Softwood* – low lying floodplain forest in the active floodplain, frequently flooded and comprising *Salix* and *Populus* species. Outside dikes, in the former floodplain, softwood forests under this definition occur only sparsely, along former small channels very close to former water bodies or as part of succession. Class 205 *Bar with pioneer vegetation* can also include young softwood habitats.
- *Hardwood* – primarily remaining areas of hardwood forest (in the active floodplain) that is still directly flooded (oak, elm and ash forest). A significant portion of hardwood lies outside the flood dikes (in the former floodplain) and is still sporadically flooded by tributary backwaters and rising groundwater from both the main river and the hinterland. It comprises oxbows and other floodplain remnants. However, it also includes less moist stands in transition to oak-hornbeam forests. There is a smooth transition to non-flooded lowland oak forests. Hardwood forests include *Fraxinus angustifolia* stands (and partly *Alnus glutinosa*), which occur naturally in the deepest floodplain depressions with long lasting floods and on the lowland floodplain, even on swampy land and areas of still water. The regulation of tributaries and the disconnection from direct Sava floods may cause long-term hydrological changes to stands outside the active floodplain.
- *Lowland forest* – non-flooded forests dominated by oak and hornbeam (in the former floodplain). It includes forests at the margin of the floodplains and dry stands outside the flood dikes but mostly still connected to large aquifers in the main valley.

☐ *Table 3: Land structure types (colour scheme corresponds to pie charts and map annex).*

Main group	Code and Title	Description
Water bodies	101 River	All main rivers and tributaries
	102 Impoundment	Impoundments of hydropower plants and drainage canals (raw estimation of backwater influenced river stretches)
	103 Lake	Natural lakes
	104 Oxbow	Oxbows and floodplain backwaters
	105 Filled gravel and sand pit	Filled pits in the floodplain
	106 Fish pond	Fish ponds in the floodplain
	107Tailing pond and ash dump	Special cases for steel industry in Jesenice (SI), petrochemical industry in Kutina (HR) and for Obrenovace coal plant in the floodplain (RS)
Pioneer stands	201 Rock bar	Rock bed material in the Slovenian gorge section
	202 Gravel bar	Gravel bars in main rivers and tributaries, visible during mean to low water levels
	203 Sand bar	Sand bars in main rivers and tributaries, visible during mean to low water levels
	204 Mud bar	Mud bars in main rivers and tributaries, visible during mean to low water levels
	205 Bar with pioneer vegetation	Bars, islands with pioneer vegetation (still open substrate parts)
Forests	301 Softwood	Willow and natural poplar (black and white) woods
	302 Hardwood	Ash and oak-elm woods and forests inside and outside the active floodplain (outside active floodplain only flooded by backwater and underground water pressure)
	303 Lowland forest	Oak-hornbeam dominated lowland forests, mostly not flooded but with regular groundwater connection
	304 Poplar plantation	Hybrid poplar plantations inside and outside the active floodplain
	305 Clear-cut	Clear-cuts of all kind of forests
	306 Other forest	Other forest, e.g. beech forest on neighbouring hills or other dry lowland forest, as well as sub-montane forest along upper Sava
Floodplain swamps	401 Floodplain swamp	Floodplain swamps along oxbows and depressions including floating leaves vegetation, reed beds and sedge stands
Grasslands	402 Wet grassland	Wet meadows and pastures inside and outside the active floodplain (includes dense mosaic of grasslands and forests, forest fringes and wet succession areas)
	403 Other grassland	Other meadows and grasslands mainly outside the active floodplain, also within settlements and traffic infrastructure
Agricultural lands	404 Orchard	Orchards and gardens close to villages
	501 Small sectioned agriculture	Small sectioned agriculture, mainly close to villages, subsidiary agriculture
	502 Large sectioned agriculture	Large sectioned agriculture and agroindustry (including fruit/wine production)
Settlements and infrastructure	601Settlement	All kinds of settlements with scattered built environment
	602 City, agglomeration, commercial	Areas with densely built environment
	603 Harbour and industrial	Harbour and industrial sites
	604 Road traffic line	All kind of roads
	605 Railway line	All kind of railway
	606 Recreation area	Recreation areas (e.g. for sports and bathing)
River engineering	701 Flood dike	Flood dikes (mainly grass and lane)
	702 Groyne, traverse	Visible (T-) groyne and boat/ferry pears
	703 Dam, weir, sluice, pumping station	Major hydraulic structures
	704 Concrete bank	Fortified river bank within town stretches and harbours
	705 Gravel and sand pit as well as deposit and dump site	Gravel and sand pits along rivers and within floodplain or to a minor part other deposits or dump sites

Floodplain swamps – all forms of wetland vegetation, including floating leave covers of macrophytes, but in particular reed stands and wetland succession with swamp vegetation.

Grassland

- *Wet grassland* – regularly flooded wet pastures and meadows, usually in the active floodplain, but also wet succession areas in the active and former floodplain with neophytes (*Amorpha fruticosa*) at the fringes of pastures as well as abandoned fields and areas still containing land mines from the Yugoslavian war.
- *Other grassland* – all kinds of dry grassland and ruderal areas. This class comprises broad types of grass and succession areas including small agricultural and forestry roads.

Agricultural land

- *Orchard* – typical orchards, but also gardens and very small-scattered agricultural areas close to villages, and glasshouses
- small sectioned agriculture (smaller field size and mixed crops)
- large-scale agriculture (large fields with monoculture crops).

Settlements and infrastructure – all types of built environments, including towns and villages and the major transport routes.

River engineering

- Flood defence infrastructure
- Major hydraulic structures such as dams and weirs
- Major river regulation structures such as riprap bank revetments and concrete bank sections
- Groynes, which are low water regulation structures to increase river depth during low-water periods
- Gravel and sand deposits, including sites owned by private companies and river dredging deposit sites

Figure 15 is a typical land structure map produced for the study. It shows a regulated stretch of the Sava at the Bosna confluence, where the former floodplain has been almost entirely disconnected from the river by dikes. The lower stretch of the tributary Bosna is in better hydromorphological condition. Zooming reveals several beige-olive coloured spots – sites of intensive gravel mining.

Figure 15: Map section example showing land structure types at the Bosna confluence at Bosanski Šamac in BA (details in map annex).

Land structure evaluation

About 43% or 386,482 ha *of the morphological* floodplain still comprises land use types typical of large river landscapes, i.e. all kind of water bodies, forests and grasslands, including clear-cuts and more dry stands (Figure 16). About 50% of the entire (morphological) floodplain is used for agriculture; another 7% is covered with settlements and other man-made structures (Figure 16, left chart).

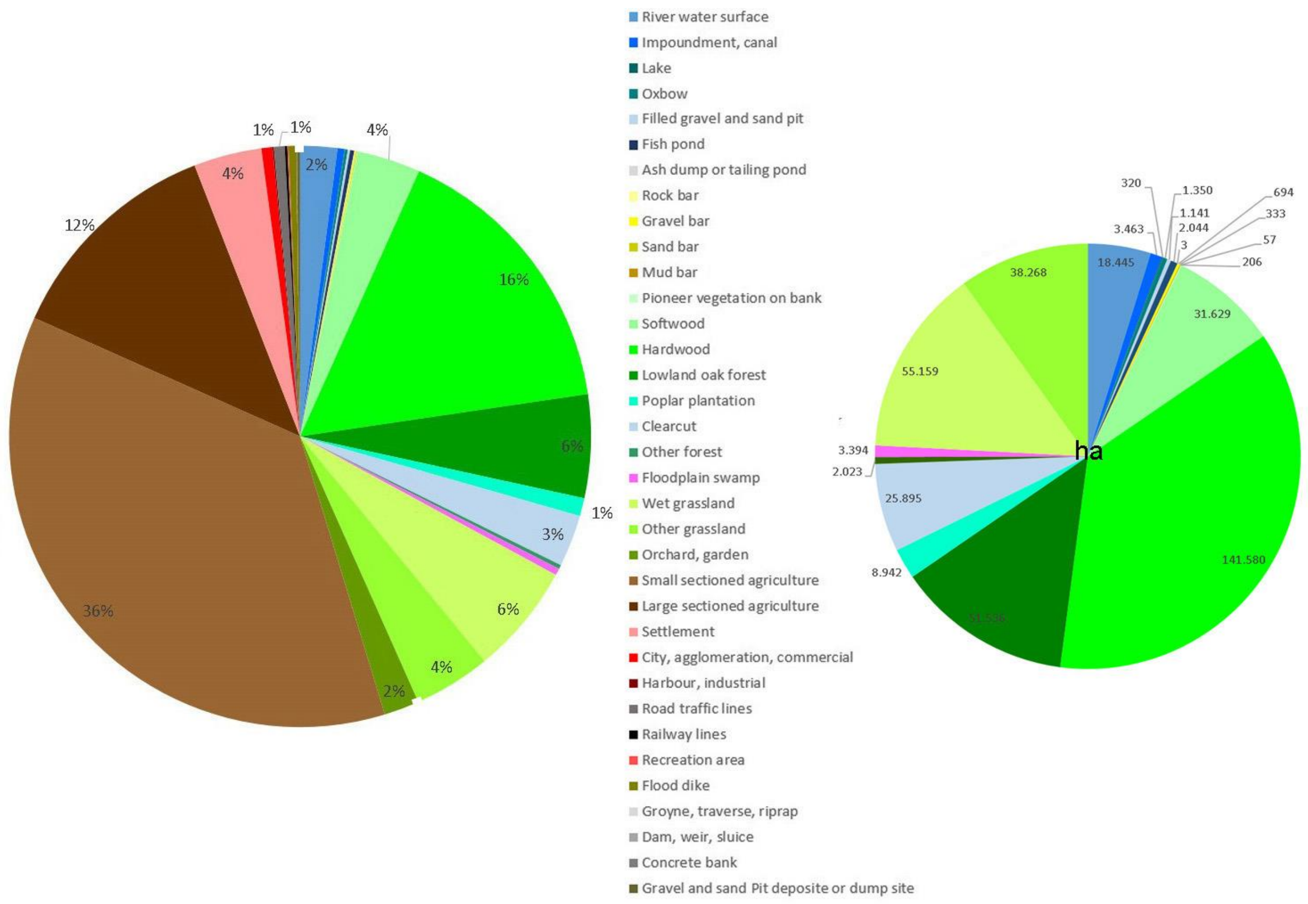
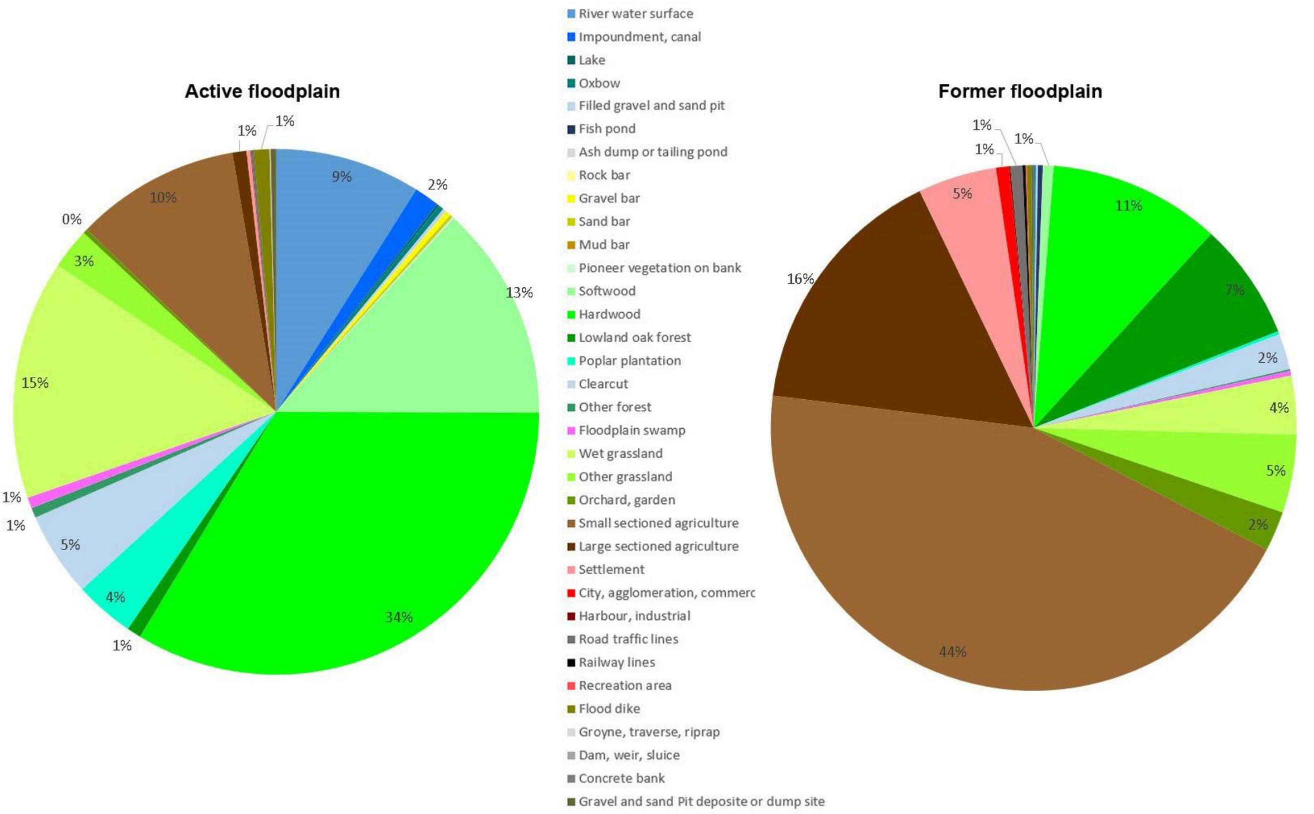


Figure 16: Total distribution of land structure types in the morphological floodplain of the Sava: The chart on the left shows the percentages of all land structure types (i.e. 100% = 894,350 ha); the zoom chart on the right shows figures in hectares and depicts only land uses which are typical for riparian landscapes, namely water bodies, wetlands, forests and grasslands (all together 43% or 386,482 ha); areas <1% are not labelled. *The analysis uses the classification and colour scheme of Table 3.*

Figure 17 compares the land structure of the active floodplain with that of the former floodplain areas. The active floodplain contains a significant proportion of agricultural and altered areas such as sediment deposits, harbours, ferries, river engineering structures and local infrastructure (in total 13%). The hardwood forests in the former floodplains, although ecologically important, have been disconnected from Sava flood water and are affected by the straightening of tributaries and the lowering of river levels as well as groundwater tables due to over-dredging and other causes. As a result, they are becoming extinct in the long term [3]. The size and number of floodplain remnants such as oxbows, floodplain swamps and wet meadows are important feasibility indicators for any goals that might be set for nature conservation and restoration of the former floodplain area.

Known changes in the hydromorphological situation (Chapter 4) and human activities such as the development of hydropower, navigation, sediment exploitation and flood defence (Chapter 6) are reflected in the land structure maps. Different data aggregations are prepared for the different land use and habitat types and in relation to the location of the land structures within the river corridor (active versus former floodplain). This approach will give insight into the current situation of the Sava river and its floodplain, and how the situation is developing.



☐ *Figure 17: Comparison of the land structure of active floodplain (206,725 ha) and former floodplain (687,625 ha); areas <1% are not labelled.*

Results

The following listing and Figure 18 show the areas with high riparian ecological value. They cover 265,255 ha or 30% of the entire morphological floodplain.

(Percentages refer to total area of morphological floodplain, 894,350 ha.)

- **The river water surface of the Sava and its tributaries has a total area of 21,908 ha (3%)**[4] and comprises water bodies with a wide range of size, depth, trophic conditions and flow velocity. The most altered water bodies are impoundments of dams along the upper Sava and the 100 km long section upstream from the confluence with the Danube, which are influenced by the Iron Gate I dam. The total water surface at mean water level is about 18,445 ha for free flowing channels and another 3,463 ha for impoundments.

- **Bars of rock, gravel, sand and mud, and pioneer stands on bars cover a total of 1,293 ha (<1%)** [5] and constitute the typical and most significant riverine habitats. The analysis is based on visible bars at mean water level. Gravel bars, predominantly found along lower Drina and southern tributaries make up the largest proportion of bars without vegetation (694 ha), followed by sand bars (333 ha), mud bars (57 ha) and rock bars (3 ha). Pioneer stands on bars, representing a connection to softwood habitats,

[4] 101 River, 102 Impoundment
[5] 201 Rock bar, 202 Gravel bar, 203 Sand bar, 204 Mud bar, 205 Bar with pioneer vegetation

cover an additional 206 ha. Regionally, the largest of the 713 recorded gravel bars covers 21.3 ha on lower Drina while the gravel bars on the upper Sava reach in SI sum up to 104 ha, including those on Sava Dolinka and Bohinjka.

- **Oxbows make up a total water surface of 1,350 ha (<1%)[6]** and are at various successional stages and of various sizes. There are more than 766 individual oxbow water bodies (the largest is 83 ha), often grouped in oxbow complexes together with floodplain swamps. However, there are not many young oxbows on the Sava itself due to the short but very effective bank reinforcements, which prevent lateral channel development and meander breakthrough.

- **Floodplain swamps (e.g. reed beds) cover a total area of 3,394 ha (<1%)[7]** and are mainly connected to oxbows and succession areas, or are found in depressions connected to wet grasslands and within floodplain forests.

- **Softwood forests cover 31,629 ha (3.5%) and poplar plantations another 8,942 ha (1%)[8]** of the most frequently flooded areas. Natural stands mainly take the form of galleries and fringes in the active floodplain. White willow is most common, with a few natural stands of white or black poplar. Poplar plantations are located predominantly in RS, and more than two thirds are found south of the Ramsar site Obedska bara. Poplar plantations have much less ecological value than other softwoods, however they cover primarily regulated flooded areas and in case of smaller patches, they count to the valuable softwoods.

- **Hardwood forests cover about 63,302 ha (7%) in the active floodplain and 78,278 ha (9%) outside flood dikes (totalling to 141,580 ha (16%))[9]** and are the most impressive and complex floodplain habitats. Originally, hardwood forests were widespread along the middle and lower Sava and still cover huge areas, particularly in HR and RS (the forests in Lonjsko polje, Odransko polje and Mokro polje and the Bosut-Spačva forest alone account for some 100,000 ha). The hardwood forests outside the active floodplain are located in areas subject to flooding from rising groundwater or water from hinterland and tributaries. There are some oak and ash dominated areas on flooded land and some small stands of black alder in very swampy areas at the fringe of the floodplain. Elm is another typical species in lower oak forests. Today, more than half of the hardwood forests lie outside the flood dikes, reflecting a long-term change in hydrographical and sedimentological conditions in the former floodplain, because they are no longer interconnected through the flow of high and oscillating groundwater or secondary streams and water bodies. Most of the hardwoods are managed by the state forestry agencies. Some of the near-natural stands are in Lonjsko Polje Nature Park and the forests of Obedska bara and Bosut-Spačva.

- **Wet grassland with a total area of 55,159 ha (6%)[10]** is mainly used for pastures. Large pastures such as in Lonjsko polje and Mokro polje account approximately for half of the total area (25,000 ha) of this land structure type. The other half is largely made up of small and scattered sites. Many pastures and meadows are abandoned and covered by neophytes (namely *Amorpha fruticosa*).

[6] 104 Oxbow
[7] 401 Floodplain swamp
[8] 301 Softwood, 304 Poplar plantation
[9] 302 Hardwood
[10] 402 Wet grassland

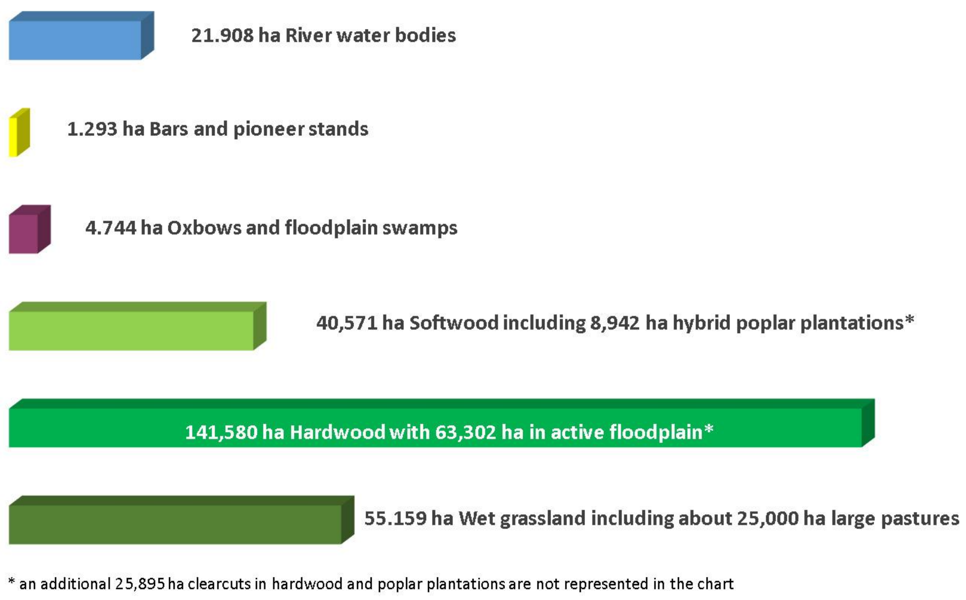


Figure 18: Distribution of riparian land structure types with high ecological value in the morphological floodplain of the Sava (in total 265,255 ha).

The extent of hardwood forests is particularly significant. Out of a total of 141,580 ha, an area of nearly 63,302 ha lies within the active floodplain – a tremendously high value. In Germany, the overall size of intact hardwood forests within the active floodplain of the largest rivers (>10,000 km² catchment size) is estimated at merely 5,700 ha [15] out of 15,000 ha in the entire morphological floodplain.

The area of about 1,293 ha comprising bars and pioneer stands does not seem very large at first, but the figure must be considered in the light of the meandering lowland character of Sava and its tributaries. The Sava itself has never developed large point bars (or at least there is no historical evidence for them). Bank substrates include a lot of confined silty, fine substrate which is relatively resistant against lateral erosion. Although intensive dredging along some reaches over the past decades has reduced bar building processes, pioneer stands still cover remarkable areas on southern tributaries.

The main influences on major land structure types are increased disturbance from dredging in the river bed, affecting pioneer areas and bars, and a slow but constant incision of the main Sava channel in the middle reach, leading to a decrease of lateral connectivity and a drop of groundwater tables. This has adverse consequences for water dependent habitats (wet grasslands and floodplain forests).

Neophytes are present in a wide range of structure types and can spread out periodically, but occur particularly around river regulation construction sites and within clear-cuts or at fringes of pastures (where abandoned) and other succession areas. A few of the over thirty frequently occurring species in this area are: *Elodea canadensis*, *Impatiens glandulifera*, *Amorpha fruticosa* (as one of the most significant in terms of the extent of the areas it occupies), *Helianthus tuberosus* and *Solidago canadensis*, and the trees *Acer negundo*, *Populus x canadensis* or *Fraxinus americana*.

Conclusions

- With a focus on the river, the active floodplain and the riparian landscape, 35 typical land structure types have been differentiated and mapped (incl. human-made structures).
- The mapped project area comprises the whole morphological floodplain (active and former floodplain), covering a total of 8,943 km².
- About 43% of the total morphological floodplain is still made up of land use types and habitats typical of large river landscapes, including clear-cuts and more dry stands for forests and grasslands.
- 30% of the Sava's morphological floodplain contains ecologically valuable habitats (265,255 ha). These habitats are found in river water bodies (21,908 ha), bars and pioneer stands (1,293 ha), softwood galleries and poplar plantations (40,571 ha), large hardwood forests (141,580 ha), wet grasslands (55,159 ha), oxbows at all stages of succession, and swampy floodplain vegetation (4,744 ha).
- With 63,302 ha of hardwood in the active floodplain and about 25,000 ha of regularly flooded large pastures, the Sava counts among the ecologically most important riparian landscapes in Europe.

Figure 19: Flooded hardwood forest in Sava's active floodplain (© Tibor Mikuska).

4 HYDROMORPHOLOGICAL ASSESSMENT

This chapter assesses the intactness of the hydromorphological conditions of the Sava river and its tributaries. It is the first concise hydromorphological analysis of the Sava. It also examines the official WFD assessments and compares it to the findings of this study. The analysis centres on a comparison of the specific scores for channels, banks and floodplains in the current status and the "type-specific reference conditions" – the hydromorphological condition before intensive human intervention. The classification is based on the absence or presence of specific features such as river engineering structures, gravel and sand bars or bank reinforcement. This gives a comprehensive picture of the current situation

Method

The scale of hydromorphological assessment for a large river like the Sava is limited to an overview (also taking into account the overall length of assessed rivers). This study considers the "visible" features of the three main parameter groups of *channel*, *banks* and *floodplains*, but does not feature any cross-sectional, sediment and in situ morphological analysis. The approach is based on the standards for assessment of hydromorphological features of rivers published by the European Committee for Standardisation (CEN) [16, 17]. This is the umbrella under which most WFD standards for fresh water assessments were developed. The parameters of the assessment are the same as those used in the Joint Danube Survey 2 of the International Commission for the Protection of the Danube River [18]. More extended surveys, combining descriptive approaches with physical measurements in the manner of the Joint Danube Survey 3, [19] would be a consequential follow-up study to this assessment.

For the purpose of this study, the rivers are subdivided into long continuous assessment stretches rather than standard sections of equal length. In addition, the three parameter groups – channels, banks and floodplains – are evaluated separately. A summary of figures is given for left and right banks and floodplains. The overall assessment score is the arithmetic mean of values in the main parameter groups. This approach differs from the worst case approach of the WFD, where the worst individual value for a parameter group is the final value. This holistic approach uses the average of all three parameter groups and gives a far better representation of the overall hydromorphological condition.

Hydromorphological classes

The following classification and colour scheme was used both for the individual assessment of channel, banks and floodplains and for the final overall assessment:

☐ *Table 4: Classification and colour scheme for hydromorphological assessment.*

Class 1	**Near-natural - Reference conditions**
Class 2	**Slightly modified**
Class 3	**Moderately modified**
Class 4	**Extensively modified**
Class 5	**Severely modified**

In the case of tributaries, only one overall class integrating all three main parameter groups, was assigned.

Figures 20 - 23 show the typical channel patterns of the upper, middle and lower Sava reaches, based on historical maps (military surveys of the Austro-Hungarian Monarchy, "Franziszeische Landesaufnahme 1806 - 1869" [20]). These maps depict the reference conditions for the hydromorphological assessment.

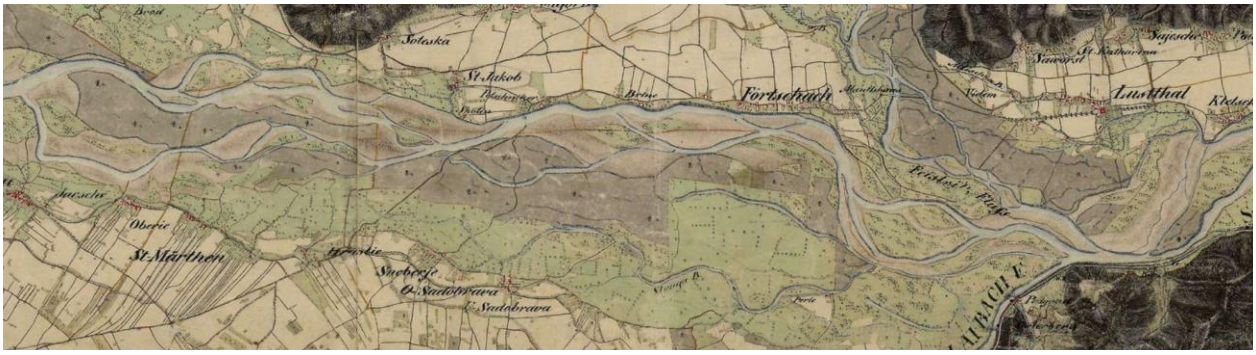


Figure 20: Upper Sava just upstream from the Ljubljanica confluence. Example for transition from braided (multi-channel) to anabranching (main channel with side-channels) river types [20].

Figure 21: Upper middle Sava near Zagreb. Example for transition from anabranching to meander types [20].

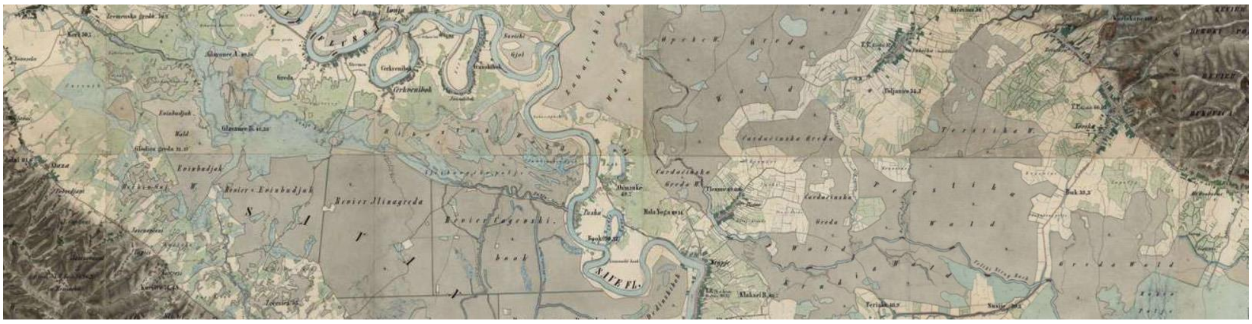


Figure 22: Middle Sava between Sisak and Jasenovac. Example for meandering river type within natural bank levees and huge floodplains from southern to northern foothills [20].

Figure 23: Lower Sava near the Bosut-Spačva forest. Example for meandering type with large floodplain (in left corner, the historical map is missing and a satellite image shows the meandering border Sava) [20].

Figures 24 - 28 show examples for river sections of the five hydromorphological classes listed in Table 4.

- *Figure 24: Class 1 (near-natural): active meander development on the Sava near Krapje (HR), within large intact softwood and hardwood floodplain forests, unique in the Danube basin [21].*

- *Figure 25: Class 2 (slightly modified): the Sava near Domaljevac (BA), still meandering, partially among natural banks, surrounded by floodplain forests, wet grasslands and agricultural lands. The floodplain is limited by dikes [21].*

- Figure 26: Class 3 (moderately modified): the Sava near Slavonski Brod (HR), still free-flowing (continuum) with stabilised banks and detached floodplains [21].

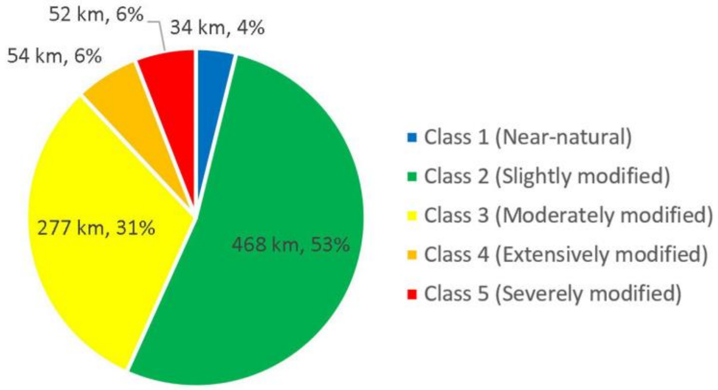
- Figure 27: Class 4 (extensively modified): the Sava in Zagreb (HR), strongly altered, with trapezoid cross section, detached floodplains and ramp for retaining cooling water [21].

- Figure 28: Class 5 (severely modified): the upper Sava at the Boštanj dam (SI). This upper reach has been turned into a chain of hydropower dam impoundments [21].

Results

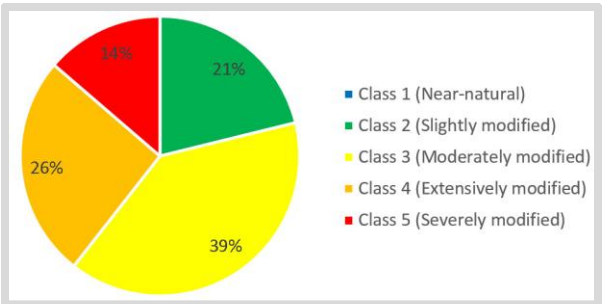
A total river length of 1,577 km was examined: 885 km of the main Sava river in detail and an additional 692 km of tributaries (including the spring branches Sava Dolinka and Sava Bohinjka).

Sava (without spring branches and tributaries): In total, 57% of the river fall in class 1 or 2, meaning these stretches are still in near-natural conditions (class 1: 4%) or only slightly modified (class 2: 53%). This underlines how the Sava stands out among large rivers in Europe. Moderately modified stretches (class 3) account for 31%, while the remaining 12% is extensively (class 4) or even severely modified (class 5), mainly due to the effects of hydropower plants (Figure 29). The stretches leading through big cities score as extensively modified.



☐ *Figure 29: Overall hydromorphological assessment of the Sava river (without spring branches and tributaries), totalling 885 rkm.*

In order to demonstrate the excellent hydromorphological conditions of the Sava, the overall assessment of the navigable Danube (2,412 rkm) is presented for comparison in Figure 30. The data is based on the Joint Danube Survey 3, published in 2013 [19]. Near-natural conditions are entirely absent, less than one quarter of the Danube is slightly modified, and extensively and severely modified stretches make up a total of 40%.

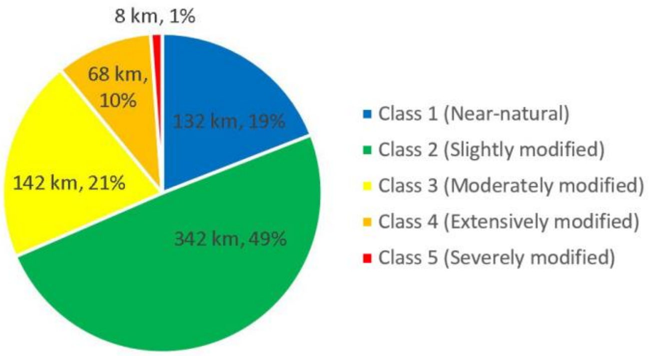


☐ *Figure 30: Overall hydromorphological assessment of the Danube, totalling 2,412 rkm [19].*

An overview of Sava's hydromorphological assessment is depicted in Figure 32. The hydromorphological conditions are most diverse along the upper course. At the upper reach of the main Sava, there are several short, strongly altered stretches in-between near-natural stretches and along narrow valleys. Two impounded hydropower stretches on the upper Sava in SI have a total length of about 80 km. The next strongly altered reach is in the middle course, extending approximately along 20 km in Zagreb and including a floodwater bypass. Finally, the last 100 km of the Sava from Šabac to its confluence with the Danube is influenced by the Iron Gate I dam on the Danube, including the most influenced and extensively modified city stretch of Belgrade, but also the Obedska bara in the less influenced upper reach (better scoring due to intact floodplains).

Along the remaining 550 km of the middle and lower stretches, the Sava is moderately regulated and large floodplain areas are detached, but several longer stretches are still strongly meandering. The upper middle Sava flood polder system between Zagreb and Jasenovac, with its extensive areas of near-natural floodplain, significantly improves the assessment results. As mentioned in Chapter 2, settlements along the banks of the entire middle Sava have not fundamentally changed the hydromorphological conditions, and this stretch is characterised by natural banks and levees, so that the huge floodplain is still connected and regularly flooded. This long free-flowing stretch is mostly assessed as slightly modified, although there are some moderately modified sections but even some very short near-natural stretches at the best preserved meanders, which retain an active lateral shift.

Spring branches and tributaries: The spring branches, Sava Bohinjka and Sava Dolinka, as well as the lower courses of Sava tributaries – being part of the morphological floodplain – were assessed, totalling a length of 692 rkm. Tributaries considered in this study are: Ljubljanica, Krka, Krapina, Odra, Kupa, Lonja, Cesma, Ilova, Una, Strug, Jablanica, Sumetlica, Resetarica, Vrbas, Orljava, Ukrina, Bosna, Drina, Bosut and Kolubara. Most of the river stretches of spring branches and tributaries score even better in hydromorphological conditions than the Sava itself (19% of them fall in class 1 and 49% in class 2). The most valuable lower courses of tributaries enrich – or even substitute – anabranching river stretches of the upper Sava around the Slovenian-Croatian border and Zagreb. They feature lots of bars, islands, steep banks and pioneer areas. Near-natural stretches have been identified on lower Drina and Vrbas, and also on smaller tributaries such as Lonja, Ukrina, as well as on Sava Bohinjka and Sava Dolinka.

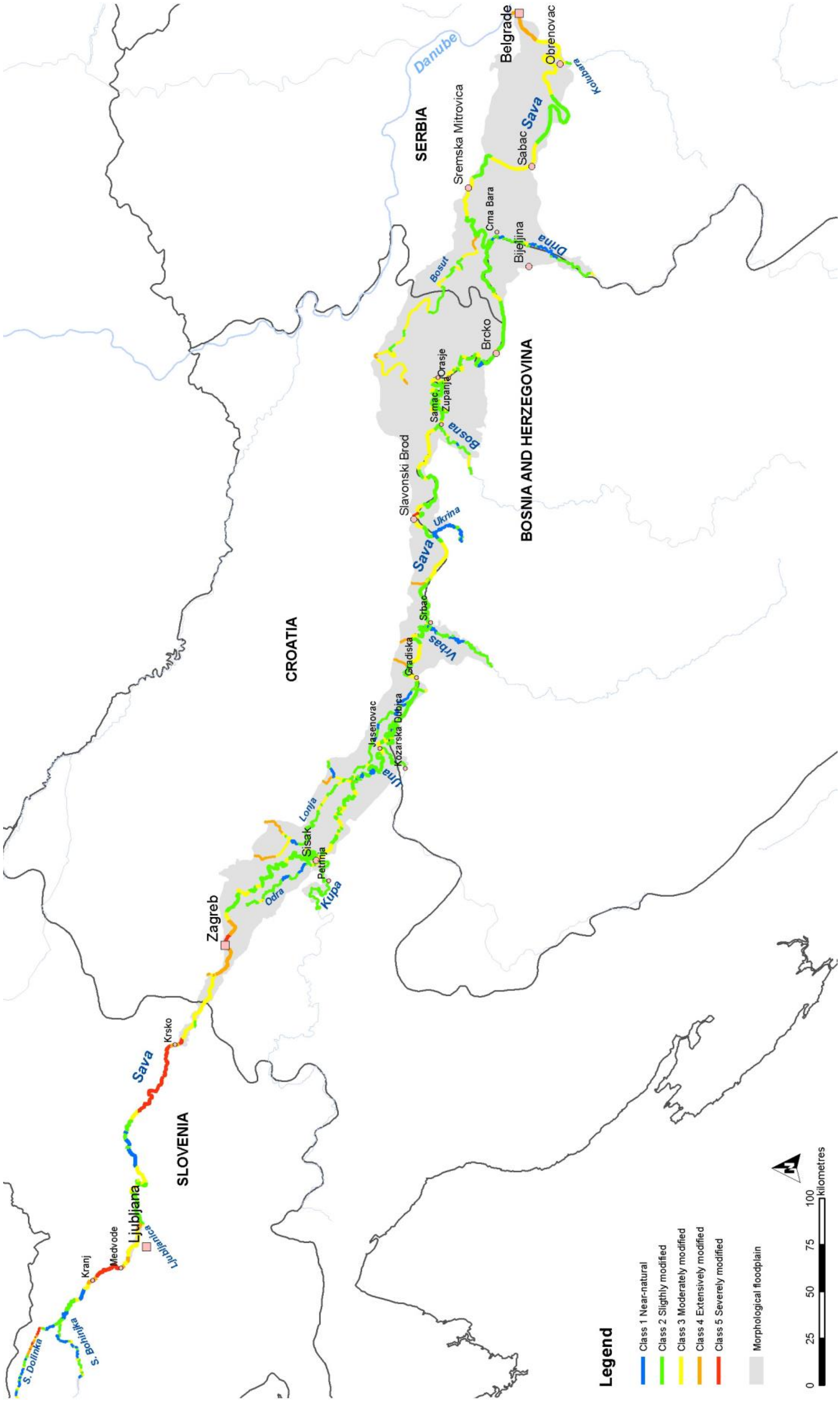


☐ *Figure 31: Overall hydromorphological assessment of Sava's spring branches and the lower parts of larger and smaller tributaries within the morphological floodplain, totalling a length of 692 rkm.*

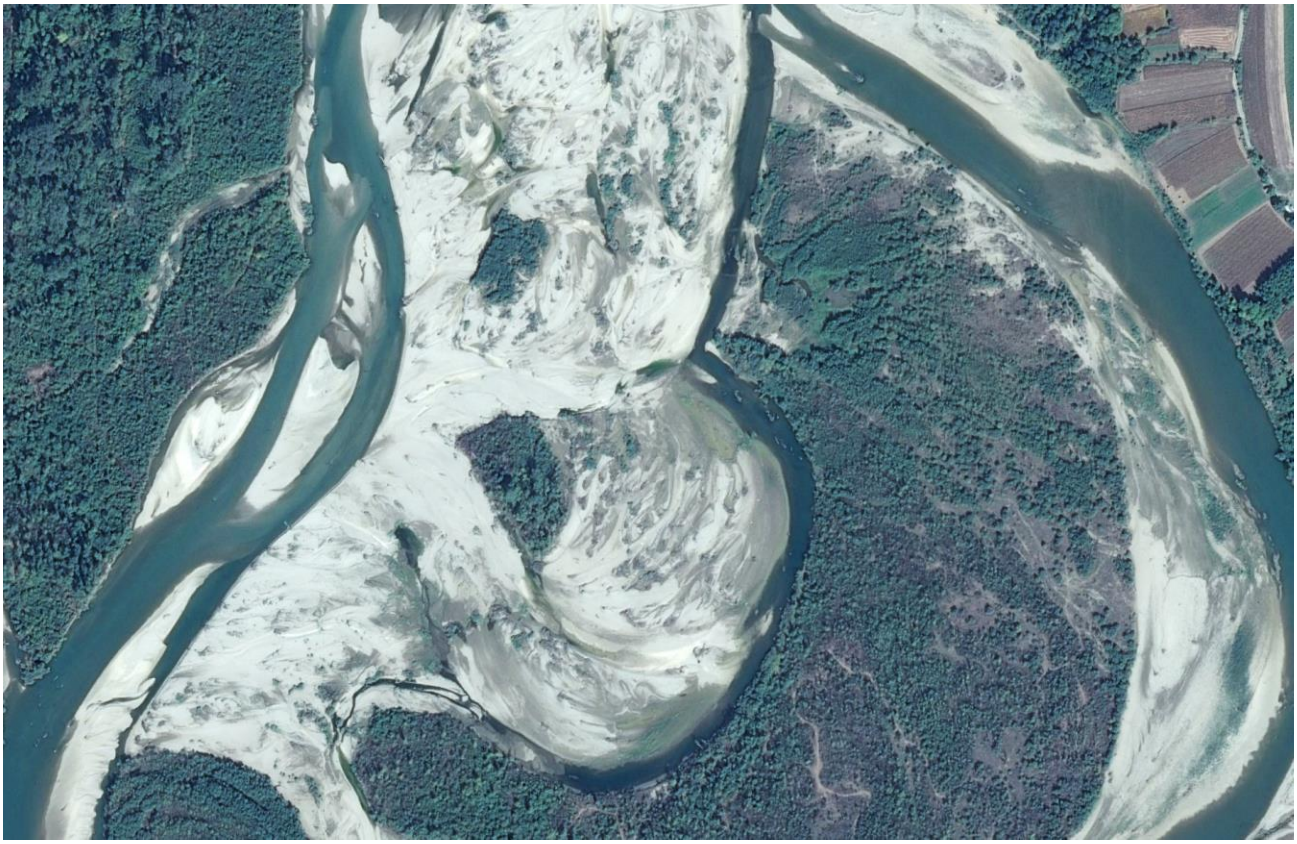
Long stretches of Drina, Bosna, Vrbas and Una are still only slightly modified (class 2), even though the lower courses are rather densely populated and sediment mining is common. In the case of Drina, conditions are worsened by a chain of hydropower plants, which retains significant amounts of bedload in the reservoirs and causes a daily water level fluctuation of up to one metre at the last dam due to hydropeaking [22]. Nevertheless, since the Drina is not regulated in the 50 km downstream between the last dam and the Sava confluence, a strong lateral erosion and a shifting channel with numerous bars, islands and steep banks significantly improve the hydromorphological conditions (see Figures 33 and 34).

Navigation only slightly affects conditions on the tributaries, but navigation-related dredging activities along the Sava have a negative effect on the erosion base of tributaries.

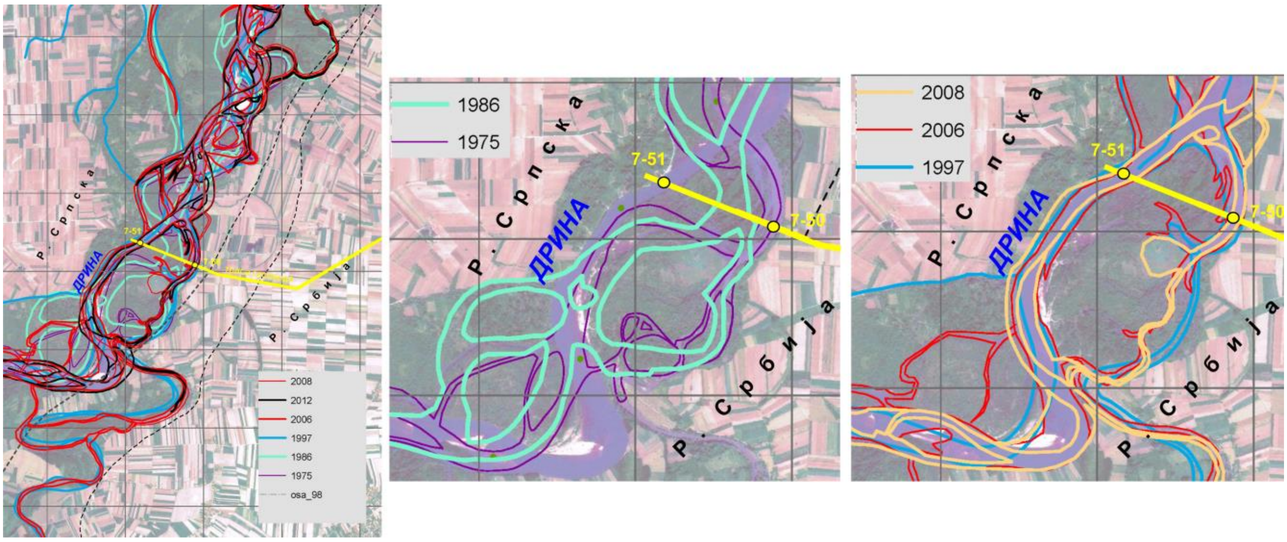
Several small northern tributaries in HR are extensively or severely modified due to river regulation for drainage (Sumetlica, Resetarica and Orljava).



□ *Figure 32: Overall hydromorphological assessment of the Sava and its tributaries in the morphological floodplain.*



☐ *Figure 33: The lower Drina close to its confluence with the Sava (BA/ RS), still near-natural (class 1) [21].*



☐ *Figure 34: The development of the Drina channel system between 1975 and 2008 clearly indicates the considerable dynamic and morphological changes in the lower course [22].*

Detailed results for channel, banks and floodplains

The separate assessment of the channel, banks and floodplains enables a more thorough examination of the hydromorphological conditions. Left and right sides of banks and floodplains are evaluated collectively, which is a pragmatic approach reflecting the overall situation. Some locations might merit a further detailed analysis featuring a separate survey of each side. Along certain stretches, important bank reinforcements and the last remaining long steep banks were analysed using short assessment units of about 1 km (there are 204 assessment stretches with lengths between 1 and 25 km).

Figure 35 shows the hydromorphological classification of the three assessment units, i.e. channel, banks and floodplains. In general, these charts reflect the overall assessment; however, they clearly show that, with a higher proportion of classes 1 and 2, channel and banks are in a better condition than floodplains.

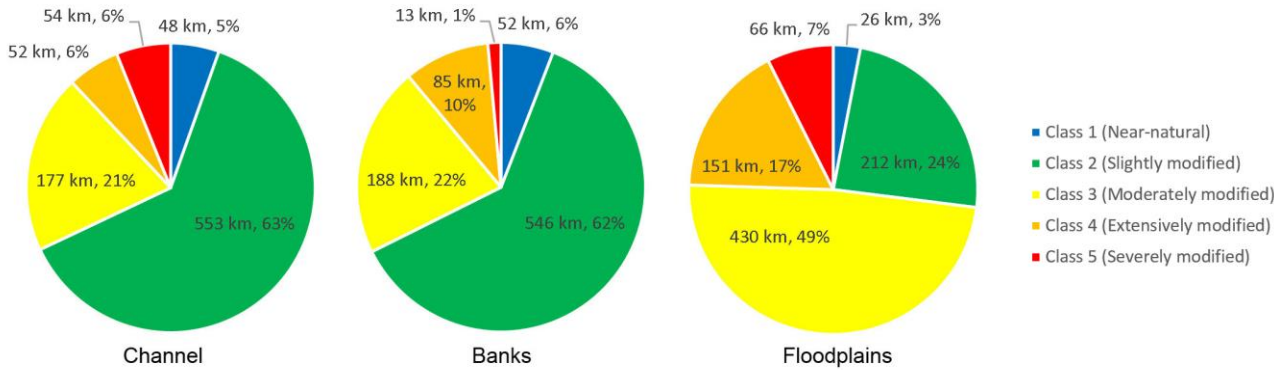


Figure 35: Detailed assessment for channel, banks and floodplains of the Sava (for continuous view compare map annex at the end of the White Book)

Sections with near-natural conditions are mainly present in the upper Sava gorges and the upper stretches immediately downstream of the confluence of Sava Bohinjka and Sava Dolinka. In the middle Sava reach upstream of the Una confluence, several very short and one longer stretch fall into class 1. The meandering middle and lower reaches of the Sava are in rather good conditions by comparison with the historical reference (Figures 22 and 23). However, some groyne fields and bank reinforcements along steep banks have significantly reduced channel development and dynamics.

Along great extents of the middle and lower Sava, the banks are free of continuous reinforcement and have fairly intact riparian vegetation. Some short stretches and steep banks, particularly on the outer curves of meanders, are reinforced with riprap, although it is rather old and overgrown in some places. Entirely free steep banks with strong side erosion are limited to a total length of about 30 km along the middle and lower Sava, e.g. near Srbac, downstream from the Vrbas confluence and within the Lonjsko Polje Nature Park (see Figure 36). The lateral erosion rates are relatively low in the fine and compact bank substrates with up to 3 m/a [23] in comparison to gravel and sandy rivers (10 m and more).

There are also distinctions between different kinds of extensively and severely modified bank and channel reaches. Since they significantly reduce flow velocity and sedimentation processes, impoundments have a much more significant impact on the river than reinforced banks and the effects are visible on a much longer stretch downstream.

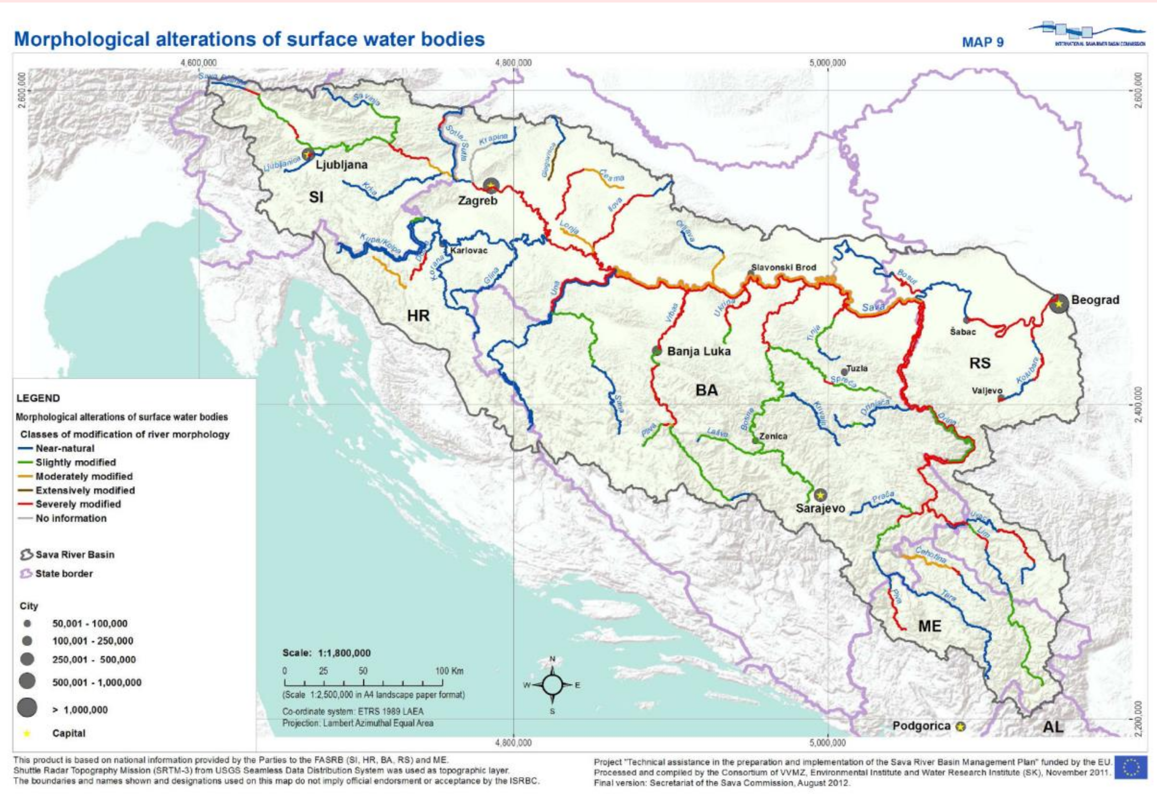
Near-natural floodplain conditions occur at two locations delimited by natural foothills on the south bank and by large floodplain forests on the north bank. These sites are found downstream of Jasenovac and south of Obedska bara. Floodplain areas (poljes) separated from the main Sava by a flood dike but reconnected during floods by short flood canals did not attain the near-natural score. These huge retention areas nonetheless play a vital role in the mitigation of floods. They are rated as class 2, slightly modified. This is a good condition for the floodplain of a lowland river of the size of the Sava.

☐ *Figure 36: Natural steep banks along middle Sava (© Kerstin Sauer).*

☐ *Figure 37: Bank reinforcements are degrading numerous meander bends (© Martin Schneider Jacoby).*

Comparison of study data with the Sava River Basin Management Plan

The results of the hydromorphological assessment of the middle and lower Sava and its large tributaries Vrbas, Bosna and Drina in this chapter are incompatible with the official evaluations of the Sava Commission's Management Plan [1]. The (hydro-)morphological evaluation in the Management Plan comes out much worse, as shown in Figure 38. Even if allowing for the different methods used in the Sava Management Plan, 70% of rivers' courses differ considerably in results. In addition, there is some inconsistency within the Sava River Basin Management Plan itself. In contradiction to the map of the Sava Commission, where some 75% of Sava fall into classes 3 - 5 (Figure 38, considering that orange might mean "class 3" instead of "class 4, which is not recognisable in the map), the special annex *Background Paper No 4 for Hydromorphology* [1] states that for the Sava, 28% are rated class 1, while 36% are class 2 and 35% class 3 (only 14 non-Heavily Modified Water Bodies on upper Sava were examined). Moreover, 60% of the tributaries fall in class 1 (blue) and 30% in class 2 (green) according to the special annex.



☐ *Figure 38: Map 9 of the Sava River Basin Management Plan [1]. Legend entries for class 3 and 4 (supposed to be yellow and orange) are unclear or simply wrong.*

The stretches of the Sava marked red on the map were provisionally designated as Heavily Modified Water Bodies (HMWB) already taking into account planned hydropower plants and navigation project to upgrade the current navigation class, rather than reflecting the status quo. According to the official WFD definition, HMWB's "are bodies of water which as a result of physical alterations by human activity are substantially changed in character and cannot, therefore, meet 'good ecological status'. In this context physical alterations mean changes to e.g. the size, slope, discharge, form and shape of river bed of a water body".

It seems that the Management Plan tries to pave the way for positive decisions on planned navigation and hydropower development by including future negative effects in the current evaluation of the hydromorphology of the rivers. Sections of the middle and lower Sava were rated almost entirely as "potentially heavy modified" and were therefore not assessed in detail. RS designated the lower 100 km of the Sava as HMWB. There is a backwater effect of the Iron Gate I, but it requires better analysis, because the only significant effects at the beginning of the backwater occur at low water and the remaining reach to Drina confluence is a natural water body (compare Figure 33). Nonetheless, the Drina was preliminary designated as HMWB, as were the Bosna and Vrbas in BA.

Conclusions

- More than 50% of the Sava river stretches have been classified as only slightly modified, some small stretches even fall in reference class 1. In regards to the Sava spring branches and tributaries, 68% score class 2 or better. These are remarkable results compared to many large rivers in Western Europe.
- Hydromorphological conditions are diverse, especially along the upper course of the Sava. Entirely free steep banks with strong erosion are limited to about 30 km total length along the middle and lower Sava.
- The Sava River Basin Management Plan prepared by the Sava Commission provisionally designates heavily modified water body status as if plans for navigation and hydropower were already reality. The designation should reflect the current situation rather than a potentially deteriorated future status.
- Up to 70% of the lower Sava and most tributaries are in a far better hydromorphological condition than the Sava River Basin Management Plan conveys.

Figure 39: The Vrbas in BA. The hydromorphology of the Sava tributaries are still in excellent condition: 68% score class 2 or better. (© Tibor Mikuska).

5 PROTECTED AREAS

The Sava valley and lowlands are of outstanding ecological value. As mentioned in Chapter 3 and 4, about 30% of the morphological floodplain is comprised of ecologically highly valuable riparian land structure types and 57% of Sava's course is in slightly modified or even near-natural hydromorphological conditions. Consequently, there are numerous protected areas along the entire course of the river and its floodplain.

The five main categories of protected areas in the morphological floodplain:

1. **National parks**
2. **Ramsar sites/biosphere reserves/World Heritage sites**
3. **Natura 2000 sites** (present in the EU member states SI and HR)
4. **National strictly protected areas and candidate Emerald sites**
5. **Other protected areas**: landscape protected areas with lower protection status

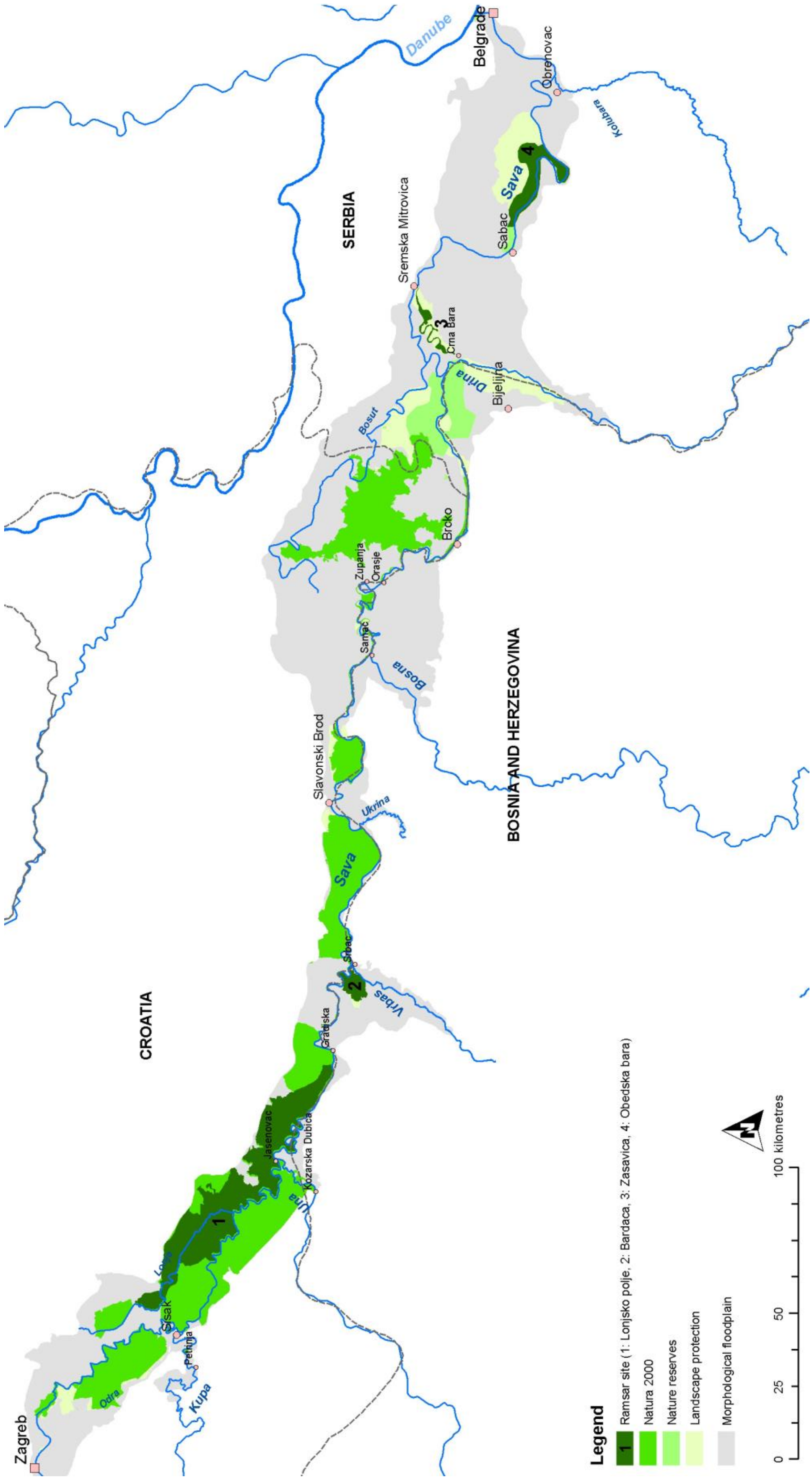
In some cases, these protection categories overlap. This is particularly important for the Ramsar sites, which contain designated wetlands of international importance. For example, Lonjsko Polje Nature Park in HR is both Ramsar site and Natura 2000 site, and Obedska Bara Nature Reserve in RS is both a protected nature park and a Ramsar site. The order of protection strictness is important for the evaluation. The highest protection is applied for the core zones of national parks, followed by strict nature reserves and finally all other areas, buffer zones and landscape protection areas.

The total size of protected areas in Sava's morphological floodplain is 322,875 ha, 36% of the entire area. Nearly half of these protected areas (45% or 144,656 ha) are within the active floodplain (206,725 ha), which also means that 70% of active floodplains are protected.

With partial overlap, the areas of the categories listed above are as follows (compare also table 5 below):

- 1 National park: 16 ha (Sava Bohinjka headwater as part of Triglav National Park (SI))
- 4 Ramsar sites: 73,316 ha
- 20 Natura 2000 sites: 222,826 ha (including the Lonjsko Polje Ramsar site of 50,521 ha)
- 11 protected areas: 31,982 ha (including nature reserves Obedska bara with 9,896 ha and Zasavica with 621 ha, Bardača with 748 ha as well as a candidate Emerald site in BA covering some 10,000 ha)
- 41 other protected areas: 162,917 ha but many overlaps with other categories (56,030 ha without overlaps)

A few sites along the Slovenian Sava and tributaries and the entire Croatian river course are protected as Natura 2000 sites. The famous Lonjsko Polje Nature Park (HR) and the Obedska Bara Nature Reserve (RS) are protected as Ramsar sites. Ecologically important areas with national protection in BA and RS include the Bardača (BA) and the Zasavica (RS) oxbow systems, which are also Ramsar sites. There are several other important protected areas, such as the *ecologically important* river stretches in SI, the landscape protected Spačva-Bosut forests in HR and the lower Drina valley in BA.



☐ *Figure 40: Protected areas between Zagreb and Belgrade within the boundary of the morphological floodplain (for better perceptibility, only part of the morphological floodplain/Sava is depicted)*

The lower courses of the Vrbas, Bosna and Drina are still not sufficiently protected. Gravel and sand bars with pioneer stands on those lower tributaries, together with the alluvial Sava lowland with its huge forests, wetlands and wet meadows, form a wide spectrum of habitats.

Only 15% or 132 km of the 885 km length of the Sava (excluding headwater branches) has no protection status. There is protection on a firm legal basis along a total of 563 km (64%). The remaining 21% merely have the Slovenian landscape protection status "*Ecologically Important Area*", but this formally also includes impoundments. This corresponds to the Ramsar and Natura 2000 sites as well as nature reserves. By far the longest protected section is the Croatian Natura 2000 stretch of 457 km. Where the Sava forms the border between HR and BA, however, the river is only protected on the Croatian side (up to the middle of the river course). Even though the Sava is so densely protected, these protection statuses are commonly not enforced very thoroughly.

All the protected areas are listed in Table 5. The data is based on GIS analysis bounded by the morphological floodplain, thus the areas given might not match the official areas. Moreover, high quality GIS boundaries were not available for all protected areas, which is another source of size deviations. Sometimes different protection categories overlap, for example in the case of Obedska bara, which is a Ramsar site and a nature reserve, or Lonjsko polje, which is Natura 2000 and a Ramsar site. The areas are grouped in the five main categories.

Despite the relatively dense network of protected areas, important river stretches are not sufficiently protected: in SI, at the Sava gorge upstream of the existing dam chain between Podkraj and Ljubljanica mouth and in the border triangle of RS, HR and BA at the Drina confluence. In addition, the Sava bank and the lower sections of the southern tributaries in BA should be designated as protected areas. With the formal processes of Natura 2000 designation in RS and particularly BA in the near future, it is expected that the numbers and surface area of protected areas will increase in those countries.

The Sava and its tributaries are facing considerable threats as documented in Chapter 6, affecting many existing and valuable areas to be protected.

☐ *Table 5: Protected areas in the morphological floodplain, from upper reach to lower reach (only sites of at least 1ha are listed)*

National parks:

Country	Site name	ha
SI	Triglav National Park (only the Sava Bohinjka headwater is inside the park)	16

Ramsar sites:

Country	Site name	ha
HR	Lonjsko Polje Nature Park	50,521
BA	Bardača Wetland	3,381
RS	Zasavica	1,913
RS	Obedska Bara	17,501

Natura 2000 sites:

Country	Site name	ha
SI	Mirna	1
SI	Nakelska Sava	105
SI	Krka	18
SI	Spodnja Sava	125

Country	Site name	ha
SI	Vrbina	145
SI	Sava - Medvode - Kresnice	372
SI	Veliko Kozje	1
SI	Posavsko hribovje - ostenje	1
HR	Kupa	1,036
HR	Odra kod Jagodna	5
HR	Sutla	13
HR	Sava nizvodno od Hruščice	12,959
HR	Žutica	4,661
HR	Spačvanski bazen (includes Spačva JZ with 5,326)	38,129
HR	Potok Bregana	7
HR	Sava kod Hruščice	1,528
HR	Turopolje (includes Odranjsko polje with 13,683)	20,057
HR	Sava uzvodno od Zagreba	210
HR	Donja Posavina (includes Lonjsko polje with 50,521 ha, Sunjsko polje with 19,571 ha, Dolina Une with 1,499 ha and Ilova with 43 ha)	108,672
HR	Jelas polje (includes Jelas polje s ribnjacima with 4,758 ha, Vlakanac-Radinje with 2,918 ha, Dvorina with 1,482, Gajna with 422 ha, Pričac - Lužani with 200 ha and Davor – livade with 18)	34,781

National protected areas:

Country	Site name	ha
BA	Bardača	748
BA	Lower Semberia	10,136
RS	Obedska bara	9,896
RS	Zasavica	621
RS	Vinicna	58
RS	Radjenovci	83
RS	Majzecova bašta	58
RS	Varoš	43
RS	Stara Vraticna	29
RS	Vinicna	10,142
RS	Veliko Ratno Ostrvo	168

Other protected areas (e.g. landscape protection; for BA and RS several official area names are missing, location was added in brackets; many overlaps with other categories):

Country	Site name	ha
SI	Rastisce Kluzijevega svisca na Lovrencu	220
SI	Julijske Alpe	27
SI	Sava Bohinjka in Sava Dolinka - sirse območje sotočja	453
SI	Kanjon reke Kokre	1
SI	Sava od Radovljice do Kranja s sotočjem Tržiške Bistrice	114
SI	Zasavsko hribovje	5,371
SI	Sava od Mavčič do Save	1,148
SI	Brežice - park med Dobovsko cesto in Ulico pod obzidjem	1

Country	Site name	ha
SI	Kozjanski Park	9
SI	Cernickova jama	19
SI	Kamenski potok	1
SI	Obrecni prostor Ljubljanice, Grubarjevega prekopa in spice	18
SI	Sava od Radeče do državne meje	279
SI	Zelenjak - Risvicka i Cesarska gora	23
SI	Vaska lipa	19
SI	Breznikarjeva bodika v Mariji Reki	2
SI	Gorjanci	7
HR	Žumberak - Samoborsko gorje	1
HR	Odransko polje	22,748
HR	Gajna	36,919
HR	Sava	11,937
HR	Sava kod Hrušćice	1,759
HR	Savica	80
HR	Spačva	275
HR	Zvirinac	44
HR	Kanovci	17
HR	Vinkovci - park Lenije	3
HR	Sava - Zaprešić	478
HR	Sava in Croatia	12,959
BA	Bardača Wetlands (Bardača- močvarni kompleks) incl. buffer	556
BA	Sava nizvodno od Hrušćice	2,102
BA	NN (Bardača)	749
BA	NN (Bardača)	337
BA	NN (near Gornji Svilaj)	415
BA	NN (near Brezovo Polje)	383
BA	NN (near Crnjelovo Donje)	980
BA	NN (lower Drina Valley)	14,853
RS	NN (Zasavica)	5,162
RS	NN (five smaller areas in the Bosut-Spačva forest)	270
RS	NN (Bosut-Spačva forest)	19,921
RS	NN (Obedska bara)	22,257

Conclusions

- 322,875 ha of the morphological floodplain are designated as national or supranational protected areas, equalling 36% of the entire area.
- 563 km of the Sava river course excluding headwaters (64%) are protected.
- Nearly half of the protected areas (144,656 ha) are located within the active floodplain.
- Many tributaries in BA and some shorter stretches of the Sava itself (such as the Sava breakthrough in SI and the Drina confluence in RS) are not protected in accordance with their value.

☐ *Figure 41: Posavina pigs and horses in the Lonjsko polje: extensive pastures in protected areas have a great potential for attracting visitors and fostering sustainable usage of the active floodplains through preservation of traditional husbandry (© Kerstin Sauer).*

6 THREATS

Hydropower projects, extraction of gravel and sand, river canalisation and the construction of flood dikes present major threats to the future of the Sava river and its floodplain areas.

Additional threats the Sava basin is facing, such as water quality and qualitative sediment aspects, fall outside the scope of this study, despite their undoubted importance. Pollution due to nutrients and hazardous substances in the Sava basin is recognised by the international river basin management, in particular by ICPDR (International Commission for the Protection of the Danube River) [24].

6-1 HYDROPOWER

The planning for hydropower development in the Balkan region has been monitored since about 2012 [25], and international awareness is reflected by a guidance document on hydropower developed by the International Commission for the Protection of the Danube river (ICPDR). Seven hydropower plants along the Sava are currently in operation and one is under construction at Brežice in SI. Another twenty are planned, mostly in SI, but several proposals for hydropower schemes are also under investigation around the city of Zagreb. In the entire Sava basin, a total of 231 hydropower plants already exist. Eleven dams are currently being constructed and an astonishing 582 projects with capacities ranging from <1 MW to >50MW per plant are projected. Damming the tributaries would have a severe impact on the ecological status of the Sava itself, even if no further dam projects were constructed on the main river. One example is the recently started construction on the first major hydropower plant on Bosna (Vranduk), which is only the kick-off for many further dams on Bosna and plans to regulate the entire river from Sarajevo to its mouth.

Of all the threats considered in this chapter, dams have the greatest impact on the (1) flow regime, (2) passage of species and (3) transport of river sediments.

(1) Fundamental alterations of flow regime by dams
- Upstream of retaining dams, a section of the dynamic river is turned into a monotonous stagnant water body, which is reflected in the biocenosis [26].
- It is common for large areas to be permanently inundated, causing a loss of floodplain habitats.
- In reservoirs, impairment of the self-purification capability of surface water leads to the accumulation of harmful substances. This degrades the quality of surface water and groundwater and the emission of methane is a considerable contribution to climate relevant gases.
- The river's natural floodplains are cut off, causing a loss of valuable habitats and flood retention areas.
- Reducing the size of natural flood retention areas increases the risk of downstream floods. Both the speed and height of flood waves increase. In most cases only smaller flood discharges can be stored by hydropower dams in larger catchments (depending also on dam type, such as reservoirs dam or dams of run-off-river projects), but during major floods the waste floodwater is released downstream all of a sudden, often causing considerable damage.
- In many cases, the operation of dams for electricity generation causes hydropeaking – violent and unpredictable artificial changes in downstream water levels due to flushes on a daily basis, which negatively affect spawning and resting sites of aquatic fauna.

(2) Blockage of passage for river species by dams
- Fish and other river fauna cannot pass dams and weirs. Mitigation measures like fish ladders are inadequate solutions because they fail to provide safe passage up- and downstream for many species, which is reflected in a decreasing quantity of migrating individuals with each dam further upstream.
- Reservoirs destroy the habitats that numerous fish species and other fauna require for their lifecycles and reproduction.

(3) Blockage of river sediment transport by dams

- The retaining dam blocks the natural transport of gravel and sand along the river. This material accumulates in the reservoir and is missing in the river downstream.
- As a result, incision increases downstream, i.e. the river cuts deeper and deeper into its bed. Particularly were the river banks are fortified and the channel is rectified, the erosion concentrates on the riverbed and cannot mobilise bank material to at least partially substitute missing bedload. Fortified banks and a rectified channel also prevent the natural development of a sinuous and longer shifting channel to reduce slope, which could mitigate shear stress.
- Riverbed incision, in turn, leads to a drop in groundwater level of up to several metres in the long-term, because the river level correlates with the groundwater level in the adjacent floodplain. With major dams, this impact can often be monitored over distances of more than hundred kilometres. The lowering of water levels and tables and hydrological disconnection cause long-term changes in floodplain vegetation and a reduced rejuvenation of the dynamic floodplain habitats.
- As sediments are trapped in reservoirs, they do no longer reach the sea and deltas and estuaries decline in size, with a corresponding loss of coastal habitats for flora and fauna and protection against floods for humans.

For many hydropower plants, the river is diverted through pipelines to generate electricity at a separate location. Only a trickle of water remains in the riverbed below the dam, the so-called “residual flow” or “biological minimum flow”. During the summer months, the riverbed may even dry up completely, as minimum flow requirements are either not sufficient or are simply not complied with.

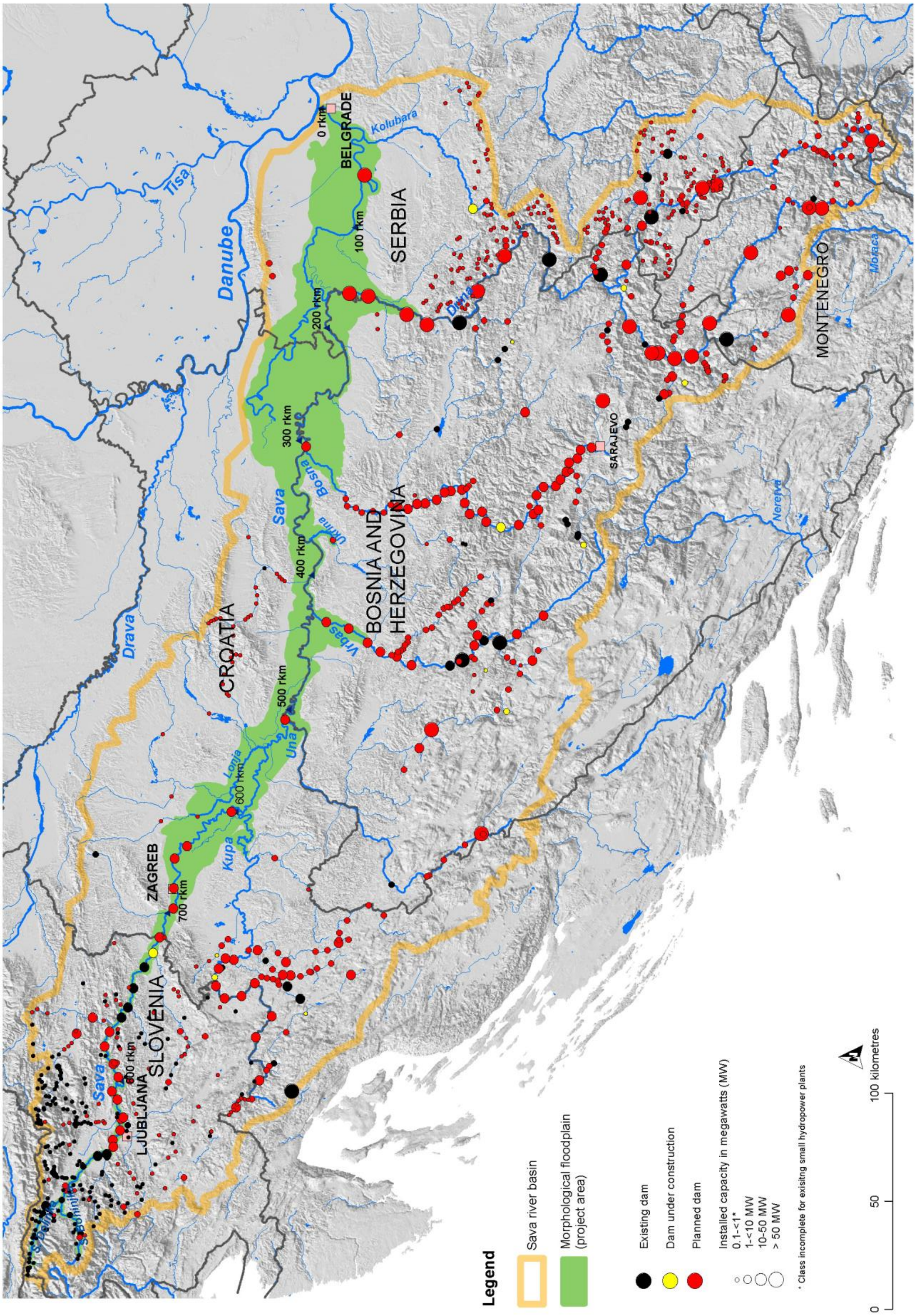
The most profitable hydropower plants are the storage types, which generate electricity at peak demand. Dammed water is only released when demand for electricity is high (lucrative), so that penstock gates taking water to the turbines are only opened for a few hours per day, resulting in a flood wave flushing down the river. These daily floods are especially devastating for aquatic life.

The series of hydropower plants at Zvornik on the Drina (RS) is assumed to alter the flow regime for at least 30 km downstream. However, the river channel in the lower Drina is still relatively natural and natural conditions provide a better buffer for alterations in the flow regime than is the case in rivers that have undergone regulation and straightening. In both cases, however, there can be a significant ecological impact on fish larvae and species living in the upper gravel layer and on bars and banks.

Retaining dams create a reservoir and have a long-lasting impact on the hydromorphological conditions upstream and downstream (see Chapter 4). Interrupted sediment transport causes erosion and degradation of the riverbed (to a depth of several metres in Zagreb within the last 40 years), and the dams cause radical hydrological changes by altering the amplitude of water level variations and the magnitude and frequency of floods. Regular floods with a return period of one to five years are ecologically important for the rejuvenation of habitats, and alterations in their frequency have a long-term influence on vegetation in the floodplains.

The decrease in flow velocities in impounded river sections increases the risks of eutrophication and the accumulation of nutrients and toxic substances in the fine sediments of the impounded river sections, causing further deterioration in water quality. The flushing of reservoirs to clear the bottom from fine sediments from time to time is not a sufficient measure to reduce the sediment deficit downstream, but it has often catastrophic impacts on species (fish kill) and brings a lot of fine sediment deposits in the reach just downstream, further disconnecting the floodplain.

Data from the lower Drina provide an illustration of changes in sediment transport. Downstream of the dam at Zvornik, the last in a chain of dams on the Drina and its tributaries, the original transport capacity was around 4.5 million tonnes of annual bedload and suspended load. The actual sediment transport has dropped to about 1.3 million tonnes/a [22].



□ *Figure 42: Hydropower plants in the Sava basin: 231 existing, further 582 planned [25]*

As selection Table 6 lists 108 hydropower plants currently in operation (16), under construction (4) or planned (88) along the Sava and the major tributaries to highlight the impact on sediment household and continuum within the catchment.

☐ *Table 6: Current status of hydropower plants (HPPs) on the Sava and its main tributaries (tabulated by river and state of completion)*

Country	HPP name	River	Installed capacity in MW	Project status
SI	Boštanj	Sava	10–50	Operating/Completed
SI	Blanca	Sava	10–50	Operating/Completed
SI	Krško	Sava	10–50	Operating/Completed
SI	Mavčice	Sava	10–50	Operating/Completed
SI	Medvode	Sava	10–50	Operating/Completed
SI	Vrhovo	Sava	10–50	Operating/Completed
SI	Kranj	Sava	1–<10	Operating/Completed
SI	Brežice	Sava	10–50	Under Implementation
SI	Globoko	Sava	1–<10	Planned
SI	Renke	Sava	10–50	Planned
SI	Suhadol	Sava	10–50	Planned
SI	Ponovice	Sava	10–50	Planned
SI	Kresnice	Sava	10–50	Planned
SI	Jevnica	Sava	10–50	Planned
SI	Gameljne	Sava	10–50	Planned
SI	Zalog	Sava	10–50	Planned
SI	Trbovlje	Sava	10–50	Planned
SI	Tacen	Sava	10–50	Planned
SI	Šentjakob	Sava	10–50	Planned
SI	Mokrice	Sava	10–50	Planned
HR	Prečko	Sava	10–50	Planned
HR	Podsused	Sava	10–50	Planned
HR	Drenje	Sava	10–50	Planned
HR	Zagreb	Sava	10–50	Planned
HR	Strelečko	Sava	10–50	Planned
HR	Jasenovac	Sava	10–50	Planned
HR/BA	Šamac	Sava	10–50	Planned
RS	Kupinovo	Sava	>50	Planned
HR	Ozalj	Kupa	1–<10	Operating/Completed
HR	Ozalj 2	Kupa	1–<10	Operating/Completed
HR	Ilovac	Kupa	1–<10	Under Implementation
HR/SI	Kočićin	Kupa	10–50	Planned
HR/SI	Dol	Kupa	10–50	Planned
HR/SI	Severin	Kupa	10–50	Planned
HR/SI	Prilišće	Kupa	10–50	Planned
HR/SI	Stankovci	Kupa	10–50	Planned
HR/SI	Otok	Kupa	10–50	Planned
HR/SI	Božakovo	Kupa	10–50	Planned

Country	HPP name	River	Installed capacity in MW	Project status
HR	Pokuplje	Kupa	10–50	Planned
HR	Brodarci	Kupa	10–50	Planned
BA	Una-Kostela-Bihać	Una	1–<10	Operating/Completed
BA	Unac	Una	>50	Planned
BA	Štrbački buk	Una	1–<10	Planned
BA	Martin Brod	Una	1–<10	Planned
BA	Kulen Vakuf	Una	1–<10	Planned
BA	Troslap	Una	1–<10	Planned
BA	Dvoslap	Una	1–<10	Planned
BA	Banja Luka	Vrbas	10–50	Planned
BA	Jajce 2	Vrbas	10–50	Operating/Completed
BA	Krupa	Vrbas	10–50	Operating/Completed
BA	Bočac	Vrbas	>50	Operating/Completed
BA	Novoselija	Vrbas	10–50	Planned
BA	Delibašino selo	Vrbas	1–<10	Planned
BA	Trn	Vrbas	10–50	Planned
BA	Laktaši	Vrbas	10–50	Planned
BA	Razboj	Vrbas	10–50	Planned
BA	Kosjerevo	Vrbas	10–50	Planned
BA	Han Skela, Vinac	Vrbas	10–50	Planned
BA	Babino Selo	Vrbas	10–50	Planned
BA	Bočac 2	Vrbas	1–<10	Planned
BA	Vranduk	Bosna	10–50	Under Implementation
BA	Cijevna 1	Bosna	1–<10	Planned
BA	Doboj	Bosna	1–<10	Planned
BA	Cijevna 2	Bosna	1–<10	Planned
BA	Cijevna 3	Bosna	1–<10	Planned
BA	Cijevna 4	Bosna	1–<10	Planned
BA	Cijevna 5	Bosna	1–<10	Planned
BA	Cijevna 6	Bosna	1–<10	Planned
BA	Janji– ći	Bosna	10–50	Planned
BA	Bosna 24	Bosna	10–50	Planned
BA	Bosna 14	Bosna	10–50	Planned
BA	Bosna 16	Bosna	10–50	Planned
BA	Bosna 18	Bosna	10–50	Planned
BA	Bosna 20	Bosna	10–50	Planned
BA	Bosna 22	Bosna	10–50	Planned
BA	Kovanići	Bosna	10–50	Planned
BA	Bosna 11	Bosna	10–50	Planned
BA	Bosna 10	Bosna	10–50	Planned
BA	Bosna 9	Bosna	10–50	Planned
BA	Dolina	Bosna	10–50	Planned
BA	Globarica	Bosna	10–50	Planned
BA	Bosna 6	Bosna	10–50	Planned

Country	HPP name	River	Installed capacity in MW	Project status
BA	Komšići	Bosna	10–50	Planned
BA	Bosna 4	Bosna	10–50	Planned
BA	Bosna 3	Bosna	10–50	Planned
BA	Bosna 2	Bosna	10–50	Planned
BA	Bosna 1	Bosna	10–50	Planned
BA	Bosna 23	Bosna	10–50	Planned
BA	Bosna21	Bosna	10–50	Planned
BA	Bosna 19	Bosna	10–50	Planned
BA	Bosna 17	Bosna	10–50	Planned
BA	Bosna 15	Bosna	10–50	Planned
BA	Višegrad	Drina	>50	Operating/Completed
RS	Bajina Bašta	Drina	>50	Operating/Completed
RS	Zvornik	Drina	>50	Operating/Completed
BA	Paunci	Drina	>50	Planned
BA	Buk Bijela	Drina	>50	Planned
BA	Ustikolina	Drina	>50	Planned
BA	Foča / Srbinje	Drina	>50	Planned
BA/RS	Dubravica	Drina	>50	Planned
BA/RS	Kozluk	Drina	>50	Planned
BA/RS	Tegare	Drina	>50	Planned
BA/RS	Drina 1	Drina	>50	Planned
BA/RS	Drina 2	Drina	>50	Planned
BA/RS	Drina 3	Drina	>50	Planned
BA/RS	Rogačica	Drina	1–<10	Planned
BA/RS	Goražde	Drina	>50	Planned
RS	Rovni	Kolubara	10–50	Under Implementation

Hydropower and protected areas

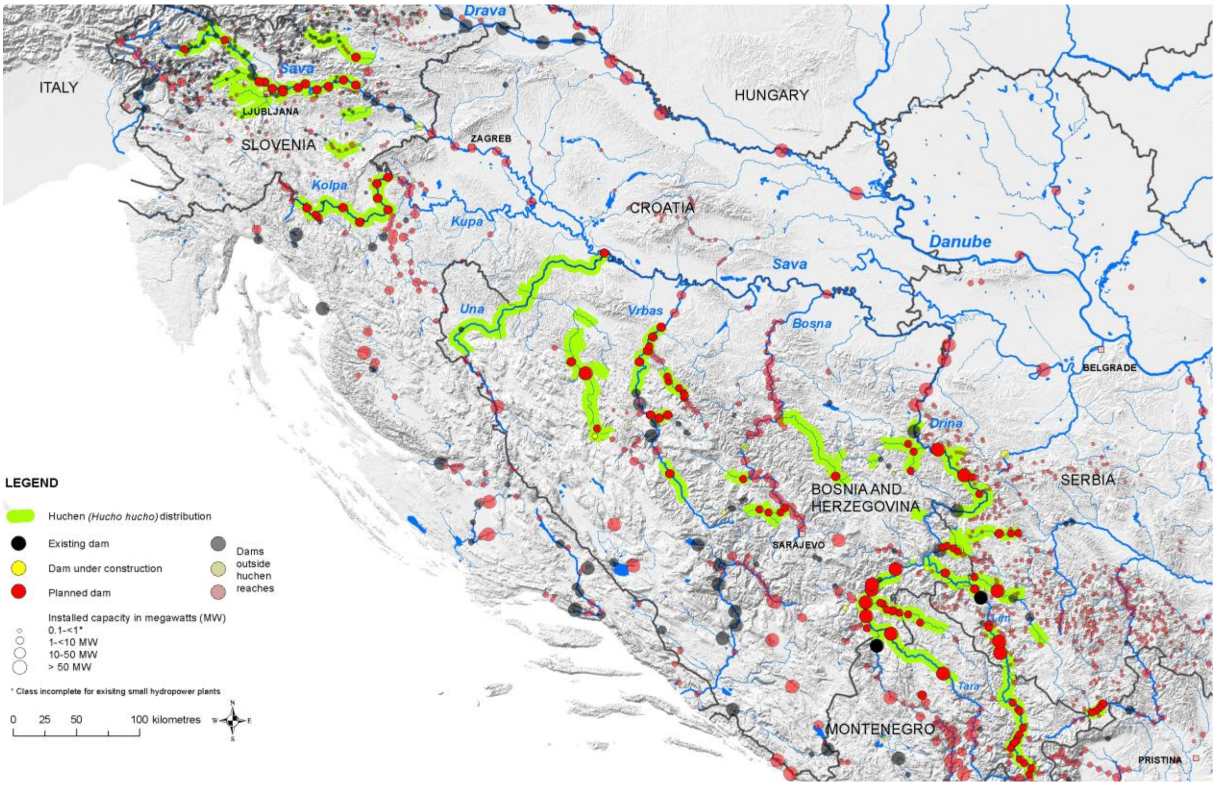
The location of hydropower plants inside existing protected areas has been determined in 2015 [27] using an overlay of the hydropower data according to the Balkan river assessment and data for protected areas in the region. In the morphological floodplain, 28 dams are planned within protected areas (2 in Ramsar sites, 10 in Natura 2000 sites and 16 in other protected areas).

☐ *Table 7: Hydropower plants projected within protected areas (PA) in the morphological floodplain.*

Country	Name of HHP planned in PA	River	PA Category
HR	Jasenovac	Sava	Ramsar site
RS	Kupinovo	Sava	
SI	Tacen	Sava	Natura 2000
SI	Gameljne	Sava	
SI	Mokrice	Sava	
SI	Brod	Sava Bohinjka	
HR	Drenje	Sava	
HR	Podsused	Sava	
HR	Prečko	Sava	
HR	Strelečko	Sava	
HR	Jasenovac	Sava	
HR/BA	Šamac	Sava	
SI	Sava Bohinjka	Sava Bohinjka	Other protected areas, e.g. landscape protection
SI	Globoko	Sava	
SI	Ponovice	Sava	
SI	Renke	Sava	
SI	Jevnica	Sava	
SI	Kresnice	Sava	
SI	Mokrice	Sava	
SI	Šentjakob	Sava	
SI	Suhadol	Sava	
SI	Trbovlje	Sava	
SI	Zalog	Sava	
HR	Zagreb	Sava	
BA	Buk Bijela	Drina	
BA/RS	Drina 2	Drina	
BA/RS	Drina 3	Drina	
BA/RS	Dubravica	Drina	

Hydropower and huchen

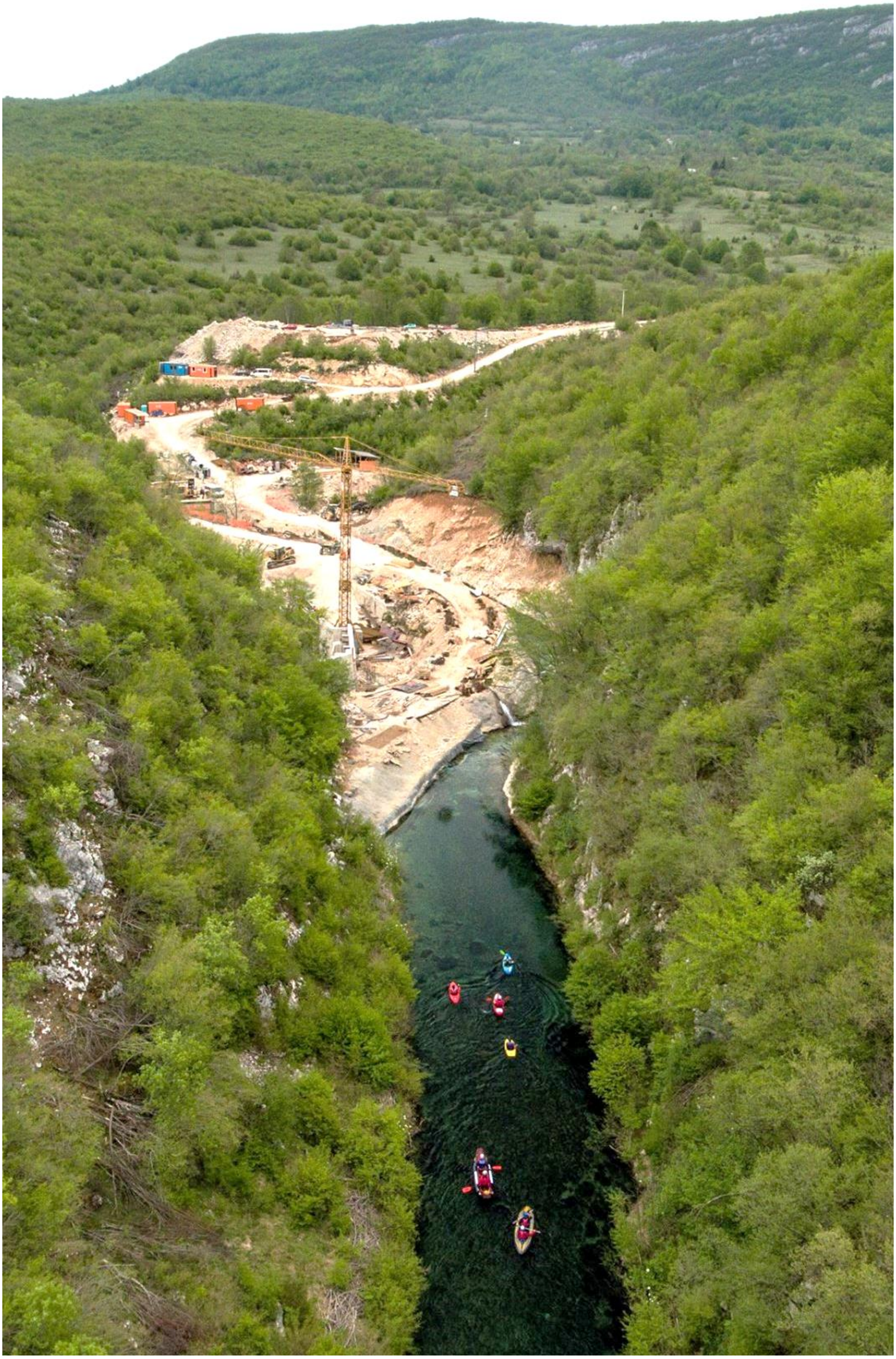
The occurrence of migrating fish species and their movement along free-flowing river stretches is a very important factor in the evaluation of hydroelectric dams. Of particular interest are species sensitive to changes in the velocity of the river flow. The map below indicates the distribution of the huchen (Danube salmon (*Hucho hucho*)) and the locations of planned hydropower plants in the entire Balkan region.



☐ *Figure 43: Distribution of 88 dams planned in huchen habitats in the Sava basin [6].*

A total of 1,000 kilometres of huchen rivers in the Balkans are under threat from no less than 88 proposed dams. If these projects become reality, the huchen population will collapse. This implies a loss of huchen population in the Balkans by at least 70% [6].

A hydropower project presently under construction within a prime huchen habitat is the Medna dam on the Sana river in BA (see Figure 44). Two more dams have been completed on the Ugar. The constructor on both rivers is the Austrian-German energy company KELAG.



□ *Figure 44: In a prime huchen river: the Medna project construction site on the Sana in BA (© Jan Pirnat).*

Hydropower projects at Brežice and Mokrice (SI)

The Sava is the longest river in SI. There are seven existing hydropower plants, and another 12 dams are planned. These projects would turn the entire Sava in SI into a chain of dams. One of them, Brežice, is already under construction, and another, Mokrice is currently undergoing an environmental impact assessment (EIA).
The dam infrastructure for the **Brežice** project includes an impoundment area of 114 ha and an additional deepening of the riverbed along a 900 m river stretch downstream of the dam.
The EIA procedure for Brežice disregarded several regulatory provisions under EU and national law. In particular, there were multiple violations of the EU Habitats Directive and the WFD (the Sava stretch downstream the dam and the lower Krka up to the confluence with Sava are Natura 2000 sites):

(1) Inadequate risk assessment during the impact assessment procedure,
(2) Breach of the precautionary principle,
(3) Replacement habitats were regarded as mitigation measures,
(4) Cumulative effects of the hydropower plants chain were not considered,
(5) Deterioration of the water body surface was ignored.

Furthermore, Slovenian authorities acted in violation of the Aarhus Convention when they prevented the Slovenian public from accessing the full environmental data on which the positive EIA decision was based. For example, NGOs requested fish data for more than one year, but data was never provided.


□ *Figures 45 and 46: The construction site of the Brežice hydropower plant in 2015 (left © Ulrich Schwarz, right [21]).*

According to the EU Habitats Directive and national legislation, the constructor Hidroelektrarne na Spodnji Savi (HESS) was obligated to establish
(1) replacement habitats (for habitats that are lost during construction),
(2) a bypass channel,
(3) a drainage ditch, and
(4) an alternative route for fish migration
prior to starting the construction of Brežice.
However, when the construction of the Brežice power plant started in 2014, none of these obligations were fulfilled by HESS, and effects on the freshwater fish species were devastating. Mitigation measures for the hydropower plant have still not been implemented, and the project will soon be completed.

The **Mokrice** dam is projected to be built less than half a kilometre from the Slovenian-Croatian border. The project is currently undergoing EIA procedure and there are strong indications that the same mistakes are being made again: numerous violations of EU and national legislation are likely. Experts predict that the Mokrice power plant would cause an additional loss of biodiversity and further degradation of Sava habitats on both sides of the border, including the loss of important spawning sites for fish species such as the rare and endangered Cactus roach (*Rutilus virgo*). Furthermore, Mokrice would also impact the Sava in HR. Downstream of the dam site, missing sediments would lead to riverbed incision of the Sava on Croatian territory. This could also further exacerbate the negative effects on the drinking water system in Zagreb.

Conclusions

- Hydropower development represents the greatest pressure on the riparian river system.
- 582 new hydropower plants are projected in the Sava catchment, 20 of them on the Sava itself.
- Not even protected areas are to be spared: 28 hydropower projects are planned within protected areas in the morphological floodplain.
- Huchen habitats along 1,000 kilometres of Sava basin rivers are at risk due to 88 planned dams. If built, these schemes would cause a population decline by at least 70% in the Balkans.

☐ *Figure 47: HPP Novakovici built by KELAG at the Ugar river in BA, a former huchen river. The fish ladder is inadequate and the residual flow downstream of the dam is insufficient - a trickle in the riverbed. (© Ulrich Eichelmann)*

6-2 NAVIGATION

The level of traffic on the Sava is low. As in many Central and Eastern European countries, roads and railways have superseded rivers as transport routes and their traffic continues to grow at rates that greatly outstrip the growth of water transport.

Although the Sava is officially navigable from the Danube up to Sisak in HR, shipping is mainly confined to the lower course. In RS, the river is classified as a class IV international waterway, but most of the middle Sava up to Sisak meets only class III specifications. River access to Sisak, the only major industrial centre along middle Sava, is an important Croatian policy goal. HR intends to reconstruct and significantly improve the waterway up to the city [28]. There are harbours of some importance in Belgrade, Sremska Mitrovica, Slavonski Brod and Sisak. Sremska Mitrovica and Sisak also have shipyards. There are smaller harbours in Brčko, and in Bosanski Šamac in BA.

The potential cargo of river transport on the Sava is mostly bulk sand and gravel, coal, and oil products from the refinery in Sisak. Table 8 gives an indication of transport volumes on the Sava. The steepest decline in traffic took place during and after the Yugoslav Wars in the 1990s. Overall, river cargo between Zagreb and Belgrade is negligible in comparison with the quantities carried by road and rail. All major harbour towns have good railway connections and access to major highways, casting doubt on the necessity for river transport. When compared to truck transport, railway transport emission figures are no worse than those of navigation, at least where the origins and destinations have rail connections.

☐ *Table 8: Annual transport of goods on the entire Sava (based on [29] for 1982 and 1991 and [30] where figures are complete for all countries)*

Year	Transport in million t/a	Description
1982	9	In Former Republic of Yugoslavia (FRY), no detailed information about goods transported is available, but mainly bulk cargo and a huge amount of gravel and sand dredged from the river.
1991	1.2	Yugoslav and Kosovo Wars from 1991–1999
2010	0.63	In general, transport goods are mainly oil and sand, but also wood, steel, cement, coal and general goods The transport of crude oil, the main item of cargo for the refinery in Sisak, dropped from 204,000 t in 2001 to 29,000 t in 2013 [31], and production was temporarily suspended in 2014.
2013	0.65	

Currently, there is hardly any shipping traffic on the Sava (some 80,000 t upstream of Sremska Mitrovica, rkm 135 and only 40,000 t upstream of Slavonski Brod, rkm 370 [30]). It is mainly an ECE (UN Economic Commission for Europe, Inland Water Transport) class III waterway, unsuitable for large vessels.

In 2008, the modal split for goods transport in HR already clearly favoured roads (72%) and rail (17%). Inland waterway transport dwindled to some 0.4%, the rest being made up by sea and coastal water transport and pipelines [32]. The current EU wide statistics for 2014 indicate a transport mix of 73% road, 20% rail, and 7% inland waterways, but it seems that these figures, given in tonne kilometres, include all other modes (e.g. pipelines, which alone account for up to 6%, and sea transport) under “inland waterways”.

Extreme hydrological events like floods and low water also have negative effects on nautical conditions. These hydrological events are in turn influenced by climate change. Since one of the risks identified for navigation on the Sava is a decrease in average discharges, climate change could be of particular significance. There are plans to compensate extended periods of low discharge by dredging and building low water regulation structures or dams to guarantee the minimum draught/fairway.

Maintenance dredging is necessary over the entire nautical stretch. It is difficult to separate the data for the volumes required for navigation maintenance from those for commercial and other purposes. This problem is addressed in detail in section 6-3. At present, dredging concentrates on tributary mouths and sharp meander bends, where sand and gravel bars hinder navigation.

Figure 48: Small vessels typical for the low-level navigation on the Sava declined dramatically in the last 30 years (© Martin Schneider-Jacoby).

Transport and navigation classes

The goal of the navigation project "Rehabilitation and Improvement of the Sava River Waterway" envisaged as EU project under the leadership of HR is to upgrade the waterway to class IV between Belgrade and Sisak, which would require modifications and dredging over the entire length [28]. The river would have to allow for the passage of vessels with a draught of 2.5 m, 300 days per year. There are some sharp bends in the river, and 24 of them do not currently meet the minimum radius for class IV. The 230 km long lower course from Belgrade to Brčko is planned for upgrade to class Va, for which it would have to accommodate ships with a draught of up to 2.8 m. This implies substantial additional dredging, not only confined to the mouth of the Drina.

All transport projects in the region are formulated within the framework of Pan European Corridor X, which covers 2,528 km of railway and 2,300 km of road routes and has been in place since 1997. Corridor X also envisages the development of navigation on the Sava up to Sisak, but seemingly without priority. In the same period, highway and railway transport has already been improved, at least within HR, but partially also in RS.

The highway and railway corridors are already in operation, although some rail sections between Zagreb and Belgrade are still single track and some stretches are subject to speed restrictions. Plans for upgrading the rail line between Zagreb and Vukovar are already on the table and supported by the Croatian Ministry of Transport and the EU. Upgrading to double track along the entire line between Zagreb and Belgrade could bring substantial benefits. A revitalisation and expansion of the freight station in Zagreb appears to offer much greater benefits than the construction of a new Sava harbour in Sisak as part of a trimodal transport hub. The good highway connection between the airport and the city of Zagreb is another advantage in this respect. The existing Sisak harbour is connected by rail and road.

The Master Plan for the Port of Sisak [33] includes an economic assessment. Even in the best scenario, the model envisages a maximum port transhipment of only 2 million tonnes by 2035 (600,000 tons in worst scenario; the figure was only 42,000 tonnes in 2013). The overall transport volume in 2013 was 649,000 tonnes, but 413,000 tonnes was confined to the lowest stretch up to Sremska Mitrovica (rkm 135) in RS. The Bosnian ports in Brčko and Šamac recorded a total of 154,000 tonnes and the long, most upstream Croatian stretch had only about 82,000 tonnes, equivalent to one freight train per week. Set against these figures is the investment required to improve navigation. This has been estimated – without giving any details – at € 80 - 200 million, but these figures are from 2010 and probably outdated. Construction of the Sava-Danube canal, which has probably already started (officially for irrigation rather than for navigation, see info box on p.70), would be even more expensive.

Planned measures and impact

The construction to maintain and improve navigation on the Sava would extend over 594 km from Belgrade to Sisak and require considerable and frequent dredging in 14 continuous planning sections. In addition, three ground sills would increase water level during low water, 24 meander bends would have to be rectified or even cut off to allow the passage of bigger ships, and four sidings would have to be enlarged to improve the passing capacity of oncoming traffic.

Table 9 summarises plans for navigation on the 594 km stretch of the Sava from Belgrade to Sisak, based on available documents [28].

☐ *Table 9: Planned measures to improve navigation on river kilometres 0 - 594 of the Sava.*

Measure	**Description**
Bank reinforcements	The stabilisation of erosive banks would prevent lateral shift of the main channel and reduce the important interactions between river and banks. Reinforcement works usually involves replacing natural banks with riprap.
Groynes, guiding walls and side-channel closures	These are low water regulation measures, maintaining the depth of the fairway. The main focus is on concentration (reflection) of flow and prevention of flow through side channels. This would affect at least 19 stretches and also reduce interaction between river and banks.
Meander bend corrections and local fairway widening for oncoming traffic	Rectification and radius enlargement would be required on a total of 24 meander bends. Although no detailed plans are available, it is most likely that point bars and meander curves would be intensively dredged and widened to achieve a radius of 300 - 360 m. There would be eleven widenings for ship waiting areas in front of sharp meander bends.
Dredging	Over 80 km of the river would require intensive dredging, and the entire navigable stretch would be subject to regular maintenance dredging. A Croatian feasibility study [34] calculates that some 1.7 million m³ of sediment needs to be initially removed over the entire stretch, causing a mean incision of the riverbed of about 10 cm. This appears to be insignificant, but it is merely a mathematical calculation, and a free flowing river reacts unpredictably. Without modelling, no definite figures can be given for sediment transport and morphological processes.
Construction of ground sills	Ground sills are planned at rkm 380, 520 and 560. These are structures on the river bottom to raise water levels during low water periods. The effect of these obstructions on the flow regime depends on their height on which no information is available. They also may disrupt fish migration.
Harbours, infrastructure	A major proposal is the entirely new construction of a harbour at Sisak. It would occupy some of the mature active floodplain. In general, harbour areas and their transport connections to the hinterland lie within the active floodplain, which is problematic for flood protection.

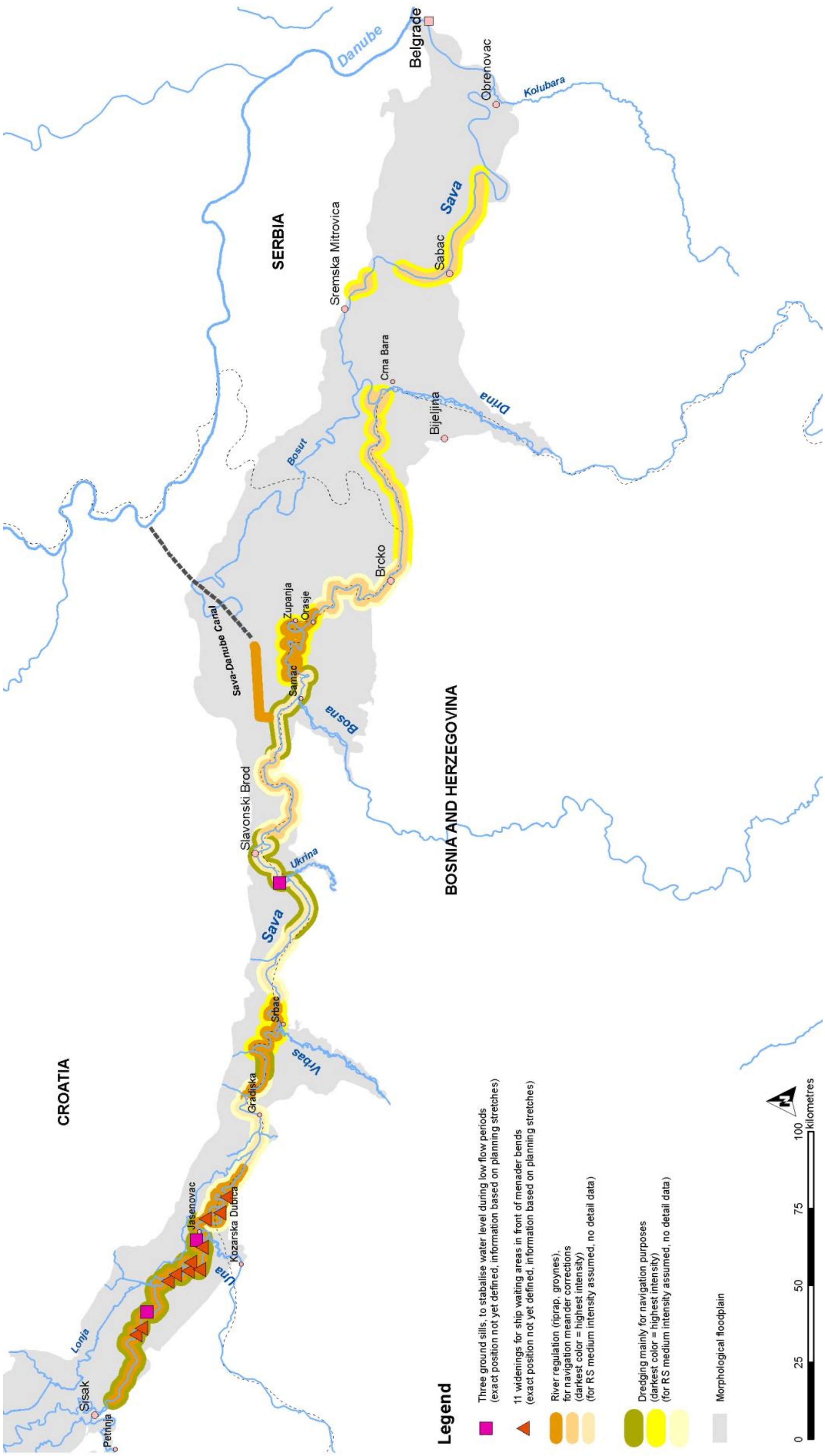


Figure 49: Impact of projected navigation schemes along middle and lower Sava.

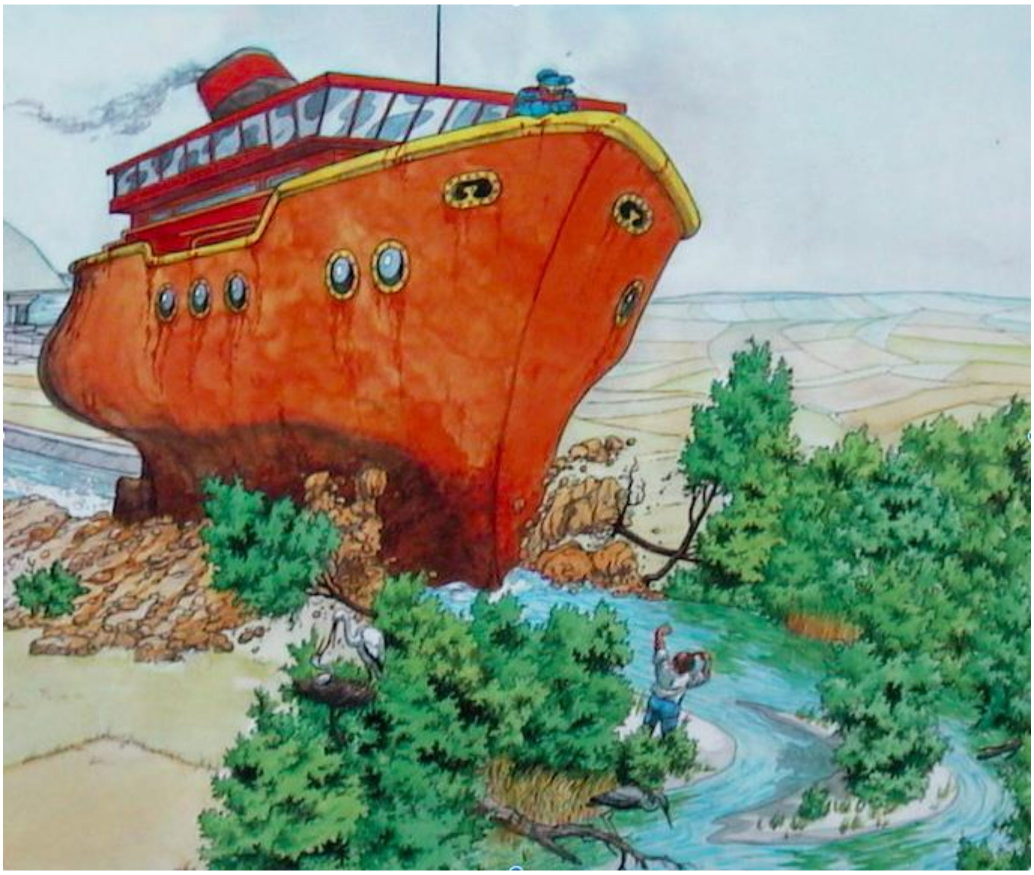
Figure 49 shows which stretches would be most affected by river regulations – ground sills, bank riprap, groynes, side-channel closures, meander bend widening and dredging. The current navigation bottlenecks are also the Sava's best preserved stretches with the most pronounced meanders. Good examples are the meanders just upstream and downstream of Jasenovac. To guarantee the 70 m width and 2.5 m depth required for navigation, 4,300 m^3 per river kilometre must be initially dredged along the Croatian stretch, a total of 1.734 million m^3 [34]. The estimated initial average channel incision is at 10 cm, but this clearly is no real indication of long-term development and the effects of regular follow-up maintenance dredging.

Construction of groynes and closures of the few remaining side channels to provide low and mean water correction would substantially degrade the hydromorphological conditions along the river, detaching the dynamics of the banks from the dynamics of the river channel and adversely affecting young fish in littoral zones and banks. Stabilisation would destroy many or nearly all of the remaining steep banks that serve as a source for sediment input and are important breeding sites for several endangered or protected bird species (e.g. sand martin and bee-eater). Cutting off meanders could degrade the river channel and create more instability, erosion and accumulation of bed material, triggering additional dredging activities. Even if meanders were not simply cut off, the hydromorphological conditions would suffer from the construction of waiting areas for ships and intensive dredging in the bends.

The proposed harbour in Sisak would occupy what is presently floodplain forest and agricultural land (including wet meadows) in the active Sava floodplain.

At present, the navigation project seems to be stalled. Opposition to the project and lack of funding have so far prevented further progress.

Current climate change scenarios for the Sava river basin foresee a rise of flood peaks of up to 8%, while droughts are also anticipated to be more frequent, and these are especially unfavourable for navigation.



☐ *Figure 50: The planned navigation upgrade is threatening in particular the middle Sava downstream of Sisak to the Drina confluence. Symbolic illustration by Dominic Groebner.*

Sava-Danube Canal (HR)

An older navigation proposal is the Sava-Danube Canal through the Orljak and northern Bosut-Spačva forests between Velika Kopanica on the Sava and Vukovar on the Danube. The canal would accelerate northbound waterway traffic to the Danube.

The proposal did not gain enough support when it was put forward several years ago and has never been the subject of detailed financial planning or environmental impact assessment. A few years ago, a project called "Irrigation Canal Bosut" started along exactly the same route. Major excavation has been going on since 2011. In 2016, the canal seems to be close to completion for irrigation/drainage purposes only. No cost intensive bridges were built (only culverts), but the dimensions and position of the canal would allow for an upgrade later on.

☐ *Figure 51: Construction of a so-called "irrigation canal" on route of the southern part of the projected Sava-Danube Canal [21].*

An option for further utilisation and development of this "oversized irrigation canal" is as a flood conveyance canal to actively flood parts of the Bosut-Spačva area, similar to the canals built for the Upper Posavina flood system. Such a bypass would lower the flood risk for Šamac (Bosna confluence, catastrophically flooded in 2014) and Županja.

Conclusions

- There is hardly any shipping traffic on the Sava at present, and no substantial increase is foreseen (some 80,000 t upstream of Sremska Mitrovica, rkm 135, and only 40,000 t upstream of Slavonski Brod, rkm 370). It is mainly an ECE class III waterway, unsuitable for large vessels.
- Navigation improvements, especially when combined with maintenance dredging, have severe impacts on the riparian river system. Significant river regulation structures are required to lift the Sava from ECE class III to class IV. They would involve 24 meander bend corrections, three ground sills, bank reinforcements, and the construction of groynes to improve low water conditions.
- Intensified navigation along an upgraded Sava would necessitate continuous dredging along almost the entire 594 km river stretch from Belgrade to Sisak.
- The newly developed "Irrigation Canal Bosut" has been constructed along the same route as previously proposed for the Danube-Sava navigation canal. There are concerns that the current canal may be further developed.
- Navigation improvement comes second only to hydropower in potential impact on the river-land complex. Luckily, opposition to the project and lack of funds are the reasons for the slow progress of the project.

6-3 DREDGING AND SEDIMENT EXPLOITATION

The middle and lower Sava and its major tributaries are dredged both for commercial purposes and to improve navigation. On the Sava itself, most dredging is done to gain construction material, only sometimes also for the purpose of navigation improvements. Dredging of fine bed material tends to be linked to navigation, as is the improvement of the river bed conveyance capacity in the lower Sava and in the city of Belgrade. Dredging of coarse material, including sand in the lower Sava in RS, primarily serves commercial purposes. Exploitation of gravel and sand along the lower tributaries is also mainly commercial.

Dredging has severe impact on the sediment balance throughout the catchment area and intensifies the effect of sediment retention behind dams. Quantitative targets must therefore take a central place in sediment management plans. The Sediment Initiative launched by the EU in 2002 recognises that sediments are an integral part of a natural river system and an important resource for minerals, requiring protection and targeted management [35]. It formulates four key principles for sediment management:

1: Sediment quantity and hydromorphology. Sediment balance (including bedload (gravel) and suspended load (fine sand and silt), channel and planform building morphological behaviour) is an important component of the hydromorphological assessment.

2: Sediment quality and remobilisation. Closely linked to sediment flux and grain sizes; this is not tackled in this study but has relevance for the Sava downstream of industrial sites and along some tributaries.

3: Sediment as habitat and river ecology. Providing habitat to e.g. macroinvertebrates, interstitial organism and (young) fish, sediments are a component of aquatic systems and as such influence the ecological status of a river according to WFD.

4: Dredged material management. This is carried out for commercial, navigation and flood management purposes. Point 4 constitutes the core topic of this chapter.

Dredging should be governed by sediment management principles. This means adapting it to the natural river ecology and adjusting it to the current sediment balance and the transport capacity of the river.

It is difficult to determine the quantities of material extracted due to a probable deviation of the actual quantities excavated from those allowed by official licences. Some data is only available as averages calculated over several years, and for different time periods [22, 36]. Neither can the assessment depend on present figures alone, as intensive past dredging can have a lasting impact. Clear examples of this can be found at two locations in the Danube, the stretch at Bratislava in Slovakia and the stretch upstream of the abandoned hydropower project Nagymaros in the Danube bend in Hungary. In both cases, huge amounts of material were taken for the construction of houses and roads, primarily in the capital cities, causing channel incision over decades. In the lower tributaries in BA and RS illegal dredging is still common, especially along the Vrbas and the Drina.

Furthermore, it is not always possible to unambiguously determine the purpose of dredging. Commercial activity certainly dominates in some locations, but may be subsidiary to navigation maintenance elsewhere.

The transport of sediments is strongly related to the geological and physical features of the river catchment areas. The geological origin of the deposit, the average slope and discharge of the river and its peak discharges, all combined determine the sediment balance of a river basin. It is important to assess specific river stretches, because different Sava tributaries have different sediment transport behaviour. Rivers strongly influenced by karst such as the Ljubljanica, Krka, Kupa and Una contribute much less to the sediment balance of the Sava than the other tributaries. Sediment balances differ from year to year, notably because extreme floods bring huge amounts of sediment from the tributaries into the river Sava.

Sediment balance and morphological changes

Approximate values for the sediment balance of the Sava (and in particular for the bedload and coarse fractions of suspended loads) are estimated using medium and long-term trends in morphology and available data for specific river stretches from different sources. Figures for the overall sediment balance in the Sava are given in a recent ISRBC-UNESCO study [37]. Further information on a critical Sava stretch in HR is given in a recent national environmental assessment [38]. The environmental study for the Mokrice hydropower plant at the Slovenian-Croatian border was used as a source for Slovenian data [39].

Despite gaps in the data and divergent methodologies, all studies ascribe the most significant impact on the balance to sediment retention behind dams, particularly in the upper Sava and the Drina. The sediment balance along almost the entire Sava is also sensitive to dredging, past and present. Unfortunately, there has hardly been any analysis of the bedload (gravel). In the middle and lower section of the Sava, where gravel is rare or absent, the only means of calculating how much of the suspended sediment load constitutes bed building sediments is to assume that 15% of the coarse sand is transported alongside the channel bottom and 85% of sediment is in suspension in the water column. A further uncertainty in the comparison arises from the incompatibility of figures given in tonnes with those given in m³, because the specific gravity and bedding of gravel and sand can vary between the values 1.5 and 2.0. This means that the weight corresponding to one m³ of material may vary between 1.5 and 2 tonnes. For the purpose of this study, all weight values were converted to m³ volumes using a factor of 1.8.

In the free-flowing stretches of the upper Sava downstream of the Ljubljanica confluence, sediment transport is fairly even and low (20,000 m³/a), because the dams on the upper Sava trap a lot of material and the remaining stretch is stabilised by several ramps. As the Sava leaves the mountains at the lower end of the upper reach, measurements and estimates indicate total annual transport (including suspended load) of up to 800,000 m³. A Slovenian study for the planned Mokrice hydropower plant [39] gives a figure of 60,000 m³ for the gravel fraction of the annual bedload transport on a free-flowing section of the river. The model estimates the maximum capacity at 185,000 m³/a, including fine fractions of 4 mm diameter.

In the vicinity of Zagreb, the gravel fraction of the bedload drops to about 30,000 m³/a, making the entire strongly regulated downstream stretch highly erosive and causing strong incision.

Further downstream, along the border with BA, coarse material, which is mainly transported along the river bed, is assumed to make up 15% of transported material. Fine gravel is frequent in the mouth of the Una and a sand/fine gravel mixture can be found in Slavonski Brod, but the total amount of transported gravel remains small. The ISRBC-UNESCO study indicated only a 5 - 10% overall share of “bedload” in lowland rivers, which would reduce the transport figures further. The Croatian dredging study [38] gives two values for the amount of bed-building gravel/sand mixture in the overall transport: 20,000 m³/a at Jasenovac and 50,000 m³/a at Slavonski Brod. There are significant contributions from the tributaries: the Bosna, for example, provides 10,000 m³/a of pure bedload [38]. The lower Drina transports a lot of gravel (200,000 - 220,000 m³/a) and has built huge gravel bars at its confluence and in the free-following stretch of the Sava. These gravel bars are dredged on an irregular basis to allow navigation. The total transported suspended load on the lower Sava in RS, after the Drina confluence, is about 3 million m³/a, so that bed building material (mainly coarse sand) amounts to some 250,000 m³/a (according to the 5 - 10% overall share of “bedload” in lowland rivers).

In the past, the natural sediment balance of the Sava river system must have been much higher than it is today, but no clear picture can be established. On the Drina, for instance, dam impoundments have caused the original sediment transport, estimated at 4.5 million m³/a, to decrease by three quarters. This also has an impact on the lower Sava, even though the Drina still generates a substantial 0.5 - 1.0 million m³ of material per year by lateral-shift bank erosion. No significant incision has been reported on the lower Drina due to the free lateral shift and low degree of regulation.

Bank erosion on the river Sava is relatively weak, correlating with slow river course shift and meander development. A study carried out between 1973 and 2006 [23] indicated a maximum channel shift of 80 m over the period or an annual average of less than 3 m.

Dredging amounts

The available data for the Sava indicates a dredging amount of about 950,000 m³/a. A careful assessment of the lower courses of tributaries estimates an additional 1.29 million m³/a of dredged material. That means a total of 2.24 million m³/a of excavated sediments. The total length of river kilometres subjected to regular dredging in the rivers of morphological floodplain is as much as 200 kilometres or 17% (compare Table 10 and Figure 52). This corresponds to 63 dredging sites. The annually dredging amount on the Sava exceeds the natural transport capacity by a factor of up to ten. On its tributaries the factor is four.

The hotspots of the dredging are on the Sava downstream of Sisak up to the confluence with the Danube and on the southern tributaries. There are two dredging sites on the lower Una, six on the lower Bosna, five on the lower Vrbas and almost 20 on the lower Drina.

Additional dredging for commercial purposes is a regular activity on a 30 km long free-flowing stretch downstream of the Ljubljanica confluence in SI. Furthermore, parts of the upper Sava are being dredged in order to clear impoundments, combined with flood management improvements in some places.

Gravel excavation for construction purposes has a long history in this area. In the 1970s, sediments from the rivers have been used to construct the highway between Zagreb and Belgrade. More recently, the Osijek–Sarajevo highway was also built from materials taken from the lower Drava and the Bosnian rivers.

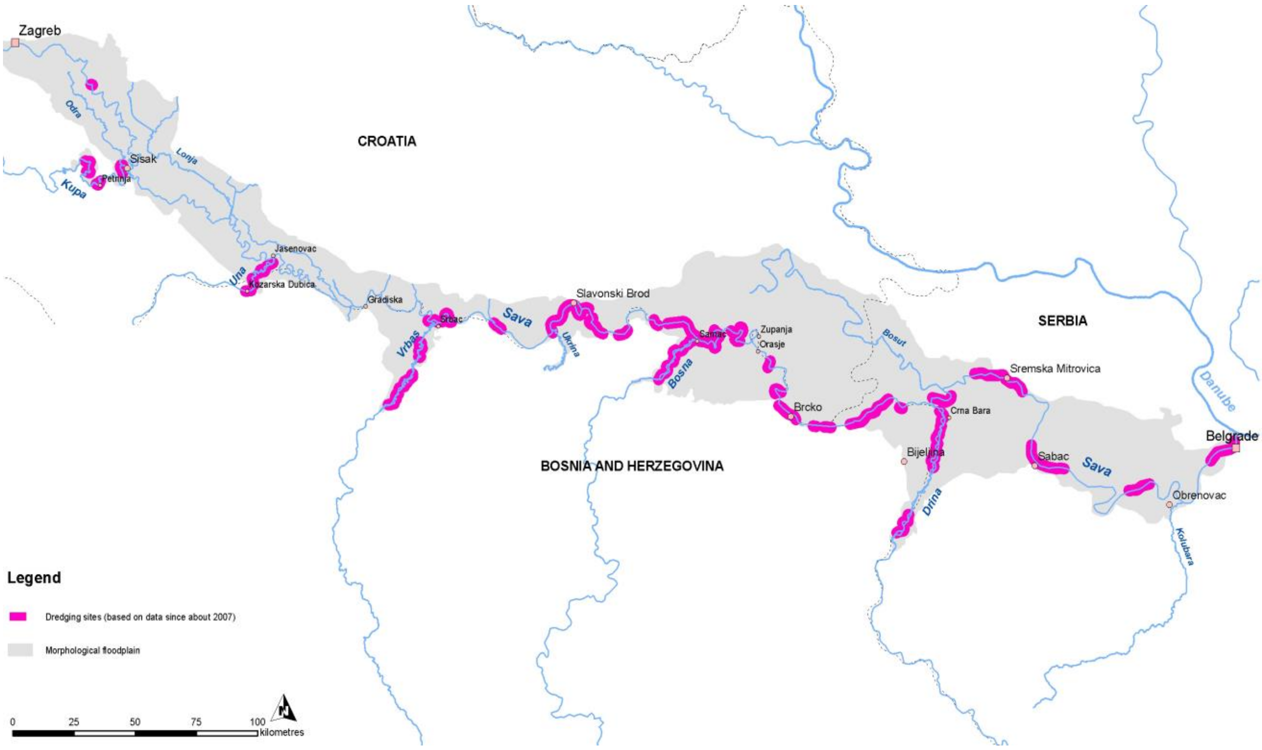


Figure 52: Dredging sites along the middle and lower Sava and along lower courses of tributaries in the morphological floodplain.

☐ *Table 10: Quantities of material dredged from river bed of the Sava and its lower tributaries within the morphological floodplain.*

River	Country	River stretch	**Average estimate of dredged material** and further explanation of time periods	Description
Sava	SI	Upper Sava between Ljubljanica mouth and Litija, entrance in gorge	**20,000 m³/a** An additional estimated **30,000 m³/a** material entering the upper dam chains and input from tributaries (e.g. the Savinja) must be removed regularly from impoundments.	The Sava in SI comprises long impoundment stretches characterised by strong sedimentation of coarse material in the upper dams of chains, and this has to be cleared after a while. Downstream of dam chains, the river is strongly regulated and tends to incision. In the very upper Sava, the incision has been stopped by ramps.
Sava	HR	Middle Sava from SI border downstream to Sisak	No evidence	Significant past and present river incision of 3.5 m in the Zagreb stretch. No significant or regular dredging in the past decade can be assumed, and gravel pits have moved to the floodplain upstream and downstream of Zagreb.
Sava	HR	Middle Sava from Sisak to the Serbian border	**200,000 m³/a** (based on data for 2007 - 2010). In 2007, licences were issued for a total of 2.18 million, in 2009 - 2013, regulations were tightened (a lot of material was then simply imported from BA). Gravel accounts for over 90% and sand less than 10%.	According to the official plan by the Croatian water authority starting in 2015: 450,000 m³/a for about eight years, 243,300 m³/a after Environmental Impact Assessment (EIA) for Natura 2000 site; half of the amount must be returned to the river.
Kupa	HR	Lower Kupa (50 km)	**15,000 m³/a** (41,250 m³/a max. licensed for this stretch. On whole Kupa some 25,000 m³/a are actually dredged, max. licensed 68,750 m³/a).	Locations between rkm 60 and 160 lie outside the morphological floodplain (see values in brackets)
Una	HR/BA	Lower Una (18 km)	**18,000 m³/a** in HR and **55,000 m³/a** in BA (based on data for 2007 - 2014) (Max. licensed 38,750 m³/a for this stretch. On whole Croatian Una, 20,000 m³/a are actually dredged, max. licensed 47,500 m³/a)	Locations between rkm 52 and 59 are outside the morphological floodplain (see values in brackets)
Sava	BA	Whole Sava in BA	**250,000 m³/a** (based on data for 2009 - 2011); Sava stretch in BA belongs to three entities (Federation BA 60%, Brčko district (15%) and Republika Srpska 25%)	Dredging is particularly frequent in the vicinity of Bosanski Šamac
Vrbas	BA	Lower 35 km	**100,000 m³/a** (based on data for 2009 - 2011)	Several large extraction sites, even diverting entire river for short stretches (see Figure 53)

River	Country	River stretch	**Average estimate of dredged material** and further explanation of time periods	Description
Bosna	BA	Lower 25 km	**100,000 m³/a** (based on data for 2009 - 2011)	Some large meander changed due to dredging of meander neck (see Figure 54 and 55)
Drina	BA/RS	Lower 65 km	**1 million m³/a** RS approximately 700,000 m³/a BA app. 220,000 m³/a (based on data for 2009 - 2011)	Many small sites, but also intensive dredging around the main road bridge between BA and RS.
Sava	RS	Lower Sava	**450,000 m³/a** in average (data from 1982 - 2004)	Includes a lot of fine material (sand)
Total dredged material for Sava (without spring branches)			**950,000 m³/a**	Entire Sava
Total dredged material for tributaries Kupa, Una, Bosna, Vrbas and Drina			**1.29 million m³/a**	River stretch within the morphological floodplain

Riverbed incision

Information on morphological changes of the riverbed is also required for estimates of sediment balance variations. This takes the form of cross section data or long-term variations of (low) water levels in the river corridor. Downstream of the Slovenian dam chain, the channel is incised severely along the free-flowing stretch to Zagreb. Sediments are trapped in the dam chain and the river bed downstream is exposed to increased stream power and concentrated erosive forces owing to major rectification, closure of side channels and bank reinforcement. As a result to the construction of dams and regulation of the river, the incision in Zagreb has increased to an average of 3.5 m in recent decades. Even infrastructure is affected by channel erosion: a railway bridge in Zagreb collapsed in 2009 due to erosion of a bridge pillar fundament. In a short transition stretch that starts upstream of Rugvica, the river changes into a lowland meandering river with less slope and more or less free lateral erosion. To a certain extent, it recovers its sediment balance in this stretch. Further downstream, where the river still meanders freely, there is much less channel incision – approximately one metre over recent decades. Upstream of Jasenovac, water level analysis has shown the incision to be only 20 cm during the past decades, downstream towards Slavonski Brod it again reaches 60 - 80 cm, a significant figure that shows a clear trend. However, the incision is still moderate compared with many other lowland rivers. On strongly regulated stretches of the Tisa in Hungary for example, riverbed incision reached 2 - 3 m over several decades. On the lower 100 km of Sava, in the backwater reach of the Danube dam Iron Gate I, accumulation would be expected, however, substantial dredging of sand causes even here to local incision.

☐ *Figure 53: Intensive gravel mining in the Vrbas near Kukulje, BA, involving diversion and excavation of the former riverbed [21].*

☐ *Figure 54 and 55: Example of the lower Bosna. Left: situation 2015, right: situation in 2003. Intensive sediment extraction has caused degradation of the river channel. [21].*

□ *Figure 56: Typical local dredging activity (© Martin Schneider-Jacoby).*

□ *Figure 57: Dredged material in the entire morphological floodplain amounts to 2.24 million m³/a (© Martin Schneider-Jacoby).*

Modern dredging practices in Germany and Austria

In Western European countries dredging from rivers to gain construction material was very common over decades, but the exploitation has shifted towards the excavations in floodplains or on terraces outside floodplains. Today, primary purposes of dredging from rivers remain the maintenance of navigation and flood mitigation, however the extraction of material for commercial purposes is prohibited. Early on, at the end of the 1970s, it became obvious that river stretches downstream of dams must be managed by giving sediments back to the river artificially in order to stop incision downstream, as is the case of HPP Iffezheim near Karlsruhe – the last dam on the upper Rhine river. It has been recognized that all the material dredged for maintenance must be fed back directly to the rivers rather than being stored outside the active channel, e.g. on banks between groyne fields, where only during bigger flood this material becomes part of the river again. Active sediment management means that morphological changes on several stretches are permanently being evaluated and locally dredged material is put back upstream into critical sections where incision is prevalent. In many cases, the available material is not sufficient and at several locations extra material must be fed into the river. The adding of extra material can be minimized if the situation is permanently monitored and lateral erosion of the river can be increased [40].

Similar approaches are intended to be applied on the Austrian Danube, where currently only a part of the missing bedload sediment is substituted downstream of the Wien-Freudenau dam. The plan is to improve and optimize the current management of dredged material for navigation purposes and to add extra material from outside. This material includes larger grain sizes to reduce and finally stop the still ongoing incision, which negatively influences the hydrological connectivity and dynamic (reduction of flood level and duration) in the Danube Floodplain National Park downstream of Vienna.

Shifting floodplain exploitation sites are not free of problems, and it is particularly important to assess the impact on drinking water and a direct linkage to groundwater bodies. Abandoned and filled gravel pits have at least a temporary potential for restoration as they can serve as secondary habitats and recreation sites and act as stepping stones for bio-corridors through a landscape of large-scale, intensive agriculture. Substituting for river gravel used in road building with recycled building materials constitutes a great potential and should be used consistently.

Conclusions

- The total length of river kilometres subjected to regular and frequent dredging is as much as 200 kilometres or 17% of all river stretches in the morphological floodplain of the middle and lower Sava. This corresponds to 63 dredging sites.
- The total annual quantity of material dredged is 950,000 m³ from the Sava and 1.29 million m³ from its tributaries. In total, 2.24 million m³/a.
- The annually dredging amount on the Sava exceeds the natural transport capacity by a factor of up to ten. On its tributaries the factor is four.
- At the same time, extraction from the river is now prohibited in Germany and Austria and material is even given back to the river.
- On the lower Drina, there is a tendency to instability and deficits are roughly compensated by strong lateral erosion, a unique process for a river of this size in Europe.

6-4 FLOOD DEFENCE

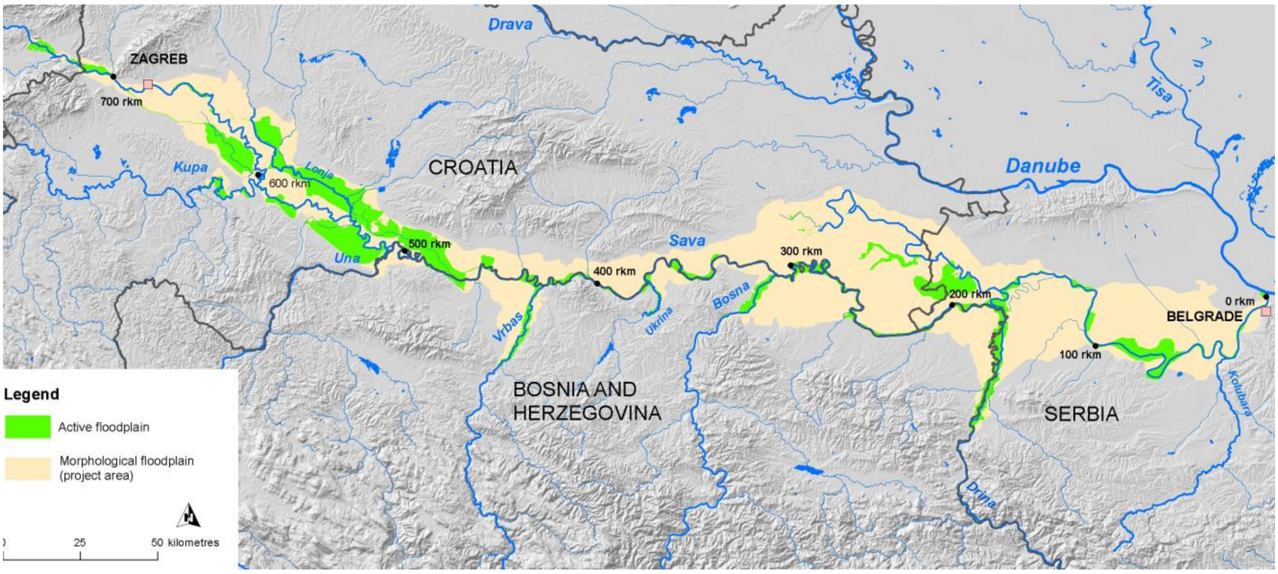
Floods are among the most serious of natural hazards and have caused annual damages of up to €5 billion in Europe in the last two decades, according to large reinsurance companies. On the other hand, the ecology of floodplains and its ecosystems depend on regular flooding. The European Floods Directive of 2007 regulates flood risk mapping and management and includes a strong thematic integration with the WFD, for which there was an urgent need. The protection of flood retention areas that are still intact and the expansion of retention areas along rivers are explicitly mentioned, alongside technical flood defences, flood forecasting and organisational issues.

Along Sava floods can occur any time during the year (compare Figure 6), but have two major seasonal causes: snow melt in the mountainous upper courses in late spring, and heavy Mediterranean rains in autumn and early winter. These periodic events show up clearly in the long-term discharge data. Tributaries of different sizes and flood regimes cause very complex patterns of flood development in the middle and lower courses of the Sava. Serious floods can even occur in the warm period as result of convective rain, as is was the case in the historic flood of May 2014. The 100-year discharge downstream of Zagreb is about 3,500 m³/s, before the Drina confluence it is 4,600 m³/s and downstream of Drina it is as high as 6,700 m³/s. There are records of single catastrophic discharges for separate tributaries: 4,000 m³/s in the lower Bosna in 2014 and up to 7,000 m³/s in the lower Drina in 1896.

Loss of floodplain area

Today, the area of land connected to the Sava and its tributaries (the active floodplain also includes those poljes connected by flood canals) has shrunk by 77% to 2,067 km², but the extent of loss varies widely between different stretches. In the Lonjsko polje reach, the loss is only about 40%, but in the lower Sava in HR and BA and in RS (with the exception of the Bosut forest, Drina confluences and Obedska bara), it is up to 85%.

Determining the extent of the active and morphological floodplains is an important step in estimating the threats that flood defence constructions pose to the natural river system of the Sava. The active floodplain is delimited primarily by a system of major and secondary dikes nearly 2,000 km in length, built in the first half of the twentieth century and reinforced in the 1970s.



☐ *Figure 58: Comparison of former and active floodplain (building together the morphological floodplain) indicates the significant loss of active floodplain area and underlines the importance of remaining river stretches capable to retain flood water.*

The morphological floodplain is defined as the maximum extent of historical floods without artificial flood defences. In addition to the area subject to floods with a 100-year return period, a determination given in several publications, the morphological floodplain includes the marginal area influenced by groundwater as well.

A feature specific to the Sava downstream of Zagreb is a system of natural bank levees (i.e. elevated banks) that allow permanent settlements to lie very close to the river. Large floodplain areas used as polders are flooded annually by tributaries and the backwater of Sava floods.

Forested areas occupy the sporadically flooded outer limits of the floodplains. The floodplains have traditionally been used intensively, and many forests have been cut down over the years to make way for agriculture, which has gradually spread closer to the rivers. Protected areas and near-natural managed retention areas at many locations in the active floodplains offer good reference and give an impression of the entire Sava floodplain before the implementation of flood defence works, river corrections and forest clearance.

Figure 59: Flood dikes along middle and lower Sava

The Sava passes through many towns, including the metropolises of Zagreb and Belgrade. The cities were originally built above the areas prone to flooding but have spread into lower-lying areas. For most of its course, however, the Sava flows through rural areas, some covered by forest. The area protected by the dikes does not have a homogenous level of flood protection. Whereas Zagreb is protected against a 1,000-year flood event by a bypass channel which diverts a significant part of the flow away from the city, the dikes on some stretches of the Sava in BA are not in suitable condition to withstand the water levels of a 100-year flood.

Pumping stations, drainage canals and weirs throughout the Sava corridor regulate water levels in the former floodplains and polder areas (see the map annex for details). The largest regulated river system, involving a weir and several pumping stations, is the 120 km long Bosut river.

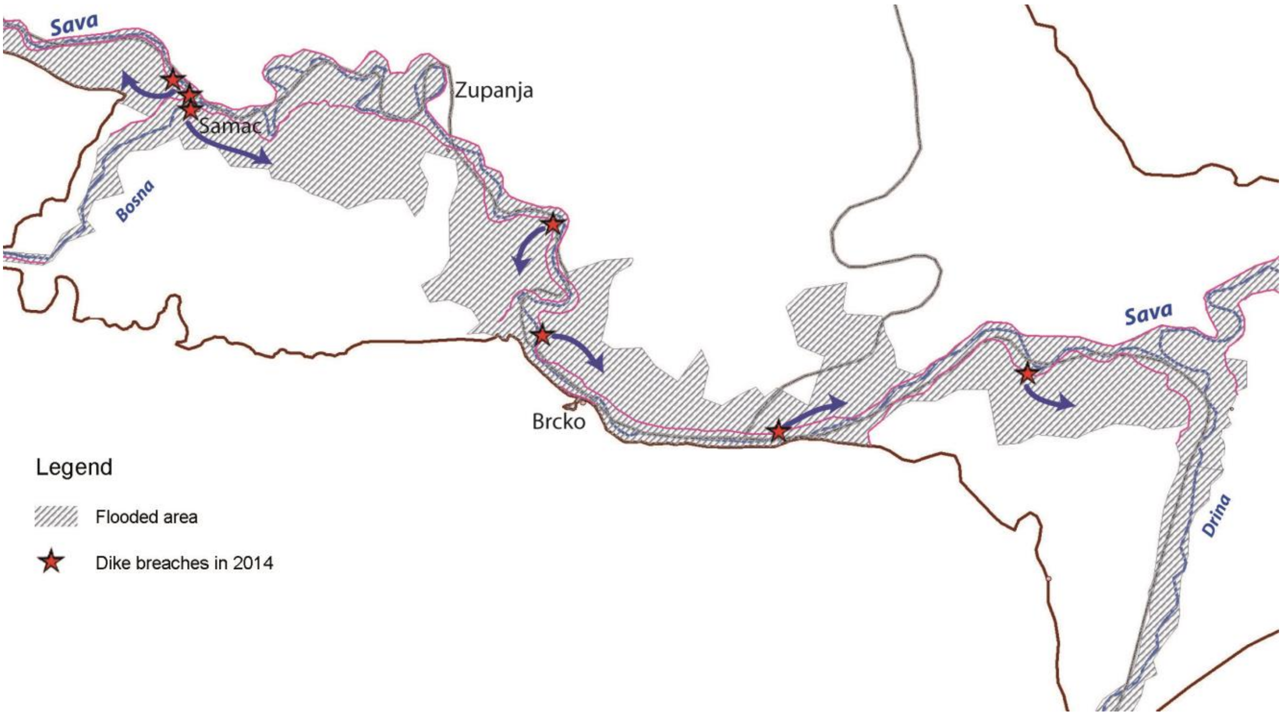
Flood retention by using large near-natural floodplain areas

The very effective natural flood retention system on the Upper Posavina retains a volume of 1.6 billion m³ [41] within the floodplain. In response to a 100-year flood event in Zagreb, a bypass connecting the Sava at Zagreb to the floodplain Odransko polje upstream of Sisak was built, reducing peak discharge of 3,600 m³/s by about 1,000 m³/s. Due to strong channel incision in the city, currently only major floods enter the bypass. Further downstream, up to an additional 500 m³/s of Sava discharge can enter the Lonjsko polje area, which fills up slowly over a period of three weeks. This large retention area can handle a flood of up to 3 m. Mokro polje, downstream of Lonjsko polje, can also be flooded. Several weeks can pass before the water recedes from the floodplain back into the Sava upstream of Gradiška. This storage reduces the water levels associated with a 100-year flood event in Sisak and Jasenovac by up to 1 m. An additional advantage of reducing the propagation speed of the flood wave by this retention is the extra time it provides for catastrophe remediation and emergency planning for downstream stretches.

Century flood in May 2014

The highest rainfall ever measured in the region of central BA and western RS occurred in May 2014 and caused disastrous floods along the lower Sava [42]. The water in the mountainous middle and upper southern tributaries, particularly the Bosna and the Vrbas, rapidly rose to dangerous levels. Many small tributaries with confluences in narrow valleys suffered landslides and brought down muddy debris, exacerbating the situation. The mountain streams, flowing between steep slopes, have no natural retention capacity. The discharge on the Bosna reached 4,000 m³/s, a peak that occurs only once in several centuries. The accumulative discharges from the Vrbas, Una and Drina caused the highest ever measured flood level in the Sava between the Bosna and the Drina. The situation could have even been worse if the peak flows of the Una and upper Sava would have been higher and had directly coincided with those of the Bosna and the Vrbas. Seven major dike breaches (see Figure 60) "mitigated" the situation downstream because the water spread out into the former floodplains and reduced the height of the flood peak below the broken dikes. This also indicates the positive effects of giving floods more space by relocating dikes further away from the river wherever possible (see Chapter 7-2). At Županja, half way between the Bosna and the Drina, the peak flow of the 2014 flood was determined at over 6,500 m³/s, which is nearly 2,000 m³/s greater than the 100-year discharge at this location. The maximum Sava discharge on the Serbian part downstream of the Drina in Sremska Mitrovica was estimated at 6,700 m³/s. The Drina peak discharge of 4,000 m³/s was equivalent to a 20-year peak, and fortunately preceded the Sava peak by a few days. The four major dike breaches between Županja and Drina mouth also reduced the peak flows further downstream. The Kolubara contributed 1,000 m³/s, and in this case numerous dike breaches in the hinterland caused the city of Obrenovac and many large open-cast coal mines to be flooded.

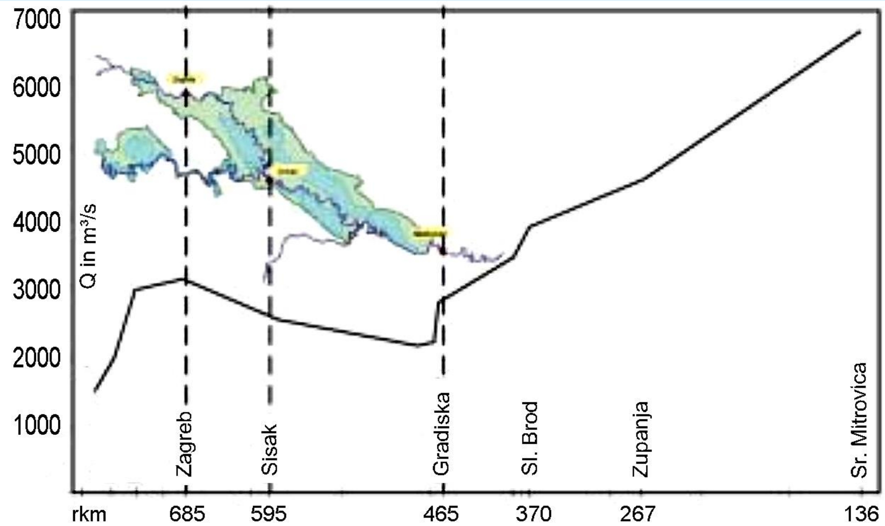
Sixty people died in the flood, including twenty in Doboj in the middle course of the Bosna and another twenty in Obrenovac at the Kolubara-Sava confluence in RS. The estimated overall damage was at least €3 billion.



☐ *Figure 60: Seven dike breaches in 2014 caused extensive flooding between Šamac and Drina confluence, but reduced flood discharge downstream. The arrows indicate the general direction of inundation in the adjacent areas [based on 42].*

Natural flood mitigation in the greater Lonjsko polje area

The Lonjsko Polje Nature Park in HR, between the towns of Sisak and Jasenovac, is a popular Ramsar site. Extending over 50,000 ha, it consists of extensive wet grasslands, floodplain swamps and floodplain forests, and retains the original lowland character of the whole Posavina. The area is still connected to the river and has a retention capacity of about 500 million m³. It is a unique European example of near-natural flood retention on a large river.
The area, in conjunction with other semi-natural flood areas, is able to protect larger settlements and many villages along 200 km of the river. Overland flow on the floodplain reduces the propagation speed of the flood wave for several days, significantly lowering the peak flow volumes and allowing for more preparation time in river reaches downstream.



☐ *Figure 61: Discharge (Q) reduction (black line) in Sava main channel by retention of the Upper Posavina flood system. This area considerably reduces the flood discharge downstream (based on [41]).*

It provides a valuable potential model for the reactivation of other flood polder systems along the lower Sava, especially the wide area west of Slavonski Brod and the floodplains east of Županja with the Bosut-Spačva forest. Chapter 7 on restoration potential gives some examples.

☐ *Figure 62: Lonjsko polje reduces the flood peak of Sava by 500 m³/s (© Goran Šafarek).*

Since the natural retention system of the Upper Posavina is upstream of the May 2014 flood area, it could not make any contribution to mitigating the disaster. The flood dikes along the affected stretch of the Sava – between the Bosna and Drina confluences – are located very close to the river (resulting in loss of floodplains of up to 85%). The dike breaches approximately neutralised the Drina contribution in this section (about 6,500 m³/s). Without these breaches, the flood wave would have caused much greater damage in the lowland stretches in RS, namely in Sremska Mitrovica, Šabac, Obrenovac and finally Belgrade.

The experience of the flood underlines the need to improve and enlarge retention capacities on the lower Sava, preferably according to the model of the natural retention storage of the Upper Posavina.

Technical flood retention measures like flood detention basins and reservoirs in the upstream catchment are clearly not a solution for the extreme floods in large catchments like the Drina. Their temporary storage capacities are equivalent to only 10% of flood waters, insufficient to prevent catastrophic flood levels [22].

☐ *Figure 63: 77% of active floodplain has been lost behind flood dikes built in the very vicinity of Sava river (© Goran Šafarek).*

Current flood defence structures and development of floodplains

The 2014 floods revived attention to the status of the flood defence structures in all the affected countries, focusing mainly on the technical reinforcement of existing dikes [43 and 44]. With the exception of some minor improvements of inlet and outlet structures of the Upper Posavina flood retention system, there are no proposals for major reconnection structures between the river and its floodplain. Reinforcing and raising existing dikes will not prevent future floods but merely pass on the problem downstream.

Spatial planning and land use management must also provide a crucial contribution, if efficient retention areas are to be preserved in the river floodplains. Unfortunately, commercial buildings are being developed irresponsibly within the floodplain areas in all of the countries, and this restricts future storage potential. A typical example of lost floodplain is an area south of Belgrade, between the river and the main railway freight yard (which was originally built on the margin of the floodplain). Today this former floodplain contains commercial areas and road connections and requires strong flood protection dikes. The Flood Risk Management Plan for the River Sava [45] is currently being produced by the Sava countries with detailed flood maps. The section for the EU member states countries SI and HR has already been completed. It recommends a hydraulic flood forecasting model, allowing real time flood modelling in all the countries. The very precise elevation data required for such a model could be acquired by modern techniques like LIDAR laser scanning.

In its Flood Risk Management Plan [45], Croatia states:

"Croatia's draft Flood Risk Management Plan (FRMP) reflects the orientation towards emphasising the natural water retention areas and flood retention areas for the flood prevention and flood protection. As a prevention measure, the FRMP provides for the continuation of ongoing activities on formal introduction of a special level of protection and maintenance of

natural water retention and wetland areas and boundaries of the public water domain in the process of physical planning. As a protection measure, the FRMP encourages selection of technical solutions that will ensure:

- *Retention of water in the watershed as long as possible and allowing room for watercourses to slow down the runoff;*
- *Preservation, restoration and enlargement of areas that can retain flood waters, such as natural water retention areas, wetlands and floodplains;*
- *Prevention of pollution of water and soil by harmful substances during flood events in areas reserved for flood water retention by land use restrictions and administrative measures;*
- *Continue creating lowland retentions in the areas of former floodplains for the purpose of flood flow reductions and flood protection of downstream areas;*
- *Usage of the existing lowland retention areas for meadows and grazing areas or for restoration of alluvial forests;*
- *Identification and preparation of protection and management programmes for floodplains and retention areas that could be used as natural water retention areas.*

In the prioritisation of the flood protection measures, the natural water retention and flood retention measures (i.e. Green Infrastructure measures) are emphasised over the structural flood protection measures where their application is technically and economically feasible. Concerning the financing of the flood protection measures in Croatia from the EU structural funds, it is stated".

These positive intentions need to be followed by the commitment to implement them, applying the positive experiences of the Upper Posavina system to the other river stretches. Flood protection also demands a more restrictive approach to spatial planning in the narrow tributary valleys. A new flood mitigation strategy must give space back to the rivers; flood defence structures must focus on settlements and infrastructure instead of agriculture or forestry. Economic effects of damage/insurance costs as a result of concentrating flood discharge to one narrow main channel must be taken into account and a paradigm shift to a more natural flood defence system must be considered. Elementary insurance (protection against flood) must be strengthened and should influence decisions to restrict construction to outside flood-prone zones. Economic decisions (flood loss and insurance) do not stand in opposition to ecological benefits. The provision and enlargement of flood retention areas is a long-lasting positive investment in society.

RS has an initiative to increase flood retention capacity in the southern Bosut area close to the Croatian border (Morovic area) using a flood polder solution.

The fact that climate change models predict up to 8% more floods must be considered in future planning [46].

Conclusions

- Since the start of flood defence constructions, 77% of the morphological floodplain has been lost (2,067 km² of an initial 8,943 km²). In addition, dozens of pumping stations keep the embanked lowland areas dry.
- The dramatic flood in 2014 emphasised the limitations of narrow floodplains. River dike failures were most prevalent along stretches where the dikes were located too close to the river (floodplain loss was particular high in these areas with up to 85%).
- The Sava has active floodplains that function as semi-natural retention areas. One of these is the Upper Posavina flood system, which – together with the Kupa lowlands – can store up to 1.6 billion m³, providing a major contribution to the lowering of water levels during peak discharges in the Zagreb, Sisak and Jasenovac areas.
- The primary reaction to the 2014 floods by all affected countries was to invest in the reinforcement of existing dikes. A more robust response would make use of possibilities to reconnect the river to former floodplains.

6-5 CUMULATIVE THREATS

While threats are discussed separately in the previous chapters, in reality these occur simultaneously as visualized in the following two maps (Figures 65 and 66). By overlaying these various current and future threats, it is evident that the entire Sava and its tributaries are at risk.

The first map (Figure 65) depicts the current alterations and threats along the Sava and assessed tributaries. Currently, river regulation and dredging are the most widespread alterations and impoundments by hydropower plants are located only on upper Sava in SI and along lower Sava in RS (stretch influenced by the impoundment of the Danube Iron Gate I).

The second map, (Figure 66) shows the future threats according to existing development plans. It makes clear that their effects would be felt throughout almost the entire river network in the morphological floodplain. The worst future impacts would be caused by long impoundments for new dams, but also by intensive river regulation structures and dredging to improve navigation along the entire 600 km of the lower Sava. These, combined with the construction of structural flood defences, would deprive the whole river system in the morphological floodplain of its ecological function, river dynamics and flood retention. Numerous dams in tributaries would interrupt the river continuum, with or without fish passes.

☐ *Figure 64: The accumulative effects of all current and future threats (such as uncontrolled sediment extraction from the river bed, as depicted in the photo) show that the entire Sava river system is at risk (© Tibor Mikuska).*

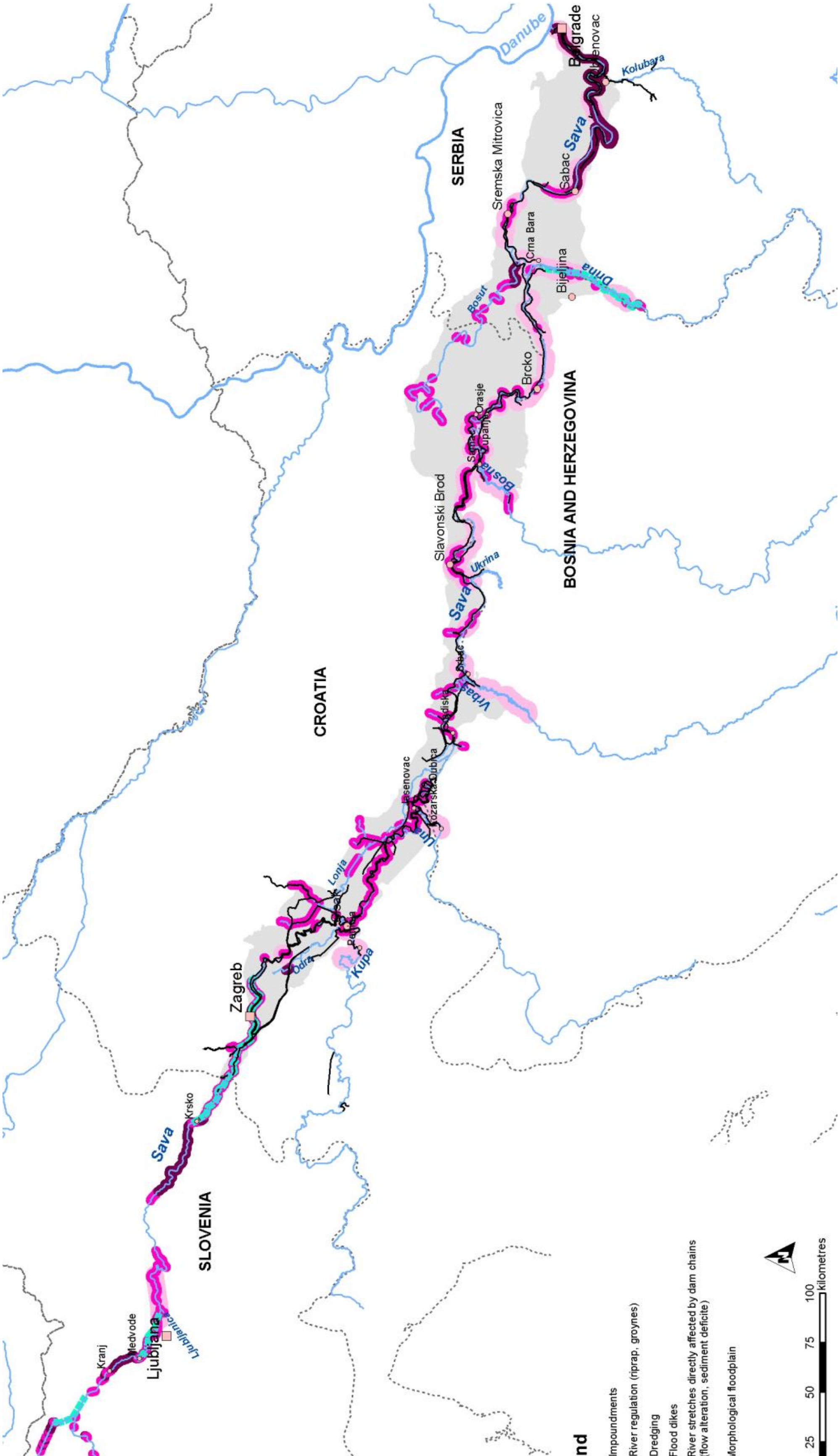
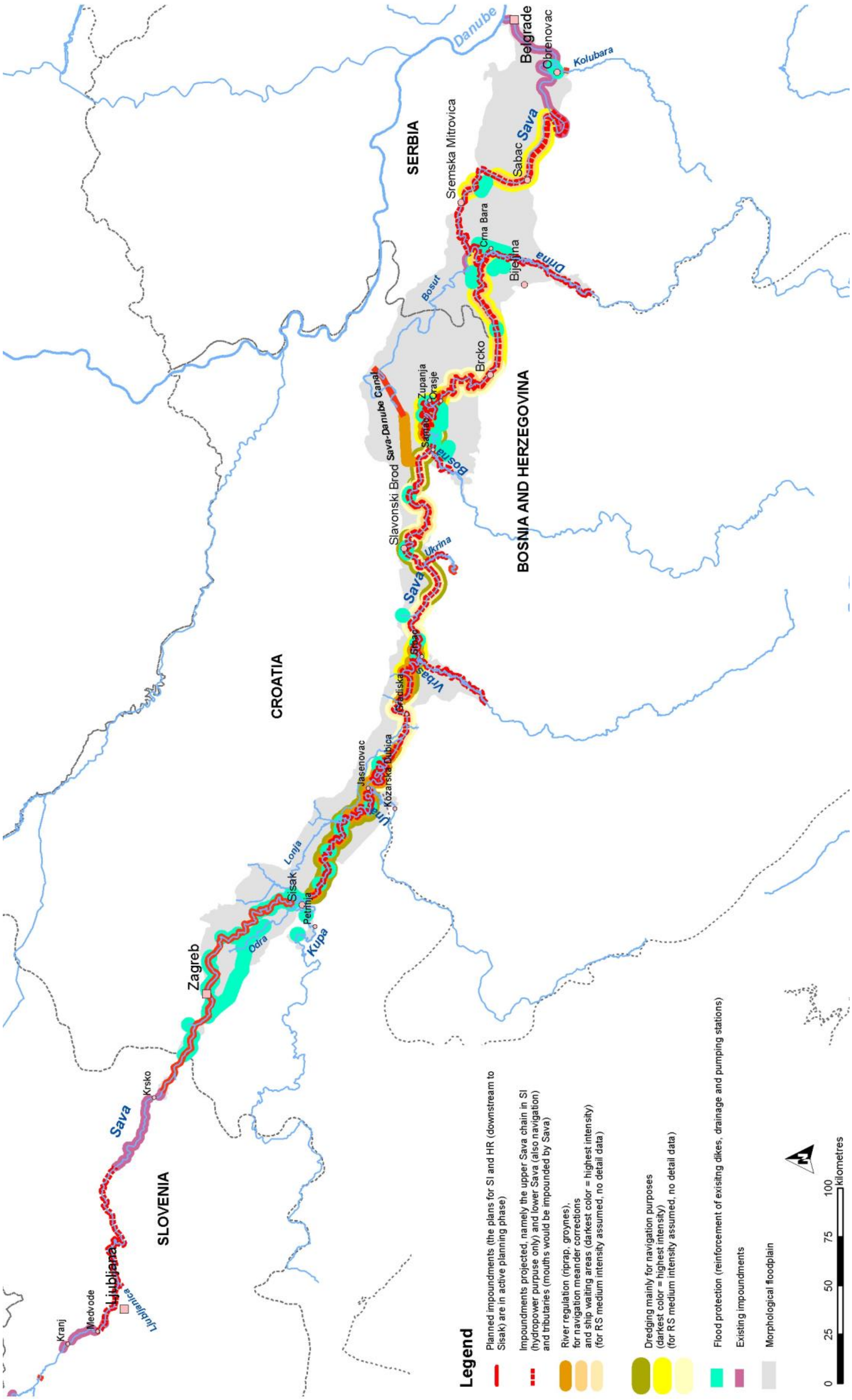


Figure 65: Current alterations and threats along the Sava and assessed tributaries



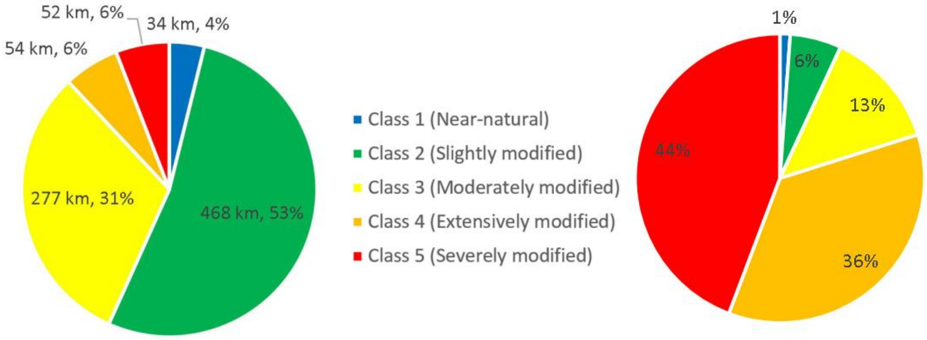
☐ *Figure 66: Projected alterations and threats along Sava and assessed tributaries. The whole Sava is at risk.*

Changes in land structure

At present, up to 30% of the land cover in the morphological floodplain is typically riparian in nature: water bodies, pioneer areas (gravel and sand bars), softwood forest, oxbows, swampy vegetation with succession and hardwood forest. If the cumulative threats are implemented, this picture could change radically. Most vulnerable are free-flowing river habitats and areas directly influenced by the river, particularly the highly valuable pioneer areas. Habitats within hydropower impoundments would be entirely lost. Stagnation upstream and downstream of the dams tends to fix water tables, degrading the dynamic softwood habitats and the conditions for hardwood forest in the long run. If all 88 projected dams are constructed, the area of valuable riparian land cover will shrink significantly, the rest being lost to impoundment.

Impact on hydromorphological condition

If proposed navigation measures and dredging along the long free-flowing stretches of the middle and lower Sava are implemented (even without the construction of dams foreseen for the middle and lower stretches), the hydromorphological status of the river would deteriorate considerably: class 2 areas would be relegated down to class 3 and class 3 areas to class 4, with an average degradation of between half and a whole class. Class 1 would disappear entirely, and class 5 would substantially increase (impoundments). The Brežice hydropower plant currently under construction in SI will turn nearly 10 km of class 3 into class 5. The next project at an advanced planning stage is Mokrice at the Slovenian-Croatian border. It will deteriorate a further 10 km stretch from class 3 to 5 and negatively influence the class 2 stretch of the lower Krka. Another ten large hydropower plants are planned on the Sava in SI in a chain that will turn about 80 rkm of classes 1, 2 and 3 into class 5, increasing the overall proportion of class 5 from currently 6% to 17%. New power plants envisaged in Zagreb and downstream to Sisak would easily cause another 100 rkm to deteriorate to poor classes and would have a strong impact on the entire middle and lower course (together with further planned dams downstream the class 5 would increase to 44% in total). In summary, the plans would reduce classes 1 and 2 from 57% to only 7%, while classes 4 and 5 would increase from 12% to 80%.



☐ *Figure 67: Current hydromorphological classification (left) for the Sava versus projected classification in case all development plans will be realised (right). Combined alterations would dramatically deteriorate the river.*

Impact on protected areas

All river regulation structures have a high impact on protected areas. The proposed projects, especially those concerned with navigation, combined with plans for dredging and hydropower, are likely to have drastic and probably irreversible effects on protected habitats and on the species these areas have been established to protect. They would take effect by altering growing conditions, making changes in the food web and opening up the areas to invasive species. An EIA for dredging the Sava within a Natura 2000 site in HR, and an EIA for the Mokrice hydropower plant in SI reveal conflicts in planning and gaps in assessment. Legal action in HR has forced projected quantities of material dredged from the Sava in the Natura 2000 site to be halved and requires parts of the material to be fed back into the river. However, even Natura 2000 sites are not well protected if overriding public interests are considered (see WFD Article 4(7) for exemptions). The impact of intensive forestry in protected areas is obvious from the land structure mapping, particularly for “clear cuts” and “poplar plantations”.

Table 11 shows the principal current and future threats in selected protected areas. They are arranged by area, starting at the upstream end in SI.

☐ *Table 11: Selected protected areas at risk from current and future threats. Protection levels: A (very high): National park or Ramsar site; B (high): Natura 2000 sites, nature reserves and candidate Emerald sites; C (moderate): Landscape protection.*

Country	**Name of protected area**	**Category of protection level (A,B,C)**	**Current threats**		**Potential future threats**	
			River regulation	**Dredging**	**Planned hydro-power plant**	**Planned navigation**
SI	Sava Bohinjka in Sava Dolinka - širše območje sotočja	C: Ecologically important area			X	
SI	Sava od Radovljice do Kranja s sotočjem Tržiske Bistrice	C: Ecologically important area			X	
SI	Zasavsko hribovje (upper part)	C: Ecologically important area	X	X	X	
SI	Sava Medvode - Kresnice	B: Natura 2000site	X		X	
SI	Rastišće Kluzijevega svisca na Lovrencu	C: Ecologically important area			X	
SI	Zasavsko hribovje (lower part)	C: Ecologically important area	X	X	X	
SI	Vrbina	B: Natura 2000 site	X		X	
SI	Krka (mouth)	B: Natura 2000 site	X		X	
SI	Sutla (mouth)	B. Natura 2000 site	X		X	
HR	Potok Bregana (mouth)	B: Natura 2000 site	X		X	
HR	Sava (SI border-downstream Zagreb)	C: Protected landscape	X		X	
HR	Sava Zaprešić	B: Special reserve (ornithology)	X		X	
HR	Sava kod Hrušćice	B: Natura 2000 site			X	
HR	Sava nizvodno od Hrušćice	B: Natura 2000 site	X	X	X	X
HR	Turopolje	B: Natura 2000 site	X		X	
HR	Odransko polje	B: Natura 2000 site	X		X	
HR	Lonjsko polje	A: Ramsar site and B: Natura 2000 site	X	X	X	X
HR	Donja Posavina	B: Natura 2000 site	X	X	X	X

Country	Name of protected area	Category of protection level (A,B,C)	Current threats		Potential future threats	
			River regulation	**Dredging**	**Planned hydro-power plant**	**Planned navigation**
HR	Sunjsko polje	B: Natura 2000 site	**X**	**X**	**X**	**X**
HR	Jelas polje	B: Natura 2000 site	**X**	**X**	**X**	**X**
HR	Gajna	B & C: Natura 2000 site and Significant landscape	**X**	**X**	**X**	**X**
HR	Spačva JZ	B: Natura 2000 site	**X**	**X**	**X**	**X**
HR	Spačvanski bazen	B: Natura 2000 site	**X**	**X**	**X**	
HR	Spačva	C: Significant landscape				
BA	Vršani	C: Other	**X**		**X**	**X**
BA	Bardača	A: Ramsar site	**X**	**X**	**X**	**X**
BA	Lower Drina	C: Other		**X**	**X**	
RS	Lower Bosut area	C: Other	**X**	**X**	**X**	**X**
RS	Vinicna	B: Nature reserve	**X**	**X**		**X**
RS	Radjenovci	B: Nature reserve	**X**	**X**	**X**	
RS	Varoš	B: Nature reserve	**X**	**X**		
BA	Lower Semberia	B: candidate Emerald site	**X**	**X**	**X**	**X**
RS	Obedska bara	B: Nature reserve		**X**	**X** (Danube dam Iron Gate I backwater, new planned dam – Kupinovo)	**X**
RS	Obedska bara	A: Ramsar site			**X** (Danube dam Iron Gate I backwater, new planned dam – Kupinovo)	**X**
RS	Obrež landscape	C: Other		**X**	**X** (Danube Iron Gate I backwater, new planned dam – Kupinovo)	**X**
RS	Veliko ratno ostrvo	B: Nature reserve	**X**	**X**	**X** (Influenced by Danube dam Iron Gate I backwater)	**X**

Conclusions

- The accumulative effects of all current and future threats show that the entire Sava river system is at risk.
- Regarding hydromorphology, the plans would reduce classes 1 and 2 from 57% to only 7%, while classes 4 and 5 would increase from 12% to 80%.
- All protected areas adjacent to the Sava are threatened by planned hydropower, river regulation and navigation.

7 RESTORATION POTENTIAL

Having covered the ecological importance of the Sava valley and the current and future threats it faces, this chapter deals with the restoration potential of the rivers and their floodplains for the benefit of local communities and biodiversity. This restoration vision is also in line with modern legal EU requirements, since the WFD, Floods Directive (FD) and Habitats Directive explicitly require measures to maintain and improve the ecological status of rivers.

Restoration projects on rivers in the EU, such as EU LIFE projects, are frequent and successful. In Austria alone, more than 25 LIFE river restoration projects on the Danube, Morava, Drava and other rivers (with a total cost of €90 million, 50% co-financed by the EU), have been implemented within the last 15 years. The first example of a large-scale LIFE restoration project on a river in HR is the DRAVA*LIFE* project, which started in 2016.

Restoration potential in the Sava river system has been assessed using an approach appropriate to all stretches along the Sava and the lower courses of its tributaries. It is based on a specifically developed set of data layers: the land structure map (see Chapter 3), the hydromorphological assessment (Chapter 4), the boundaries of active and morphological floodplains, the protected areas (Chapter 5), and general landowner information taken from national cadastral systems.

There are separate sections in this chapter for river and floodplain restoration. While river restoration focuses on giving more space to the river itself, floodplain restoration aims to reconnect former floodplains. Ideally, river and floodplain restoration measures must be combined to guarantee enough lateral space for channel development.

7-1 RIVER RESTORATION POTENTIAL

This section identifies potential river restoration stretches with due heed to existing river engineering structures and available space for lateral development. As has been demonstrated in Chapter 6, human intervention has set narrow limits to the lateral development of channels over long stretches of rivers in the Sava corridor, hindering the rejuvenation of pioneer and floodplain habitats.

To improve the fluvial dynamics of the river, restoration must start by enhancing the conditions for lateral erosion and reconnecting side channels which have been disconnected by traverses and groynes. Another objective is to stop the ongoing riverbed incision.

River stretches selected for these purposes are prioritised with a numerical classification scheme based on experience from previous floodplain restoration studies. The classification involves four parameters: length, space for lateral development, length within protected areas, and connection to potentially restored floodplain.

These are purely physical considerations, applied to select the best possible locations for restoration of original river dynamics. Under each parameter, restoration potential is assessed on a scale of one to three: 1 – very high; 2 – high; and 3 – moderate. There is no score lower than moderate, because only areas that show potential are evaluated.

Scoring scheme for river restoration potential parameters

1. *Length*. In general, potential stretches on which measures are planned score better if they are longer, even if the measures do not concern the whole stretch, but is a chain of shorter measures.
   On the upper Sava and its tributaries, the scores assigned to the length of potential restoration stretches are: 1 for >5 km; 2 for 1-5 km; and 3 for <1 km.
   On the lowland Sava and its tributaries, they are: 1 for >10 km; 2 for 5-10 km; and 3 for <5 km.

2. *Space for lateral development.* This score is assessed on both sides, where there are adjacent floodplain restoration areas. This parameter is rated according to the extent of the buffer zone, i.e. a near-natural terrace or space for free development over a longer period, defined as the next 50 years. Anabranching stretches score less than meandering stretches because of the different average time rates of lateral development – 10 m/a and 5 m/a respectively.
   The scores assigned to the width of the buffer zone in anabranching reaches are: 1 for >500 m; 2 for 250-500 m; and 3 for <250 m.
   For meandering reaches, the scores are: 1 for >250 m; 2 for 130-250 m; and 3 for <130 m.

3. *Protected areas*. Restoration stretches within protected areas are prioritised over stretches without any protection status because they offer greater potential for bio-corridor/biodiversity (Habitats Directive), improvements in interlinkage to WFD (ecological status) and FD (provision of land use adapted to floods). The scores are based on the proportion of the stretch that falls within a protected area – 1 for >70%; 2 for 30-70%; and 3 for <30%.

4. *Connection to potentially restored floodplain*. This represents possible synergies for phenomena such as lateral development. A bonus score of 1 is assigned if there is an adjacent floodplain with restoration potential, no score is assigned to all other areas.

Prioritisation score

An overall prioritisation score of 1, 2 or 3 is assigned to each potential restoration stretch, corresponding to the arithmetic mean of the scores for each parameter:

1 - 1.4 = 1 – very high potential/priority

1.5 - 2.4 = 2 – high potential/priority

2.5 - 3 = 3 – moderate potential/low priority

These scores do not take account of the feasibility of restoration at a given location in terms of financing, political willingness, local activities and community/NGO initiatives. Such an evaluation would require a further evaluation step, but this prioritisation offers a valid first selection of potential locations.

7-1-1 OVERALL RIVER RESTORATION POTENTIAL

A total of 41 river stretches with a total length of 251 km have been identified for possible restoration along the Sava and its tributaries, as shown in Figure 69. A detailed assessment is given in Table 12. The upper Sava is directly comparable with other alpine and sub-alpine river systems regarding slope, discharge, sediment and lateral erosion conditions. Accordingly, numerous short stretches have a high potential for river widening and improved fluvial dynamics. Restoration in these locations would lead to enhanced lateral erosion and bar/island development.

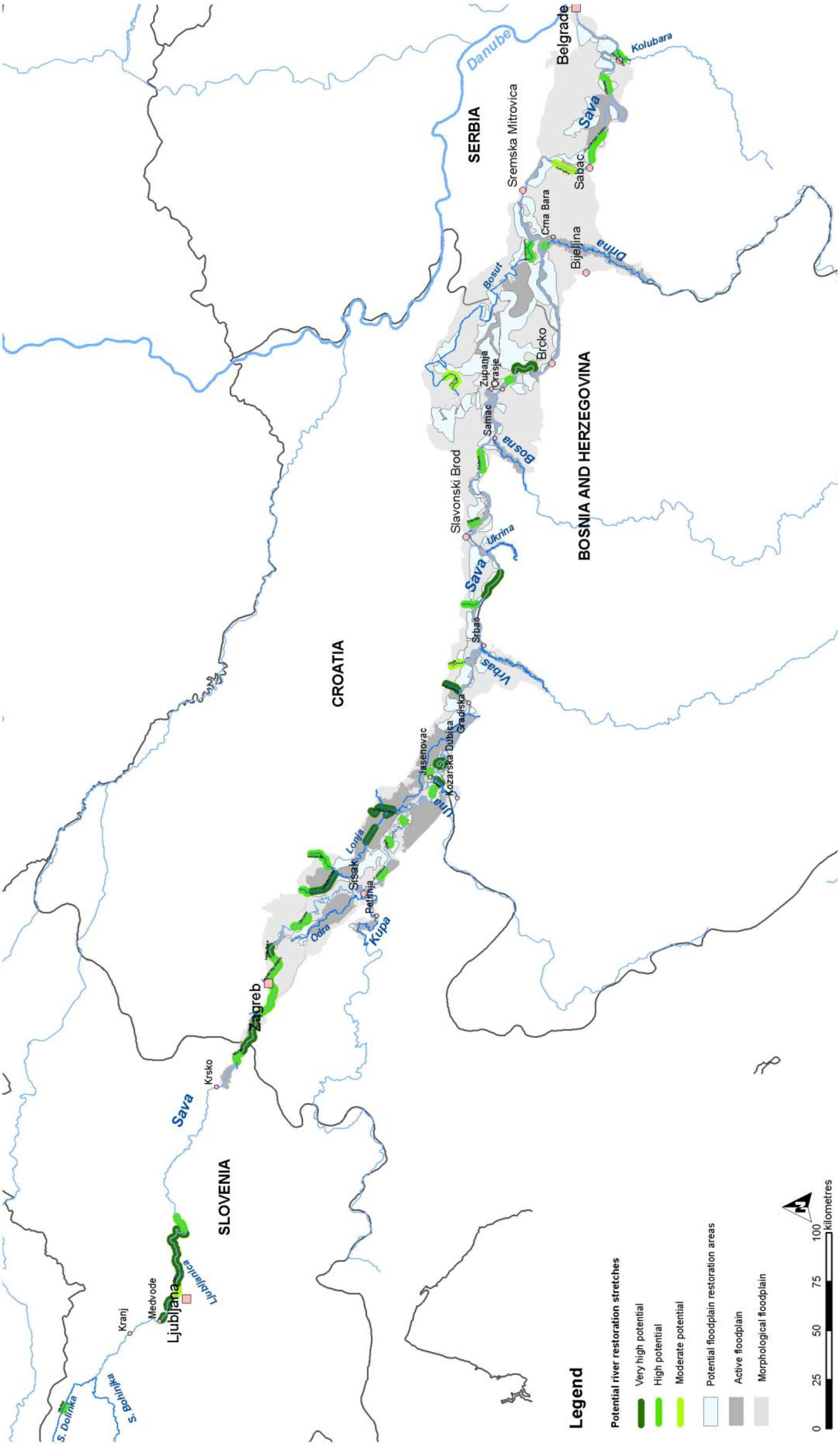
Significant restoration on the free-flowing reach from Krško to Zagreb could be achieved on the entire north bank (SI and HR) simply by removing riprap reinforcements, thus allowing lateral development through erosion in adjacent floodplain areas. On the south eastern (Croatian) side, however, the floodplains have been detached from the river by the construction of relatively recent flood dikes.

The next important stretch of the Sava is where it runs through the city of Zagreb. The restoration plan for this stretch constitutes a valuable alternative to the plan for new hydropower plants, which would finally deprive the river of its free-flowing character and have serious consequences for sediment balance downstream. The length of the stretch proposed for restoration, including the flood bypass canal, is just over 20 km. The incised main channel needs to be elevated to allow more frequent usage of the flood canal feeding Odransko polje. The restoration plan should include unhindered access to the Sava banks in order to make the whole area more attractive and ecologically valuable.

Human interventions on the middle and lower Sava include many local bank reinforcements at the erosive sections of meander bends, groynes for improved navigation during low water periods and short but rigidly reinforced banks in urban areas. Although the lateral space for channel development remains an important consideration for river restoration, channel migration is much slower in the meandering reaches of the middle and lower Sava than along the upper course of the river. Nevertheless, the potential for improvement of hydromorphological conditions is high on the Sava and even higher at the tributaries confluences, where dredging and fairway stabilisation for navigation purposes pose serious threats.

Lessons learned regarding the restoration of lowland rivers can be obtained from the Morava at the Austrian-Slovakian border [47].

☐ *Figure 68: Continuous bank reinforcements and river straightening on upper Sava in SI but also in the downstream HR reach have significant river restoration potential (© Ulrich Schwarz).*



□ *Figure 69: Potential river restoration stretches and their prioritisation: 41 river stretches are predestined for restoration.*

☐ *Table 12: Assessment of river restoration potential beginning with Sava (from upper to lower course), followed by tributaries.*

River	Country	Name of river restoration stretch	Length of river stretch [km]	River restoration potential parameter				Restoration priority score
				Size (length)	Space for lateral develop -ment	Protected area coverage	Adjacent floodplain with restoration potential	Restoration priority
Sava Dolinka	SI	Hrušica	1.8	2	2	3	-	2
Sava	SI	Spodnje Pirnice	1.8	2	1	1	-	1
Sava	SI	Spodnje Gameljne	3.4	2	1	1	-	1
Sava	SI	Tomačevo	3.9	2	3	3	-	3
Sava	SI	Zalog	4.2	2	1	1	1	1
Sava	SI	Sava from Ljubl-janica confluence to Litija	23.0	1	2	1	-	1
Sava	SI	Sava from Litja to Spodnji Log (gorge entrance)	5.6	2	2	1	-	2
Sava	SI	Mostec	3.9	2	3	1	1	2
Sava	SI/ HR	From Podgračeno (SI) to upstream Zagreb (HR)	16.9	1	2	1	1	1
Sava	HR	Zagreb city stretch	25.1	1	3	1	1	2
Sava	HR	Ivanja Reka	2.8	2	1	1	1	1
Sava	HR	Drnek	1.4	3	3	1	1	2
Sava	HR	Oborovo	2.9	3	2	1	1	2
Sava	HR	Preloščica	2.9	3	1	1	1	2
Sava	HR	Lonja (opposite river bank)	1.5	3	1	1	1	2
Sava	HR	Drenov Bok	2.7	3	3	1	1	2
Sava	HR	Downstream Košutarica	8.3	2	1	1	1	1
Sava	HR	Downstream Slavonski Kobaš	10.5	1	1	1	1	1
Sava	HR	Prnjavor	6.8	2	3	1	1	2
Sava	HR	Posavski Podgajci	9.9	2	1	1	1	1
Sava	HR	Bošnjaci	1.8	3	1	1	1	2
Sava	HR	Ruščica	2.7	3	1	1	1	2
Sava	HR	Jasenovac east	1.5	3	1	1	1	2
Sava	HR	Čigoć	2.9	3	3	1	1	2
Sava	RS	Platićevo	7.1	2	3	3	-	3
Sava	RS	Krtinska	5.6	2	1	3	1	2
Sava	RS	Drina mouth	0.9	3	1	2	-	2
Sava	RS	Downstream Šabac	10.6	2	2	2	1	2

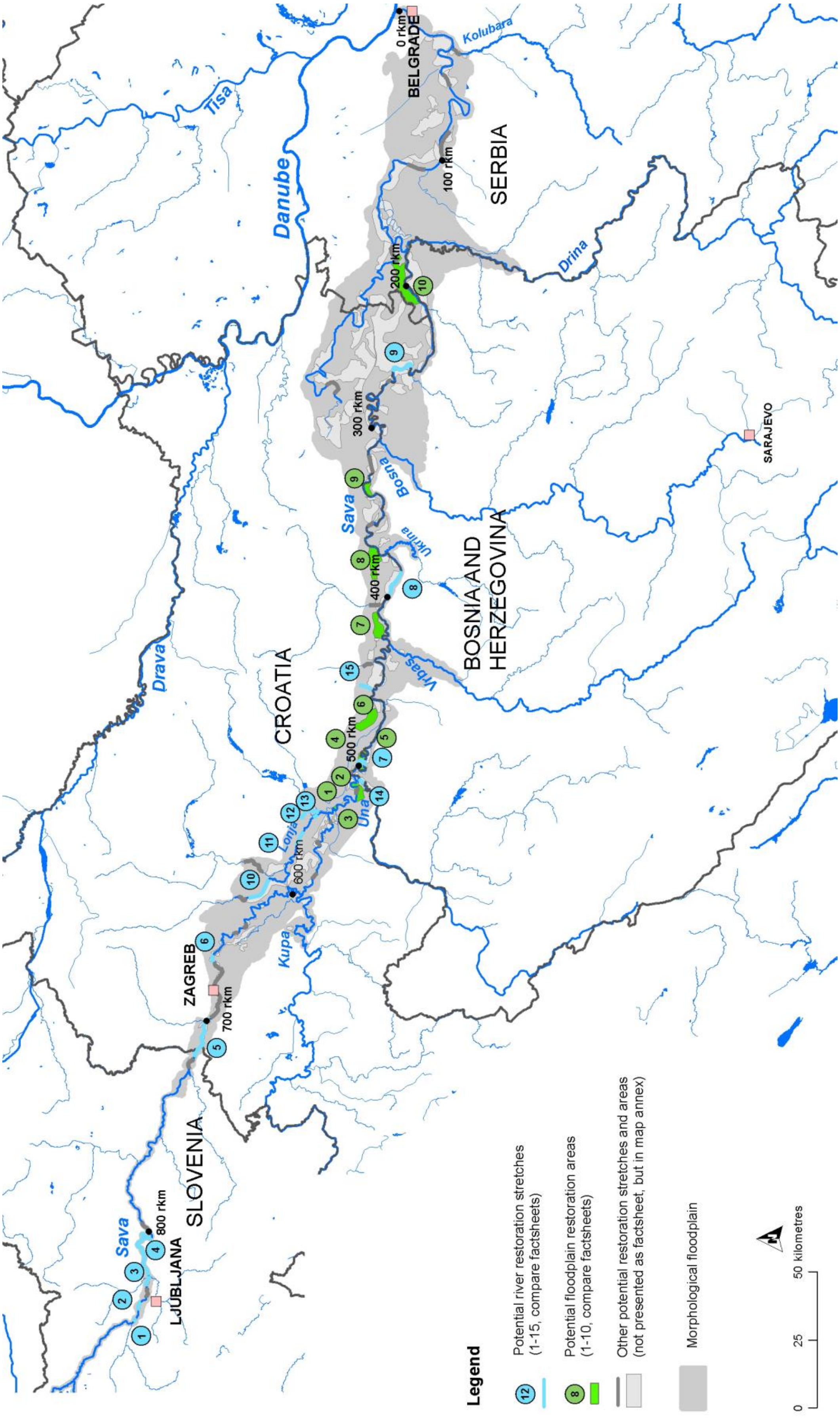
River	Country	Name of river restoration stretch	Length of river stretch [km]	River restoration potential parameter				Restoration priority score
				Size (length)	Space for lateral develop -ment	Protected area coverage	Adjacent floodplain with restoration potential	Restoration priority
Lonja	HR	Donji Šarampov	3.9	2	3	3	1	2
Lonja	HR	Lonjsko polje 1	11.1	1	1	1	1	1
Lonja	HR	Lonjsko polje 2	5.8	2	1	1	-	1
Trebez	HR	Lonjsko polje 3	1.8	2	1	1	-	1
Kutinica	HR	Lonjsko polje 4	9.3	1	2	1	-	1
Una	HR/ BA	Tanac	2.2	2	1	1	1	1
Cesma	HR	Obedišće	9.3	1	3	3	1	2
Sumetlica	HR	Savski Bok	5.2	1	1	1	1	1
Resetarica	HR	Vrbje	3.9	2	3	3	-	3
Orljava	HR	Downstream Lužani	4.5	2	2	1	1	2
Bosut	HR	Cerna	8.7	1	3	3	-	3
Bosut	RS	Bosut mouth	6.5	1	2	3	1	2
Kolubara	RS	Obrenovac	3.7	2	3	3	1	2

In general, priority should be assigned to channel widening measures such as the removal of riprap reinforcements and the providing of space for lateral development. Reconnecting side channels by removing closures or lowering banks is an effective means of intensifying dynamic processes. However, all of these plans require careful assessment of local changes in sedimentation in order to guarantee the durability of the connections. The length of restoration should be determined on the basis of such an analysis and will differ for anabranching and meandering stretches.

7-1-2 PRIORITISED POTENTIAL RIVER RESTORATION STRETCHES

In this chapter, short factsheets for the highest priority restoration stretches from the upper to the lower Sava are presented. The maps also indicate adjacent potential floodplain restoration areas, which are covered in Chapter 7-2.

The blue dots 1-15 in the overview map (Figure 70) indicate the locations of prioritised river restoration sites.



□ *Figure 70: River stretches and floodplain areas with restoration potential of highest priority (see factsheets 1–15*

☐ *Figure 71: Potential river restoration site n° 1 – Spodnje Pirnice, Sava downstream of Medvode (SI)*

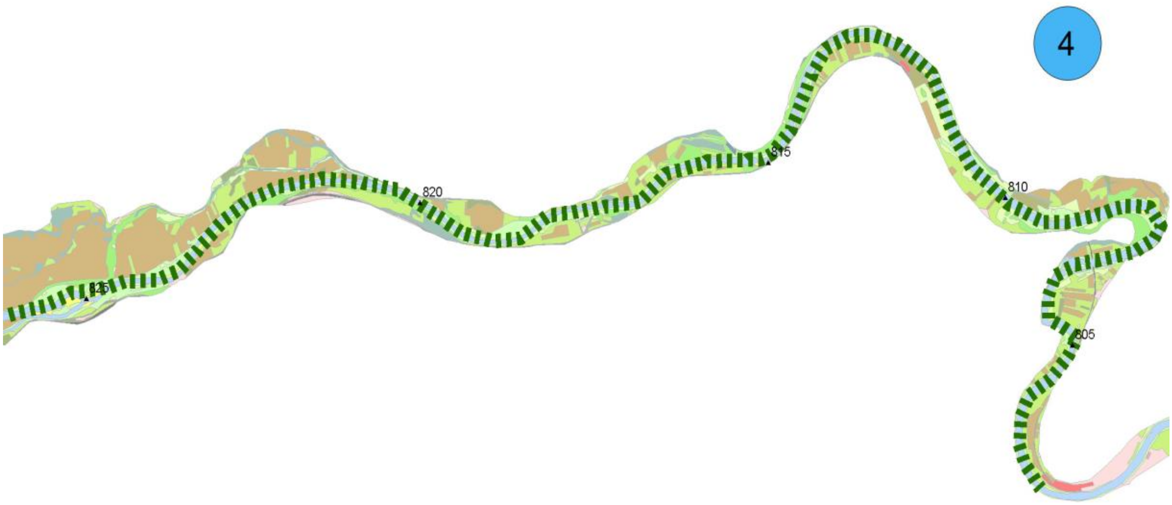
Proposed restoration measures: removal of bank reinforcement and channel widening.

☐ *Figure 72: Potential river restoration site n° 2 – Spodnje Gameljne, Sava between Tacen and Ćrnuče (SI)*

Proposed restoration measures: channel widening, restoration of braided channels, and lowering or even removal of ramps if channel stability is not endangered.

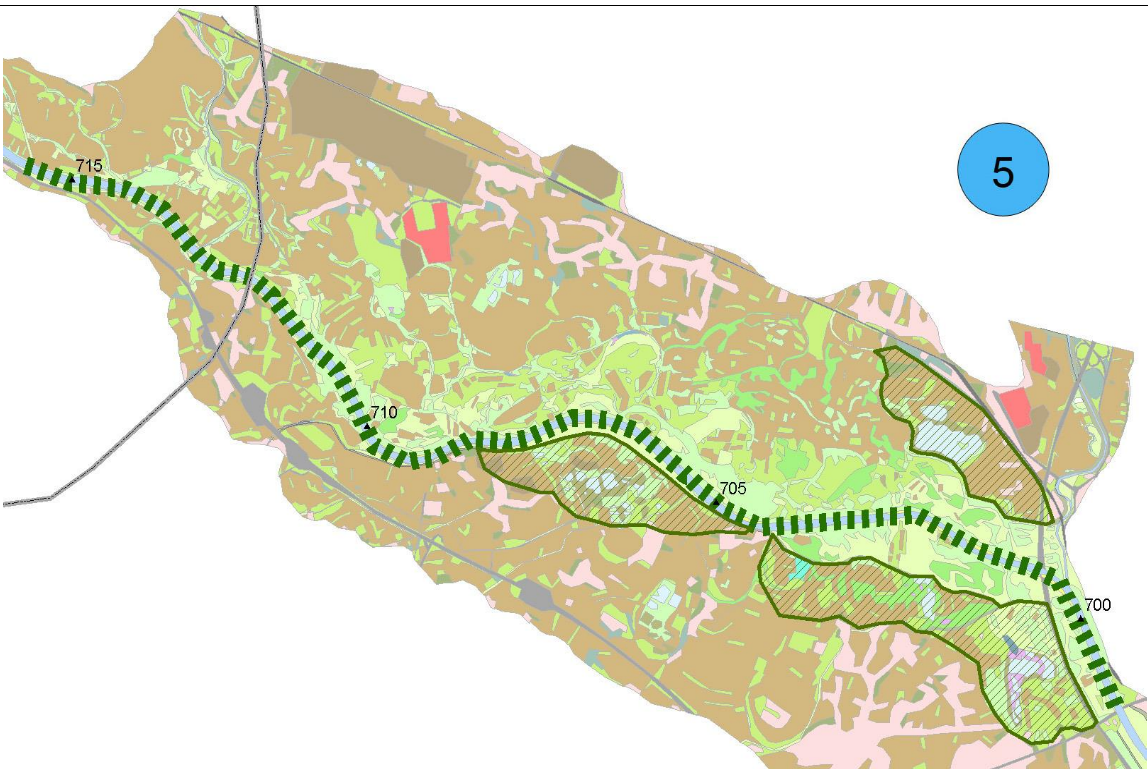
☐ *Figure 73: Potential river restoration site n° 3 – Zalog, Sava upstream Ljubljanica mouth (SI)*

Proposed restoration measures: removal of bank reinforcement and channel widening. Lateral development on the south side is only possible by reconnection of the floodplain area.



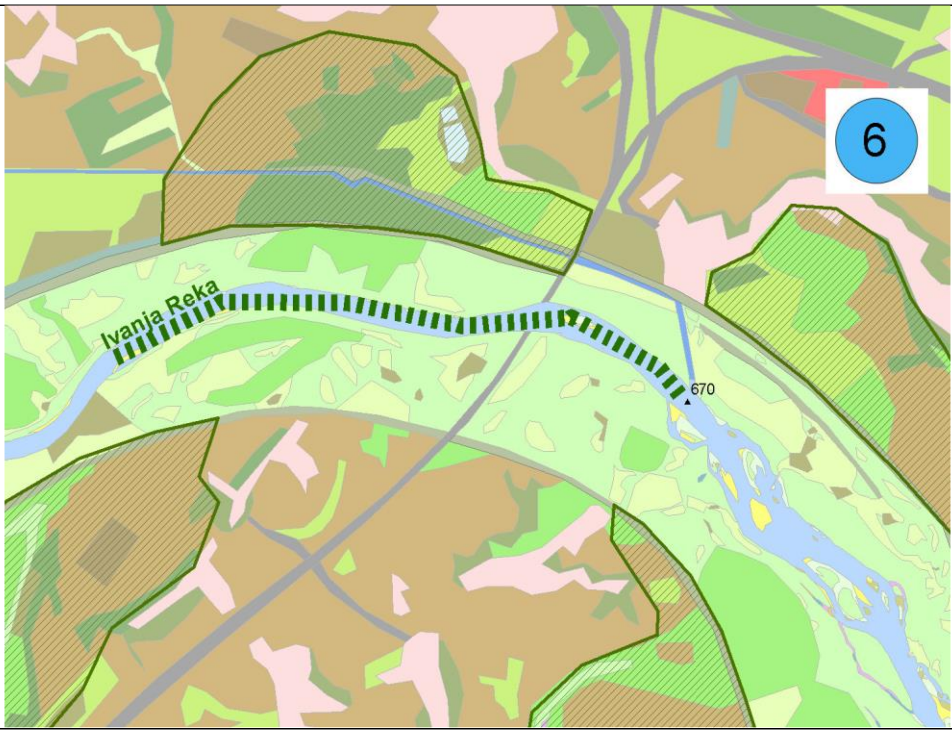
☐ *Figure 74: Potential river restoration site n° 4 – Sava from Ljubljanica confluence to Litija (SI)*

Proposed restoration measures: removal of bank reinforcement and lowering or removal of ramps if channel stability is not endangered.



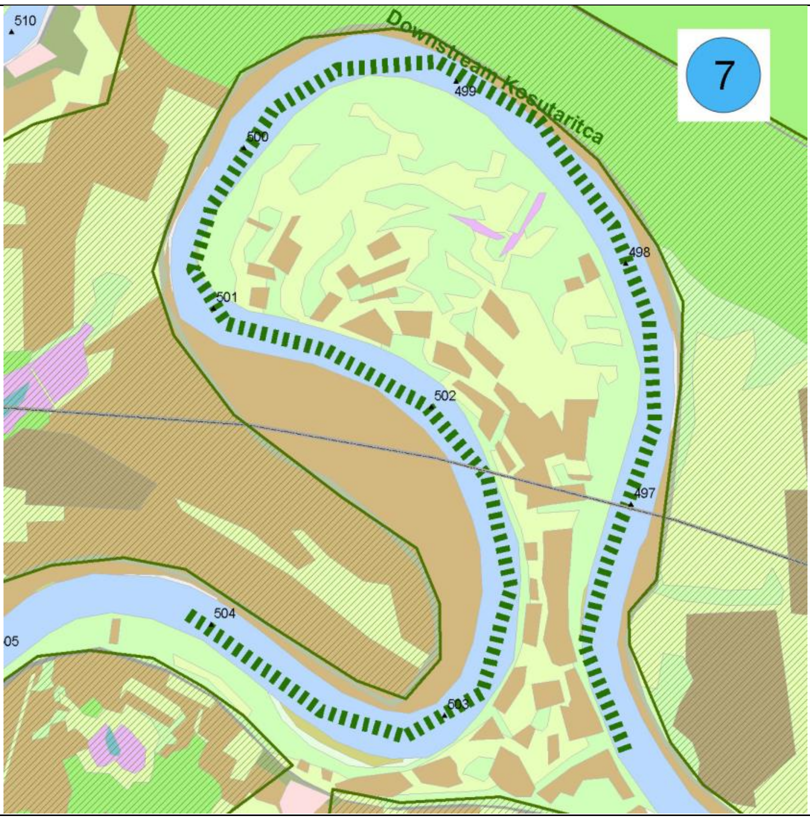
☐ *Figure 75: Potential river restoration site n° 5 – Sava from Podgračeno (SI) to just upstream of Zagreb (HR)*

Proposed restoration measures: channel widening, restoration of braided channels and reconnection of former floodplains where possible.



☐ *Figure 76: Potential river restoration site n° 6 – Ivanja Reka, Sava downstream of Zagreb (SI)*

Proposed restoration measures: removal of bank reinforcement and channel widening (with protection of highway bridge pillars).

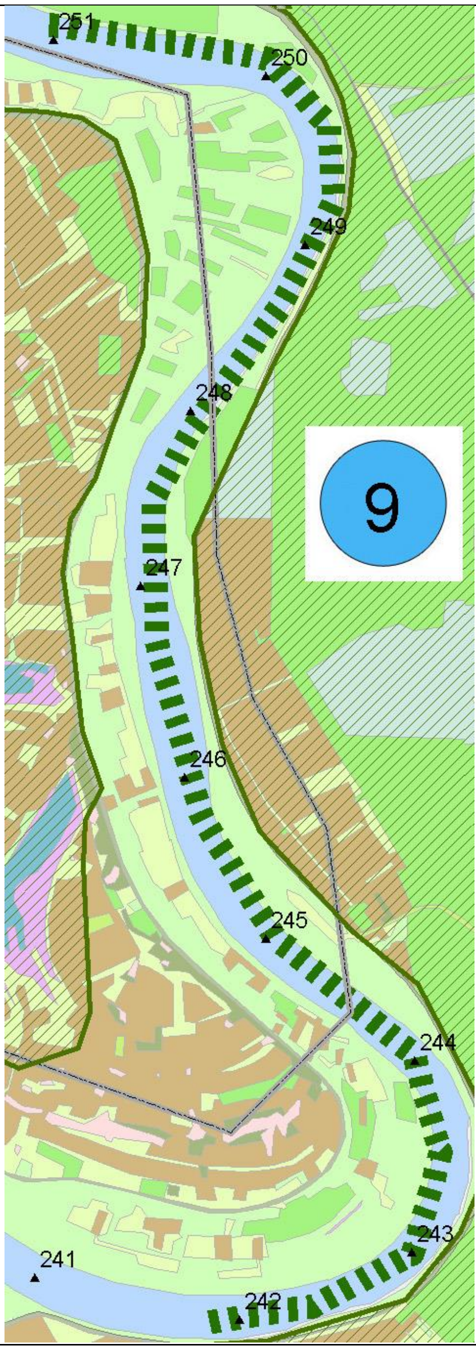


☐ *Figure 77: Potential river restoration site n° 7 – Sava downstream Košutarica (HR)*

Proposed restoration measures: removal of riprap reinforcement and lateral extension in accordance with floodplain restoration.

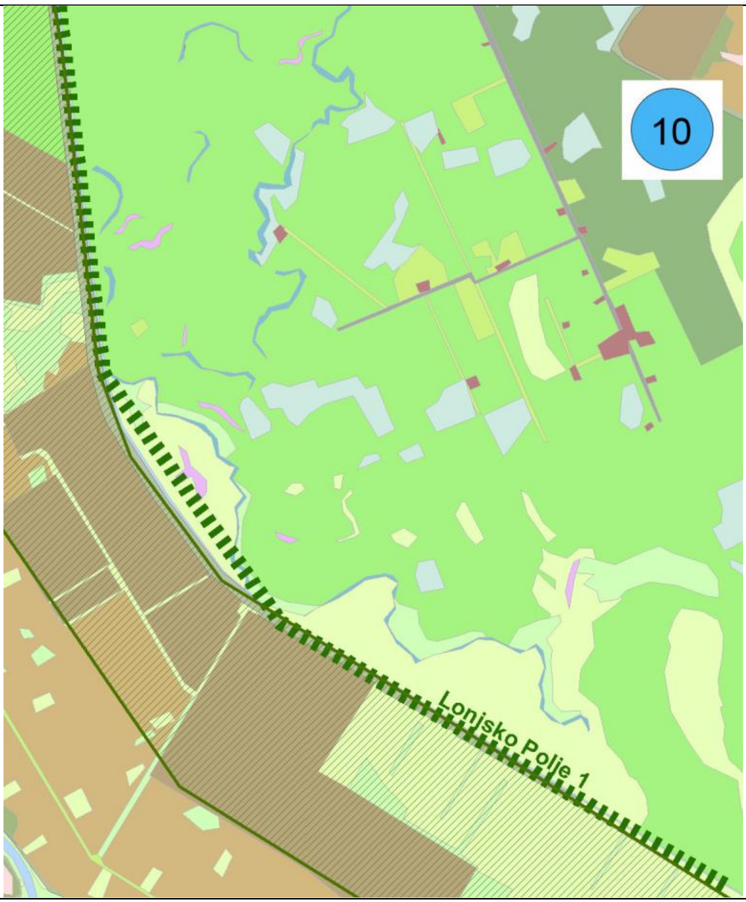
☐ *Figure 78: Potential river restoration site n° 8 – Sava downstream of Slavonski Kobaš (HR)*

Proposed restoration measures: removal of bank reinforcement in combination with lateral reconnection.



□ *Figure 79: Potential river restoration site n° 9 – Posavski Podgajci, Sava downstream of Županja (HR)*

Proposed restoration measures: removal of bank reinforcement in combination with lateral extension towards the Bosut-Spačva forest.



☐ *Figure 80: Potential river restoration site n° 10 – Lonjsko polje 1, Lonja in upper Lonjsko polje (HR)*

Proposed restoration measures: re-initiation of meandering by reconnecting the former channel.

☐ *Figure 81: Potential river restoration site n° 11 – Lonjsko polje 2, Lonja (HR)*

Proposed restoration measures: re-initiation of meandering by locally filling up the main channel and reconnecting the former channel.

☐ *Figure 82: Potential river restoration site n° 12 – Lonjsko polje 3, Lonja (HR)*

Proposed restoration measures: re-initiation of meandering by locally filling up the main channel and reconnecting the former channel.

☐ *Figure 83: Potential river restoration site n° 13 – Lonjsko polje 4, Kutnica (HR)*

Proposed restoration measures: initiation of re-meandering and reconnection of the branch system.

☐ *Figure 84: Potential river restoration site n° 14 – Tanac, on the Una near the confluence (BA and HR)*

Proposed restoration measures: removal of bank reinforcement and incision control to maintain the connection with the side channel and the former meander.

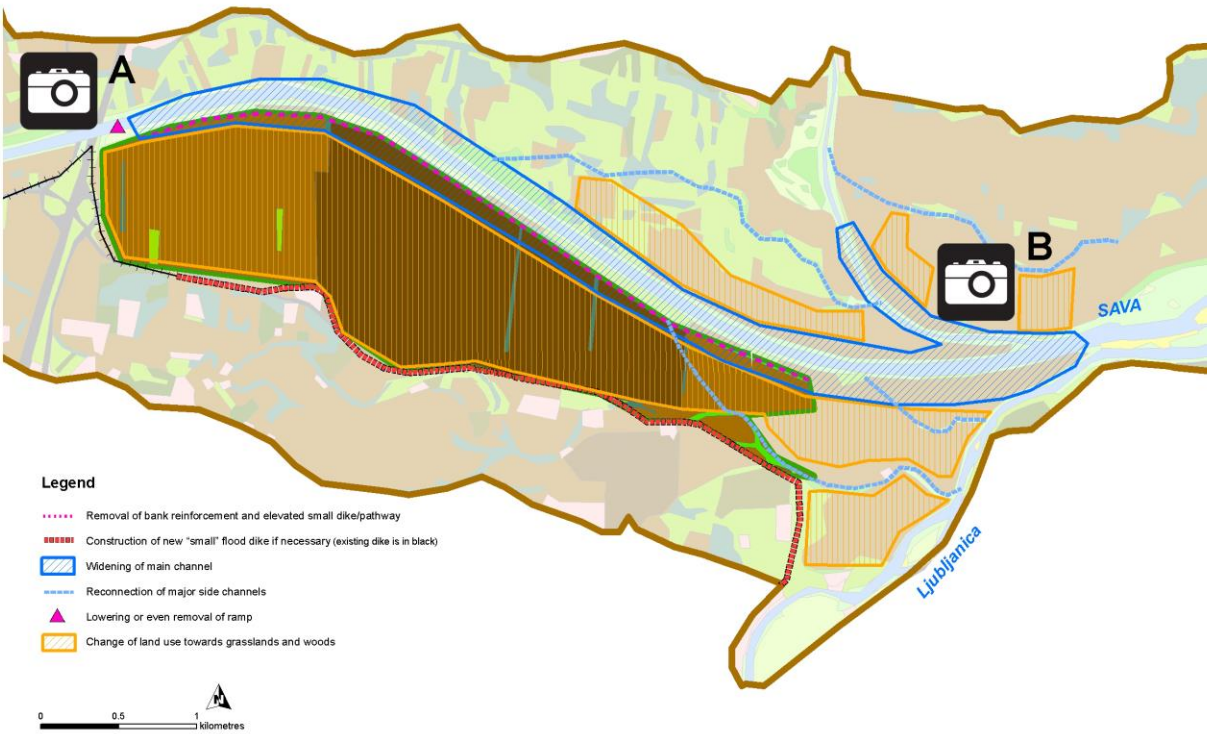
☐ *Figure 85: Potential river restoration site n° 15 – Savski Bok, Sumetlica (HR)*

Proposed restoration measures: re-initiation of meandering and reconnection of hardwood forests in the lower section.

7-1-3 POTENTIAL RIVER RESTORATION PILOT SITES

The first candidate for a pilot stretch is the free-flowing 4 km stretch "Zalog" upstream of the Ljubljanica confluence in SI (blue dot no. 3 in overview map Figure 70). It lies in the proposed chain of dams between the existing Medvode dam (at the confluence of Sava Dolinka and Sava Bohinjka) and at the projected HPP Mokrice at the Croatian border. The stretch of the Sava directly upstream of the Ljubljanica confluence has been altered by rectification, riprap reinforcement and a small lateral dike that disconnects a significant portion of the southern floodplain, the location of an adjacent potential restoration area. Incision is controlled by ramps because the river is regulated and lateral erosion is prevented by continuous riprap.

The stretch is typical of the upper mountainous Sava reach. Channel widening, at least along the north bank, would allow for lateral erosion and generate processes of sedimentation and bar building downstream. In the triangle framed by the Ljubljanica and Kaminska Bistrica near their confluences, lateral erosion has already started and the affected land behind should be managed accordingly. Since the land is privately owned, purchase or compensation may be required. The upstream end of the stretch is a ramp (just downstream of the highway bridge), which should be included in the restoration measures. The site (river and floodplain) is designated as the Zasavsko hribovje *Ecologically Important Area*.



- *Figure 86: Ljubljancia mouth (blue dot no. 3 in overview map Figure 70): mainly involves river restoration in combination with restoration of a floodplain area ("Zalog" dark coloured agricultural area). For land use classes, see map annex legend. The photo pictograms indicate the position for the illustrations on the next page.*

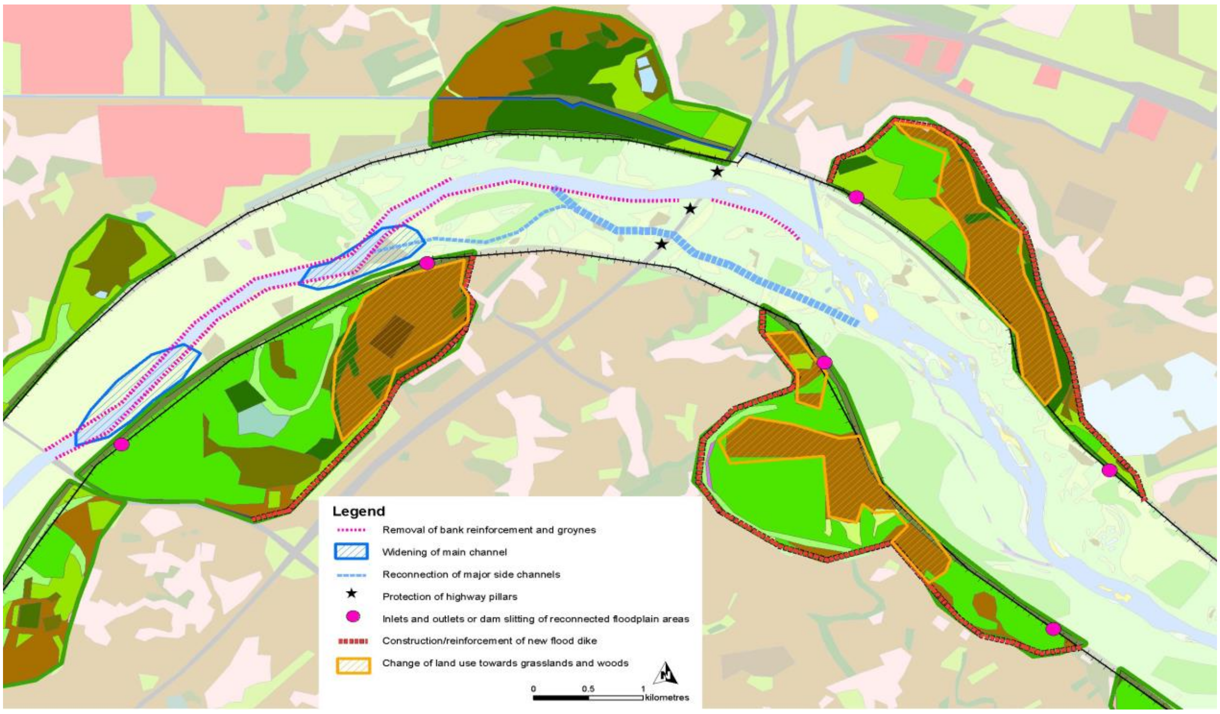
Visualisation of potential restoration sites

☐ *Figures 87 and 88: View of the Sava upstream of the confluence with Ljubljanica (camera shot "A" in Figure 86). On top: Current situation, i.e. before restoration (© Matic Oblak); below: Illustration of Sava after river restoration (© Michael Mayer)*

□ *Figures 89 and 90: Sava at Ljubljanica mouth (camera shot "B" in Figure 86). On top: Current situation, i.e. before river restoration (© Matic Oblak); below: Illustration of Sava after river restoration (© Michael Mayer).*

☐ *Figure 91: Restoration of the Sava could provide new habitats for huchen and bird species such as little ringed plover, bee-eater and even common tern (illustration by Michael Mayer).*

The second pilot stretch, just downstream of Zagreb, is shorter but covers a wider area. It could be restored as the last “wild” stretch of the upper Sava in HR. The proposed measures need to be harmonised with the general restoration of sediment balance and channel incision along the whole Croatian part of the upper Sava. At present, there is a sediment deficit caused by the dam chain upstream. Regulation of what was formerly an anabranching river system with several side arms and many islands has led to channel incision of 3.5 m on average. The area downstream accommodates the only breeding site of the little tern along the Sava. The only other important and stable breeding sites are on the lower Drina (see Chapter 2). The Natura 2000 site Sava kod Hruscice lies directly downstream of the highway crossing. Remedying the channel incision is a priority here, since gravel dredging was permitted in this stretch until only a few years ago.



☐ *Figure 92: Sava downstream of Zagreb (blue dot no. 6 in overview map Figure 70). Due to overall incision by several metres, restoration should focus on developing a new main channel in parallel to the existing channel. Lateral expansion space is limited and potential floodplain areas for reconnection are visualised in darker colours. For land use classes see map annex legend.*

„SAVision for Zagreb“: Visualisation of potential Sava restoration in Zagreb

- *Figures 93 and 94: Sava in Zagreb. On top: Current situation, i.e. before river restoration (© Stanislava Odrljin); below: Illustration of Sava after river restoration (© Michael Mayer). Instead of monotonous reinforced banks and foothills or – even worse – planned hydropower impoundments, restoration could provide attractive recreation areas (as in Munich for Isar [48]).*

☐ *Figures 95 and 96: Sava in Zagreb, a few kilometres downstream of Figure 93. On top: Current situation, i.e. before river restoration (© Goran Šafarek); below: Impression of an attractive city stretch (illustration by Michael Mayer).*

7-2 FLOODPLAIN RESTORATION POTENTIAL

The floodplains considered for restoration in this study are all located along the middle and lower Sava. These have potential for expansion by analogy with previous studies carried out for the Danube and the Mura-Drava-Danube Transboundary Biosphere Reserve [49, 50]. Candidate areas are identified by detailed land structure analysis within the active and morphological floodplain boundaries, excluding settlements and infrastructure. Potential sites are also evaluated on their shape and position as the most promising sites are unfragmented floodplain areas adjacent to the river. Limitations to restoration potential frequently arise from the scattered location of settlements and commercial areas and the cutting effect of transport routes and dikes.

The flood in 2014 and dike breaches in these stretches (see Chapter 6-4) underline the great importance of floodplain restoration and flood retention capacities in this part of the river.

Parameters for assessing the restoration potential of floodplain areas

1. *Land structure*: An important component of restoration potential is the presence of reconnectable floodplain remnants. These include former floodplain forests, oxbows, floodplain swamps and wet grasslands. Intensive, large-scale agriculture is unfavourable. Areas are scored by the proportion of typical remnants of natural floodplain elements: 1 for >70%; 2 for 30-70%; and 3 for <30%.

2. *Hydromorphological conditions*: These conditions largely determine the feasibility of restoration and are evaluated for ability of lateral shift and meander migration. As described in Chapter 4, hydrological conditions are rated in five classes from "near-natural" to "severely modified". For this analysis, the scores are 1 for classes 1 and 2 (near-natural and slightly modified); 2 for class 3 (moderately modified); and 3 for classes 4 and 5 (extensively and severely modified).

3. *Retention capacity*: The retention capacity is important for flood mitigation. The figure is an estimate calculated from the size of the potential reconnected area and its altitude relative to the flood water level, neglecting volume changes due to the movement of water through the floodplain. The score assigned to the flood retention capacity is not differentiated by type. The scoring scheme is: 1 for >15 million m³; 2 for 5-15 million m³; and 3 for <5 million m³. [11]

4. *Dike relocation potential*. Dike relocation is a very effective measure for extending the active floodplain. The assessment is based on costs, which in turn depends on length of the dikes. The score is 1 if the relocated dike is shorter than the original; 2 if it is up to 20% longer; and 3 if it is more than 20% longer. Dikes in need of renovation could be a bonus, but no concise data was available for the assessment.

5. *Protected areas*: Floodplains are prioritised with scores according to the proportion that lies within a protected area: 1 for >70%; 2 for 30-70%; and 3 for <30%.

6. *Land ownership* has a significant influence on the feasibility of restoration because of the associated complications and costs of purchasing or renting land or paying compensation. Potential areas are rated by the relative coverage of large and small holdings. A score of 1 is assigned to areas where more than 70% of the land is aggregated into large plots; 2 to mixed areas where 30-70% consist of large plots; and 3 where less than 30% of the land is in large plots.

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[11] In the floodable Lonjsko polje area (23,706 ha), the maximum flood retention capacity is about 500 million m³, with average water depth of 2.1 m. The actual potential flood depth in many parts of the former floodplain is less than this, which reduces the retention volume. The average assumption for the analysis is 1.7 m.

Prioritisation score

The overall river restoration prioritisation score (1, 2 or 3) assigned to each area is the arithmetic mean of the scores for each parameter:

1 - 1.4 = 1 – very high potential/priority

1.5 - 2.4 = 2 – high potential/priority

2.5 - 3 = 3 – moderate potential/low priority

The assessment makes use of available data supplemented by the data generated for this study and focuses on ecological improvements combined with an increase in flood retention capacity. The score does not take account of the feasibility of restoration at the location in terms of finance, political will, local activities and community/NGO initiatives. The prioritisation given here, however, should be useful in selecting the most promising locations before going on to assess feasibility.

7-2-1 OVERALL FLOODPLAIN RESTORATION POTENTIAL

Figure 97 indicates the distribution of all potential restoration areas combined with the active and morphological floodplain. Table 13 lists all areas with detailed parameters and shows the prioritisation of areas. The total size of all 143 potential restoration areas is 184,289 ha and the approximated retention capacity is estimated with 3.1 billion m³.

For many smaller and medium sized areas the potential is obvious and well documented. Special attention should be given to the southern Bosut-Spačva area, which divides into two main parts. Sremska Raka, an area of about 7,000 ha within RS, scores with the highest priority and is favoured by Serbian water management as potential flood polder. The second large area, Bosut-Spačva south, extends over 22,800 ha mainly in HR but partly also in RS. It has a priority score of 1.5 (and is therefore rated only in class 2, *high*) due to the substantial flood defence to be erected for the villages south of the area.

Remote wet forest areas such as the area to the north of the Bosut-Spačva forests and north of the Obedska Bara Nature Reserve have relatively low retention potential, but should be managed to at least maintain connection and ensure high and oscillating ground water levels.

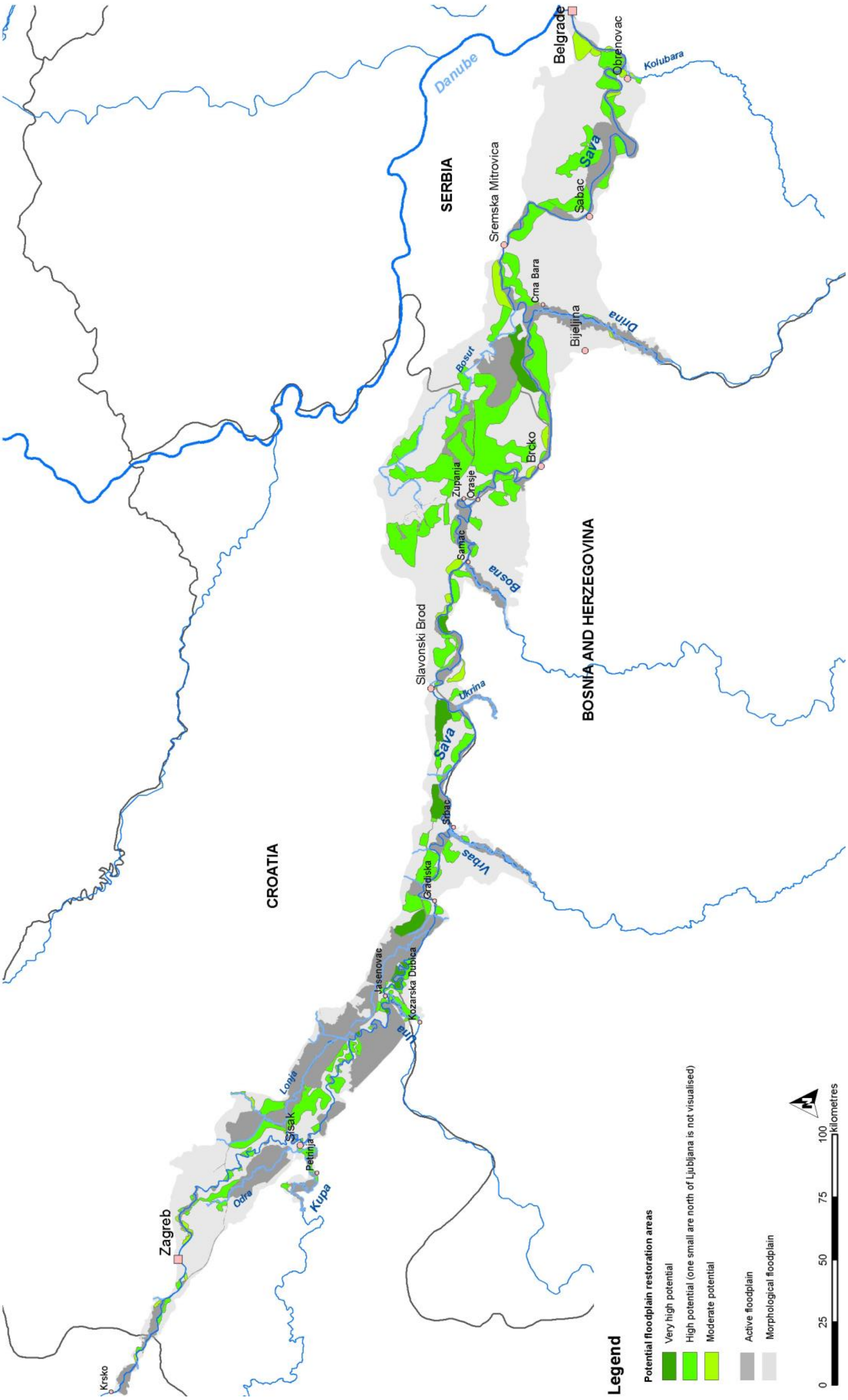


Figure 97: Floodplain areas with potential for restoration and their prioritisation

Table 13: Potential floodplain restoration areas and their scores beginning with Sava (from upper to lower course), followed by tributaries.

River	Country	Name of floodplain area	Size of pot. Flood plain area (ha)	Floodplain restoration potential parameter						Restoration priority score
				Land structure	Hydro-morpho-logical conditions	Reten-tion capacity	Dike relo-cation	Protec-ted area coverage	Land ownership structure	
Sava	SI	Mostec west	107	3	2	3	3	3	3	3
Sava	SI	Mostec east	128	3	2	3	1	2	3	2
Sava	SI	Zalog, upstream Ljubljanica confluence	194	3	3	3	1	1	2	2
Sava	HR	Prnjavor	381	2	2	2	3	3	3	3
Sava	HR	Sikirevici	1,026	3	2	1	3	3	3	3
Sava	HR	Slavonski Šamac	548	2	1	2	1	2	3	2
Sava	HR	Babina Greda	774	3	1	2	1	3	3	2
Sava	HR	Bošnjaci	733	3	1	2	2	3	2	2
Sava	HR	Rajevo Selo	468	3	1	3	2	3	3	3
Sava	HR	Gunja	222	2	1	3	3	3	2	2
Sava	HR	Đurići	937	3	1	2	3	3	3	3
Sava	HR	Jamena	1529	2	1	1	3	3	3	2
Sava	HR	Završćak	204	2	2	3	1	3	3	2
Sava	HR	Strmec	370	2	2	2	3	2	3	2
Sava	HR	Zaprešić	185	3	2	3	1	3	3	3
Sava	HR	Zagreb Jankomir	229	1	3	3	2	3	2	2
Sava	HR	Zagreb Blato	142	1	3	3	3	3	2	3
Sava, Odra canal	HR	Poljana Čička	2,380	2	2	1	3	1	3	2
Sava	HR	Zagreb Savica	279	2	3	3	3	2	3	3
Sava	HR	Mičevec	100	2	3	3	3	3	3	3
Sava	HR	Novaki Ščitarjevski	219	2	2	3	3	3	2	3
Sava	HR	Zagreb upstream water works	45	2	3	3	3	3	2	3
Sava	HR	Ivanja Reka	123	2	2	3	3	3	2	3
Sava	HR	Hrušćica	116	2	1	3	3	1	3	2
Sava	HR	Šćitarjevo	160	1	1	2	3	1	2	2
Sava	HR	Novaki Nartski	95	2	1	3	3	1	2	2
Sava	HR	Strmec Bukevski	87	1	1	3	3	1	1	2
Sava	HR	Veleševec	258	2	1	3	1	1	3	2
Sava	HR	Oborovo	92	3	1	3	1	3	3	2
Sava	HR	Lijeva Luka	260	3	1	3	1	3	3	2
Sava	HR	Lijevo Željezno	225	3	1	2	1	1	3	2
Sava	HR	Palanjek	50	3	1	3	3	3	3	3

River	Country	Name of floodplain area	Size of pot. Flood plain area (ha)	Floodplain restoration potential parameter						Restoration priority score
				Land structure	Hydro-morpho-logical conditions	Reten-tion capacity	Dike relo-cation	Protec-ted area coverage	Land ownership structure	
Sava	HR	Galdovo	47	2	2	3	3	1	3	2
Sava	HR	Topolovac	362	2	1	3	2	1	3	2
Sava	HR	Čigoć	275	2	1	3	2	1	2	2
Sava	HR	Bistrac	107	2	1	3	3	1	2	2
Sava	HR	Kratečko	65	2	1	3	3	1	3	2
Sava	HR	Suvoj	450	1	1	3	3	1	2	2
Sava	HR	Ivanjski Bok	412	3	1	2	3	1	3	2
Sava	HR	Crkveni Bok	518	1	1	2	3	1	2	2
Sava	HR	Trebež	121	2	1	2	1	1	1	1
Sava	HR	Puska	71	1	1	3	3	1	2	2
Sava	HR	Uštica	93	3	1	3	1	1	3	2
Sava	HR	Košutarica	78	1	1	3	1	1	2	2
Sava	HR	Drenov Bok	131	3	1	2	1	1	1	1
Sava	HR	Višnjica	1,634	1	1	1	1	1	2	1
Sava	HR	Mlaka west	957	2	1	1	1	1	2	1
Sava	HR	Mlaka east	201	1	1	2	1	1	1	1
Sava	HR	Gređani	3,114	1	1	1	2	1	2	1
Sava	HR	Pivare	2,125	1	1	1	3	1	2	2
Sava	HR	Stara Gradiška	675	2	2	2	1	1	2	2
Sava	HR	Radinje	2,640	1	1	1	2	1	1	1
Sava	HR	Pričac	223	2	1	3	1	1	2	2
Sava	HR	Slavonski Kobaš west	309	3	1	3	3	1	3	2
Sava	HR	Slavonski Kobaš east	1,982	2	2	2	3	1	2	2
Sava	HR	Zbjeg	418	3	2	3	3	1	2	2
Sava	HR	Kaniža	615	2	1	2	3	1	2	2
Sava	HR	Slavonski Brod south	97	1	2	3	1	3	2	2
Sava	HR	Gornja Bebrina	337	3	1	3	1	1	3	2
Sava	HR	Donja Bebrina	536	3	1	3	1	1	3	2
Sava	HR	Svilaj	303	3	1	3	2	3	3	3
Sava	HR	Ruča	93	2	1	3	3	1	3	2
Sava	HR	Jasenovac west	326	2	1	2	3	1	2	2
Sava	HR	Jasenovac north	258	1	1	2	3	1	1	2
Sava	HR	Drnek	116	1	1	3	2	1	3	2
Sava	HR	Lonjsko polje extension west	2,795	3	1	2	2	3	3	2
Sava	HR	Lonjsko polje extension east	1,945	3	2	2	2	2	2	2
Sava	HR	Veliko Svinjičko	5,765	2	1	1	3	1	1	2

River	Country	Name of floodplain area	Size of pot. Flood plain area (ha)	Floodplain restoration potential parameter						Restoration priority score
				Land structure	Hydro-morpho-logical conditions	Reten-tion capacity	Dike relo-cation	Protec-ted area coverage	Land ownership structure	
Sava	HR	Selišće Sunjsko	1,198	2	1	2	3	1	2	2
Sava	HR	Lonjsko polje extension south	960	2	1	2	3	1	2	2
Sava	HR	Jasenovac east	109	3	1	2	1	1	3	2
Sava	HR	Mačkovac	3,434	1	2	1	3	3	2	2
Sava	HR	Bodovaljci forest	931	2	1	2	3	3	2	2
Sava	HR	Stupnički Kuti fish ponds	1,012	2	2	1	3	1	2	2
Sava	HR	Slavonski Brod west	3,469	1	1	1	3	1	1	1
Sava	HR	Trnjanski Kuti	2,547	2	1	1	3	1	2	2
Sava	HR	Štitar	2,094	2	1	1	3	3	2	2
Sava	HR	Bosut-Spačva north	14,230	2	1	1	3	1	2	2
Sava	HR	Gradište forests	10,623	1	1	1	3	3	1	2
Sava	HR	Vrapčana	3,392	1	2	2	3	3	1	2
Sava	HR/RS	Bosut-Spačva south	22,861	1	1	1	3	1	2	2
Sava	BA	Novi Grad	1,214	2	2	1	3	3	2	2
Sava	BA	Šamac	455	2	1	2	3	3	3	2
Sava	BA	Vučilovac south	1,881	2	1	1	3	3	3	2
Sava	BA	Crnjelovo	6,756	3	1	1	1	1	3	2
Sava	BA	Glavinac	143	2	1	3	2	3	3	2
Sava	BA	Orahova	715	2	1	2	1	3	2	2
Sava	BA	Gradiška	398	3	1	2	3	3	2	2
Sava	BA	Greda	277	2	2	1	3	3	3	2
Sava	BA	Skele	28	3	2	3	2	3	2	3
Sava	BA	Gornji Svilaj	992	2	1	1	1	1	2	1
Sava	BA	Gradina Donja west	321	2	1	2	2	3	2	2
Sava	BA	Bardača	1,628	2	2	1	3	1	2	2
Sava	BA	Sijekovac fish ponds	685	2	1	2	3	3	2	2
Sava	BA	Liješće	1,038	3	2	2	3	3	2	3
Sava	BA	Donji Svilaj	159	2	1	3	2	3	2	2
Sava	BA	Tolisa	814	2	1	2	3	3	3	2
Sava	BA	Vidovice	1,525	2	1	2	3	3	3	2
Sava	BA	Vučilovac east	826	2	1	1	2	3	3	2
Sava/ Bosna	BA	Prud	703	2	1	2	3	3	3	2
Sava	RS	Sremska Rača	6,053	2	1	1	2	1	1	1
Sava	RS	Martinci	3,127	3	2	2	2	3	3	3
Sava	RS	Zasavica	5,136	2	2	2	3	2	3	2

River	Country	Name of floodplain area	Size of pot. Flood plain area (ha)	Floodplain restoration potential parameter						Restoration priority score
				Land structure	Hydro-morpho-logical conditions	Reten-tion capacity	Dike relo-cation	Protec-ted area coverage	Land ownership structure	
Sava	RS	Sremska Mitrovica	3,612	3	1	2	1	3	3	2
Sava	RS	Vitojevci south	1,212	2	2	3	2	1	2	2
Sava	RS	Krtinska	1,308	3	2	2	2	3	2	2
Sava	RS	Kupinovo	1,069	2	2	2	1	1	2	2
Sava	RS	Progar	1,836	2	2	2	1	3	2	2
Sava	RS	Zabrežje	404	3	2	3	1	3	2	2
Sava	RS	Obrenovac	358	2	2	3	3	3	2	3
Sava	RS	Boljevci	2,928	3	2	1	1	3	2	2
Sava	RS	Surčin	3,040	3	3	1	3	3	2	3
Sava	RS	Hrtkovci	796	3	2	3	1	3	2	2
Sava	RS	Platićevo	2,588	2	2	2	3	3	2	2
Sava	RS	Ogar	5,274	2	1	3	3	2	2	2
Sava	RS	Obrež forests	1,188	2	1	3	3	1	2	2
Sava	RS	Provo	1,164	2	1	2	1	3	2	2
Sava	RS	Downstream Umka	123	2	2	3	3	3	2	3
Sava	RS	Coal power plant Obreno-vac	358	3	3	3	3	3	1	3
Sava	RS	Mrđenovac	885	3	1	2	3	3	3	2
Kupa	HR	Sisak	104	3	1	3	1	3	3	2
Kupa	HR	Staro Pračno	667	2	1	2	1	3	2	2
Kupa	HR	Petrinja east	261	2	1	2	2	3	2	2
Kupa	HR	Petrinja west	105	2	1	3	1	3	2	2
Kupa	HR	Letovanić oxbow	315	1	1	2	3	3	2	2
Cesma	HR	Obedišće east	9	1	3	3	3	3	1	2
Cesma	HR	Obedišće south	53	2	3	3	2	3	2	3
Cesma	HR	Vezišće	216	2	3	3	2	3	2	3
Cesma	HR	Okoli	41	3	3	3	2	3	3	3
Cesma	HR	Obedišće west	153	1	3	3	3	3	1	2
Una	BA	Gradina Donja west	121	2	1	3	3	3	2	2
Una	HR	Hrvatska Dubica	213	3	2	2	1	1	3	2
Una	HR	Tanac south-west	92	2	1	3	3	1	3	2
Una	HR/BA	Čuklina	830	3	1	2	1	2	2	2
Vrbas	BA	Crnaja	227	3	1	3	2	3	2	2
Bosut	HR	Spačva northern forest west	2,578	1	1	2	3	1	1	2
Bosut	HR	Spačva northern forest east	1,077	1	1	3	3	1	1	2

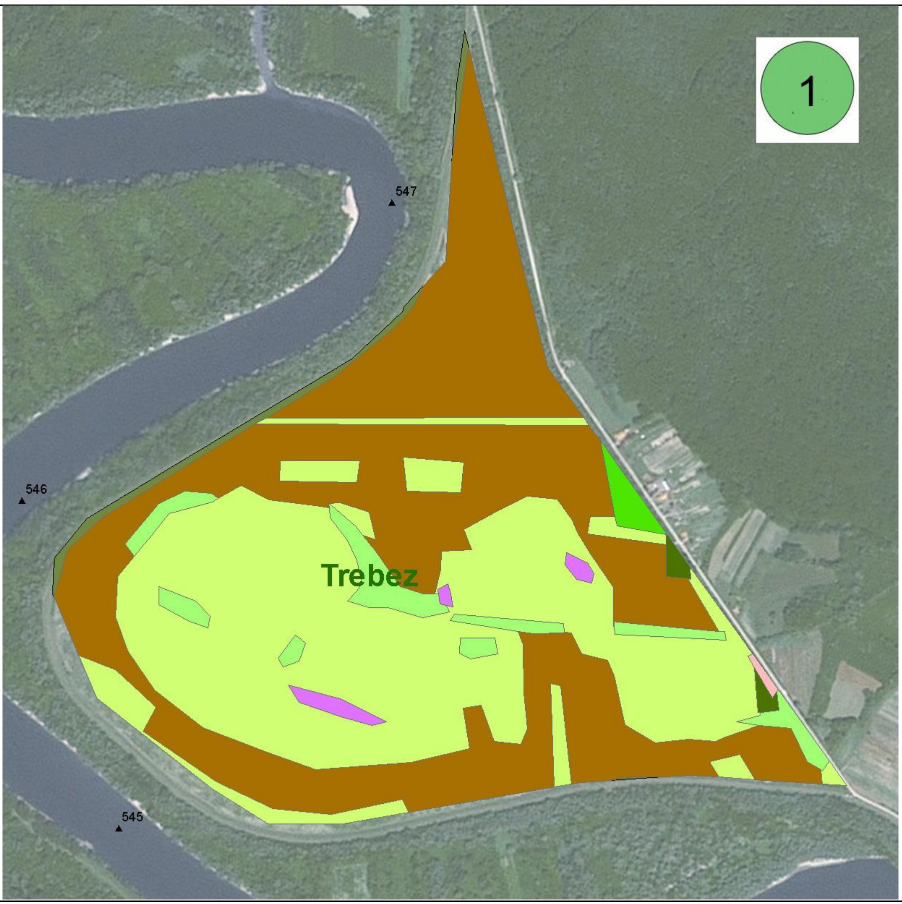
River	Country	Name of floodplain area	Size of pot. Flood plain area (ha)	Floodplain restoration potential parameter						Restoration priority score
				Land structure	Hydro-morpho-logical conditions	Reten-tion capacity	Dike relo-cation	Protec-ted area coverage	Land ownership structure	
Bosut	RS	Višnjićevo	2,374	2	1	2	3	3	2	2
Bosut	RS/HR	Batrovci	1,415	2	1	3	3	3	2	2
Drina	BA	Čardačine	159	3	1	3	2	3	3	3
Drina	RS	Badovinci	178	3	1	3	1	3	3	2
Kolu-bara	RS	Belo Polje	230	2	2	2	3	3	2	2
Kolu-bara	RS	Obrenovac south	110	2	2	3	2	3	3	3

7-2-2 PRIORITISED POTENTIAL FLOODPLAIN RESTORATION AREAS

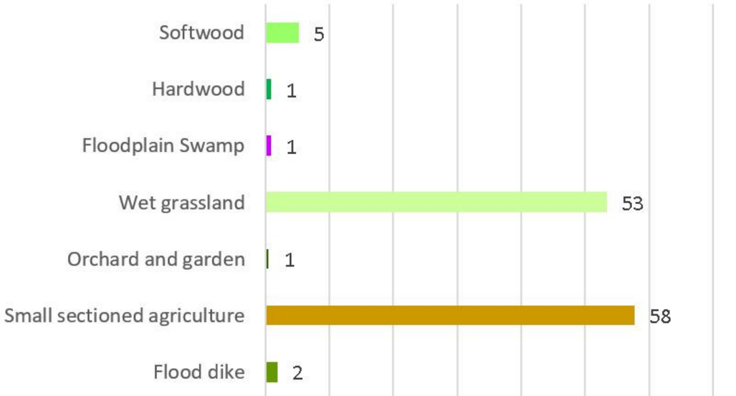
The ten areas in the highest restoration priority class are presented in detail in the following factsheets. Their locations are given by the green dots on the overview map Figure 70 (p. 97) and their extent is limited mostly by dikes.

☐ *Figures 98 and 99: Potential floodplain restoration site n° 1 – "Trebež" (HR), rkm 547–544*

Size: 121 ha



Land structure classification (in ha):



Approximately half of the area is used for agriculture. The rest is covered by wet grasslands, abandoned land and floodplain remnants. The river could easily be reconnected to the active floodplain by opening the dikes at the upstream and downstream ends. The road dike must be maintained to protect settlements.

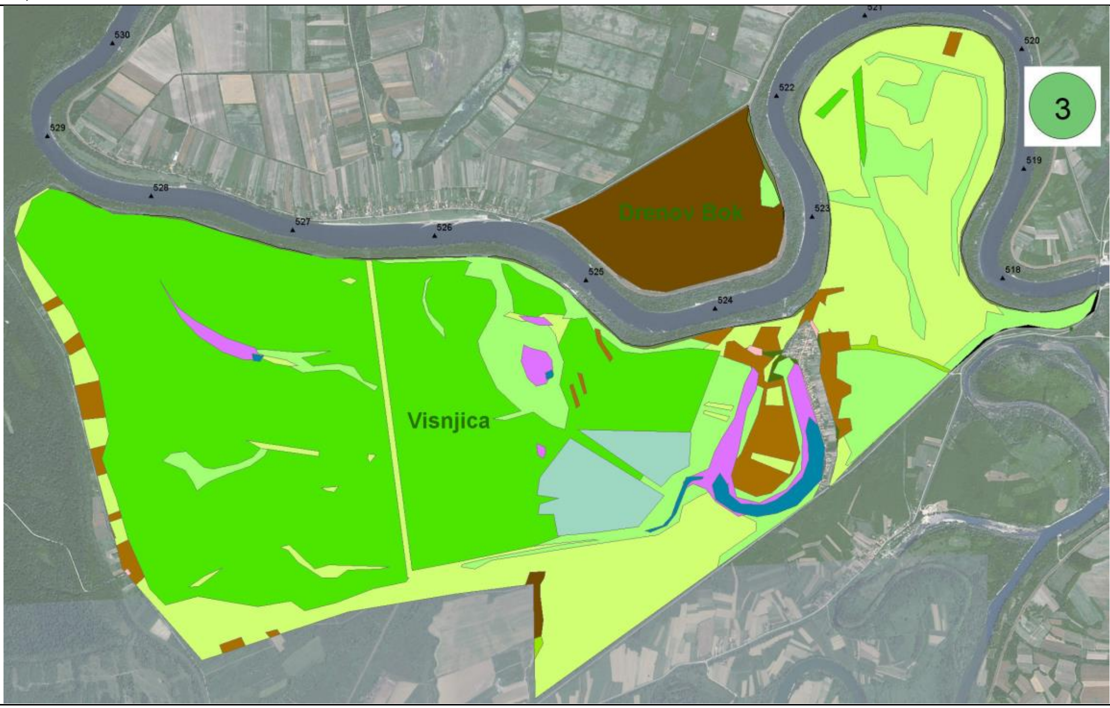
☐ *Figures 100 and 101: Potential floodplain restoration site n° 2 – "Drenov Bok" (HR), rkm 525–522*

Size: 131 ha

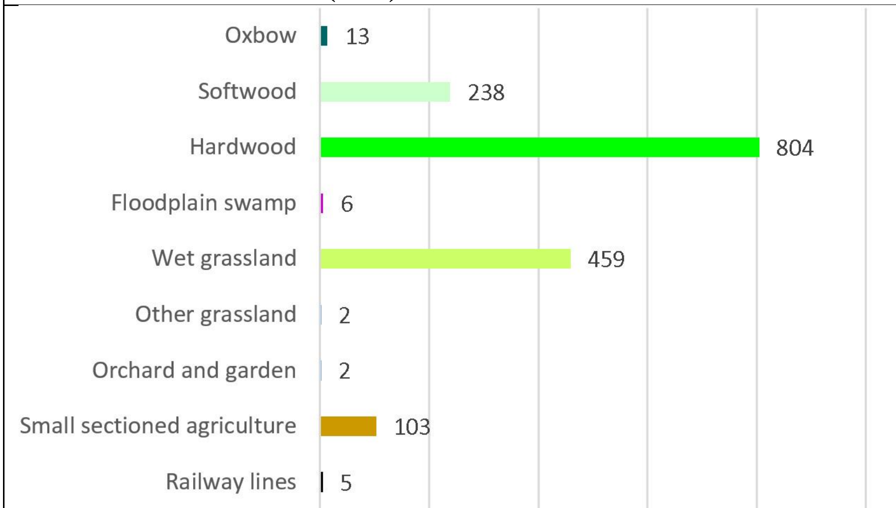
Land structure classification (in ha):

This polder area could easily be reconnected to the active floodplain by opening the dikes at the upstream and downstream ends. The road dike must be maintained to protect settlements.

☐ *Figures 102 and 103: Potential floodplain restoration site n° 3 – " Višnjica" (HR) rkm 529–517*
Size: 1,634 ha



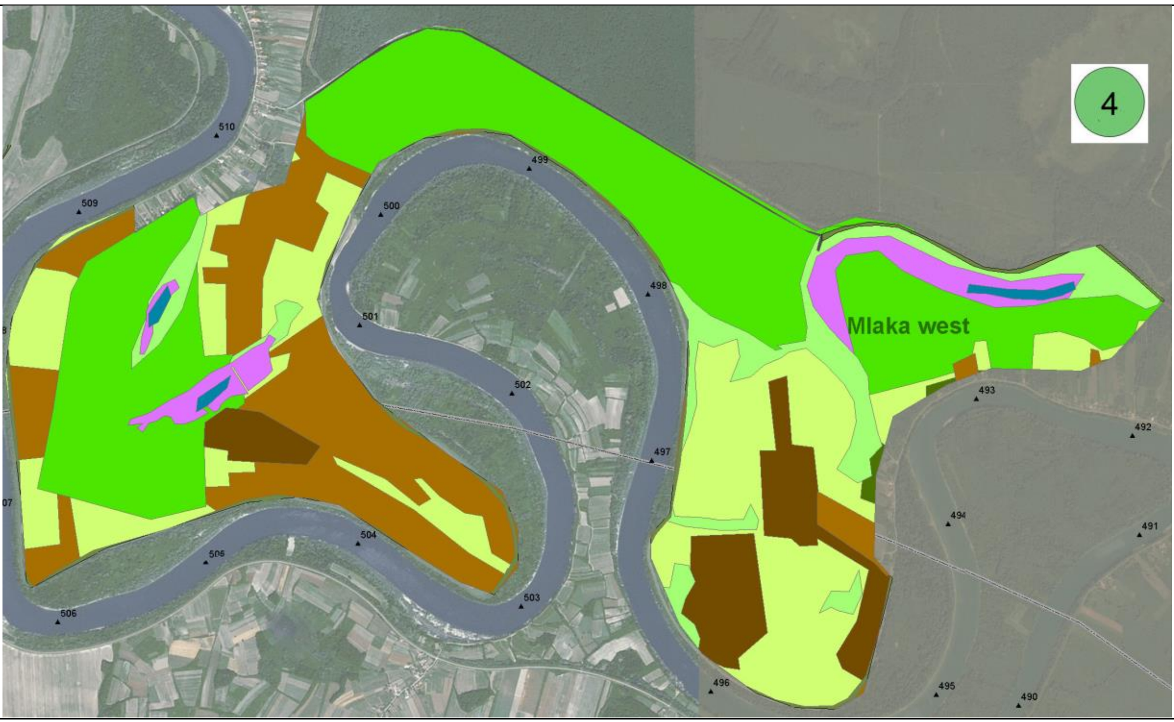
Land structure classification (in ha):



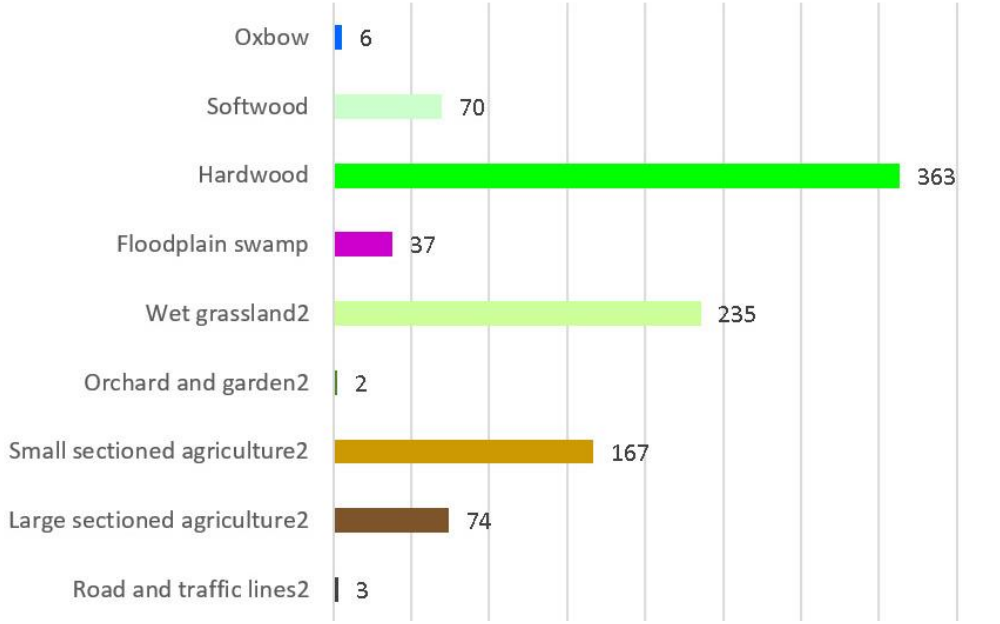
This area is mainly covered by valuable hardwood forests, large wet meadows, an oxbow and abandoned agricultural land in the eastern meander band. If the area is reconnected to the active floodplain, the village of Visnjica must be protected by a ring dike. There is already a railway dike enclosing the area near the Jasenovac/Una confluence.

☐ *Figures 104 and 105: Potential floodplain restoration site n° 4 – "Mlaka west" (HR), rkm 510–492*

Size: 957 ha



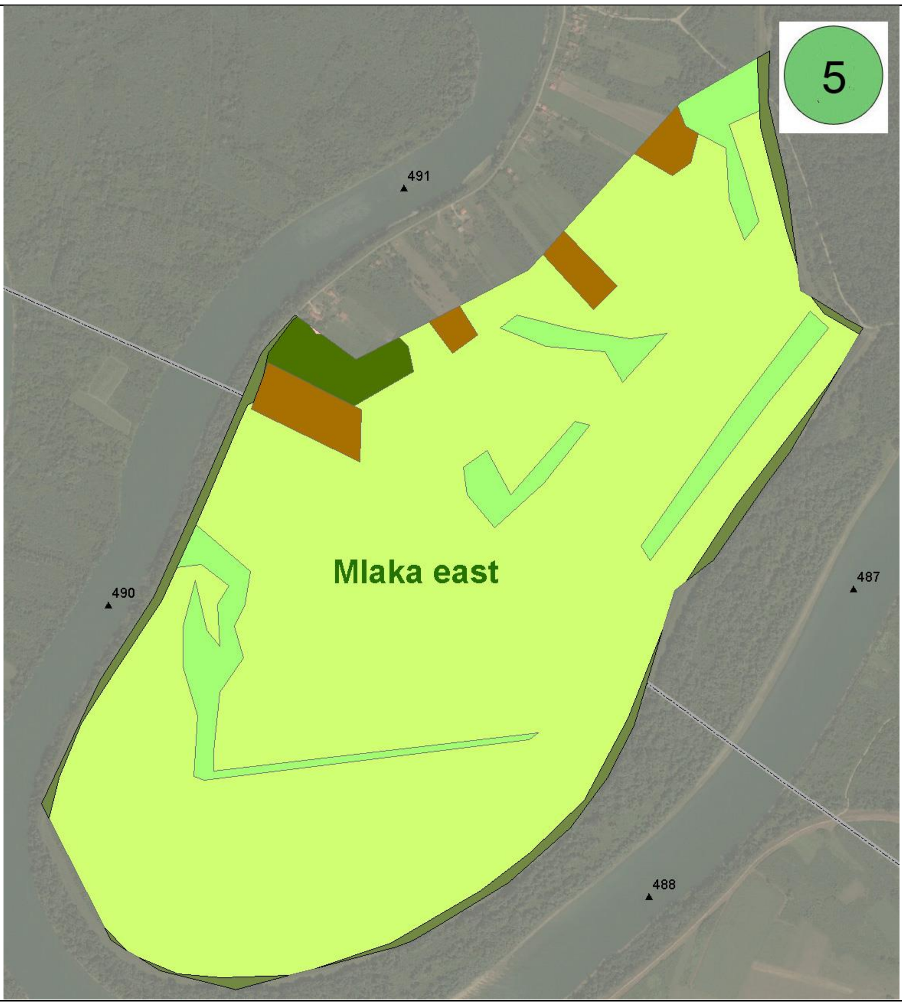
Land structure classification (in ha):



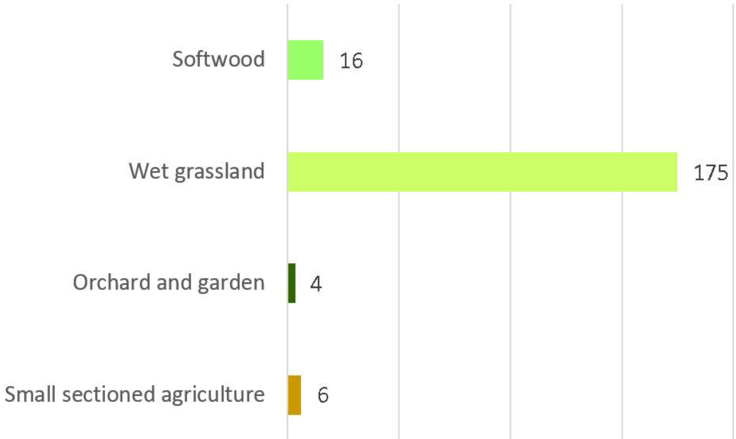
Reconnecting the land between the meander bends to the east of Jasenovac would allow the meanders to develop freely. Large areas are covered by riparian forests, oxbows and wet grasslands.

☐ *Figures 106 and 107: Potential floodplain restoration site n° 5 – ”Mlaka east” (HR) rkm 491–487*

Size: 201 ha



Land structure classification (in ha):

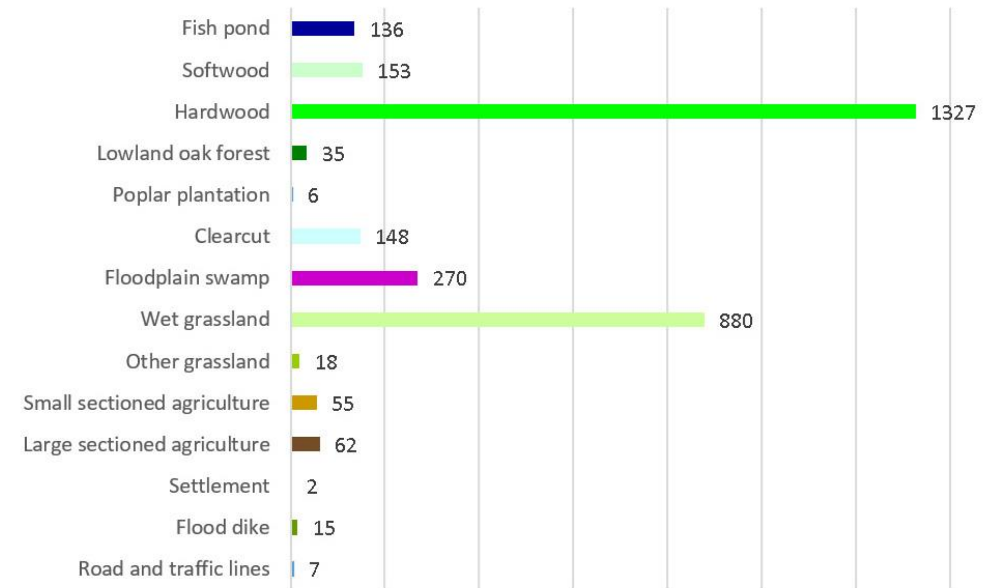


The active floodplain could easily be reconnected by opening the dikes at the upstream and downstream ends. Land structure is dominated by wet grasslands and softwood hedgerows.

☐ *Figures 108 and 109: Potential floodplain restoration site n° 6 – "Građani" (HR), rkm 481–470*

Size: 3,114 ha

Land structure classification (in ha):

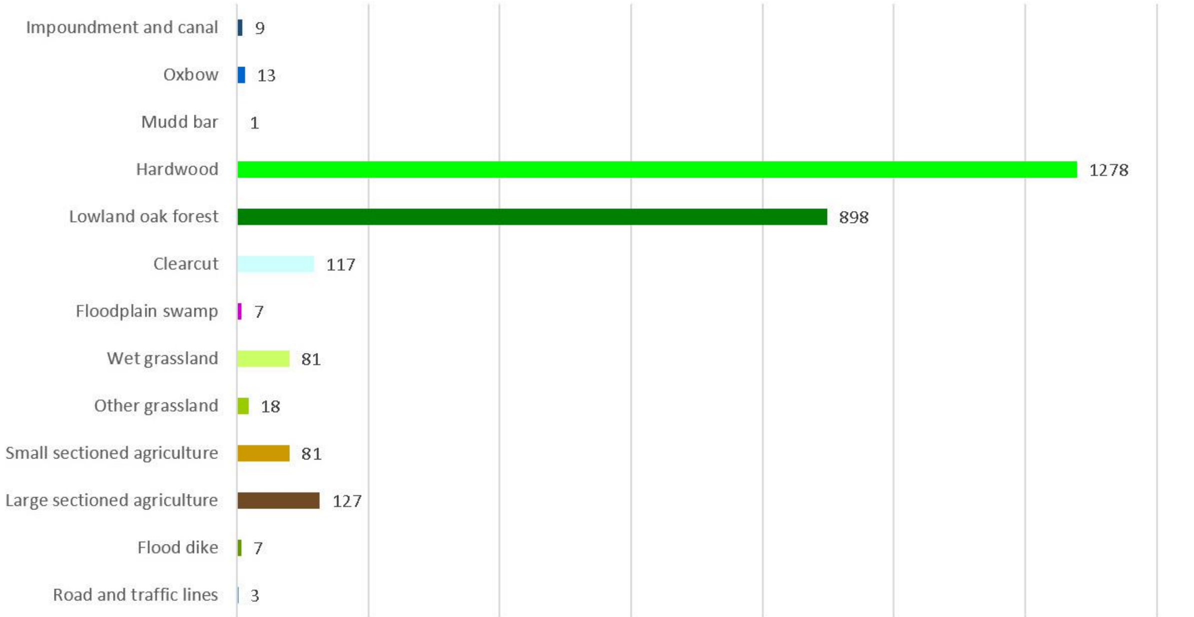


The area is not directly adjacent to the main course of the Sava but the land is suitable for restoration, comprised mainly by abandoned fish ponds, wet grasslands and large hardwood forests. It also has at least 50 million m³ of retention capacity. It would be possible to construct an upstream reconnection channel similar to the polder connections of the Upper Posavina flood system.

☐ *Figures 110 and 111: Potential floodplain restoration site n° 7 – "Radinje" (HR), rkm 408–423*

Size: 2,640 ha

Land structure classification (in ha):

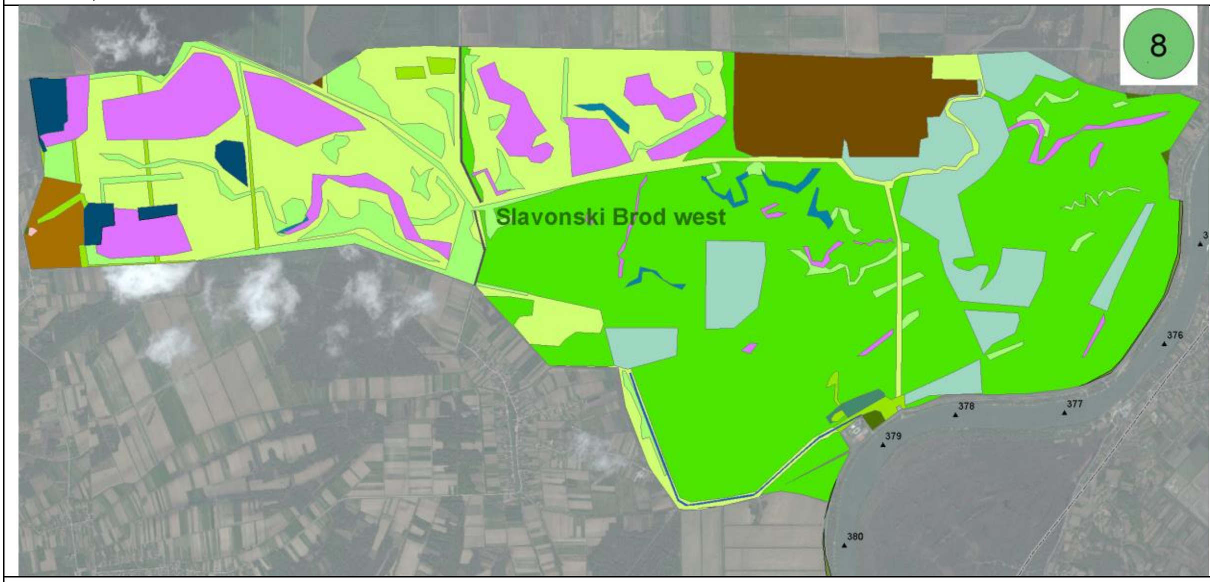


The area includes Jelas polje, a large forestry and hunting area, which forms part of a Natura 2000 site. The hydromorphological classification is *slightly modified*. There are steep banks over a length of about 1 km which permit slow but continuous lateral development. The active floodplain between the river and this area is covered by floodplain forests and pastures. The right river bank is close to the foothills.

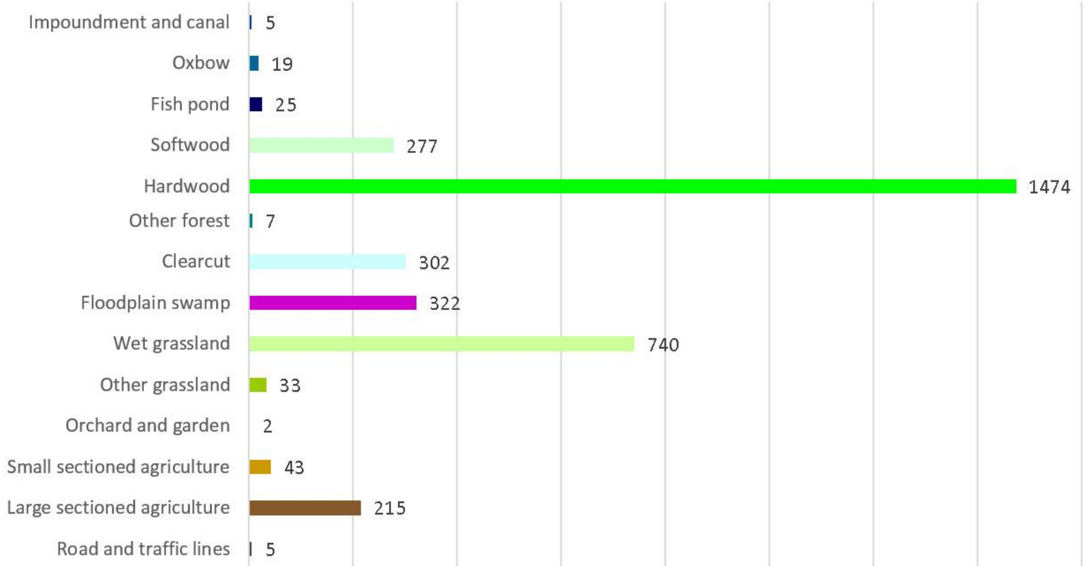
The area is 30 km upstream of Slavonski Brod and provides a retention capacity of 60 million m³. Due to its shape and altitude, the area could be easily reconnected to the active floodplain by dike relocation. The new flood dike would have approximately the same length as the old.

☐ *Figures 112 and 113: Potential floodplain restoration site n° 8 – "Slavonski Brod west" (HR), rkm 380–374*

Size: 3,469 ha



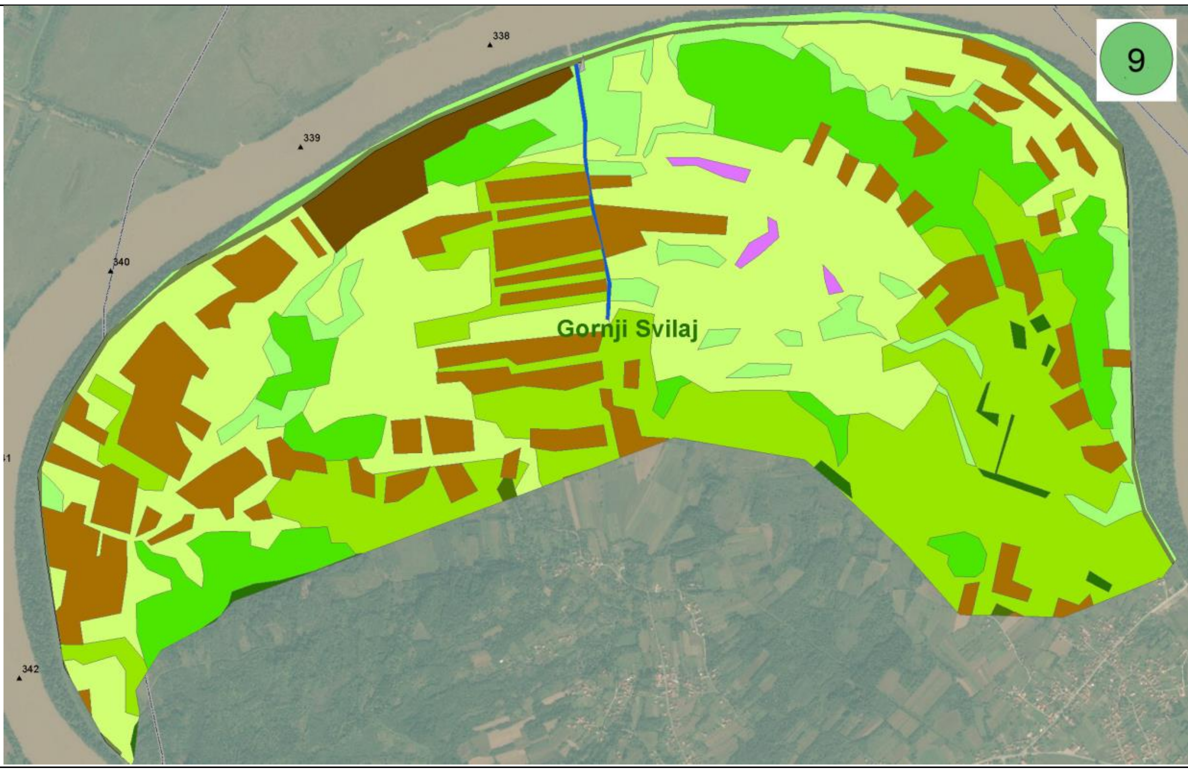
Land structure classification (in ha):



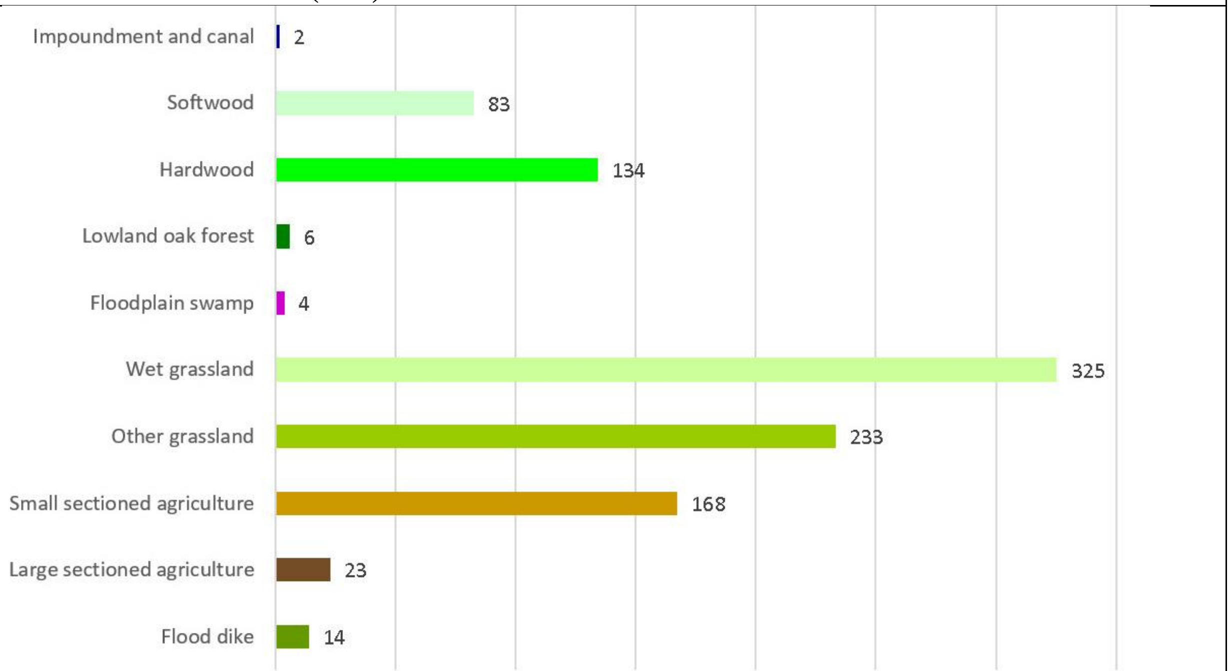
This is the third large area upstream of Slavonski Brod. Although it is connected to the Sava only at the east, it contains typical riparian land types such as large hardwood forests and – in the west – abandoned fish ponds. Theoretically, the area could be part of a polder system, which would increase its priority for ecological potential and flood retention capacity (approximately 80 million m³).

☐ *Figures 114 and 115: Potential floodplain restoration site n° 9 – "Gornji Svilaj" (BA), rkm 342–333*

Size: 992 ha



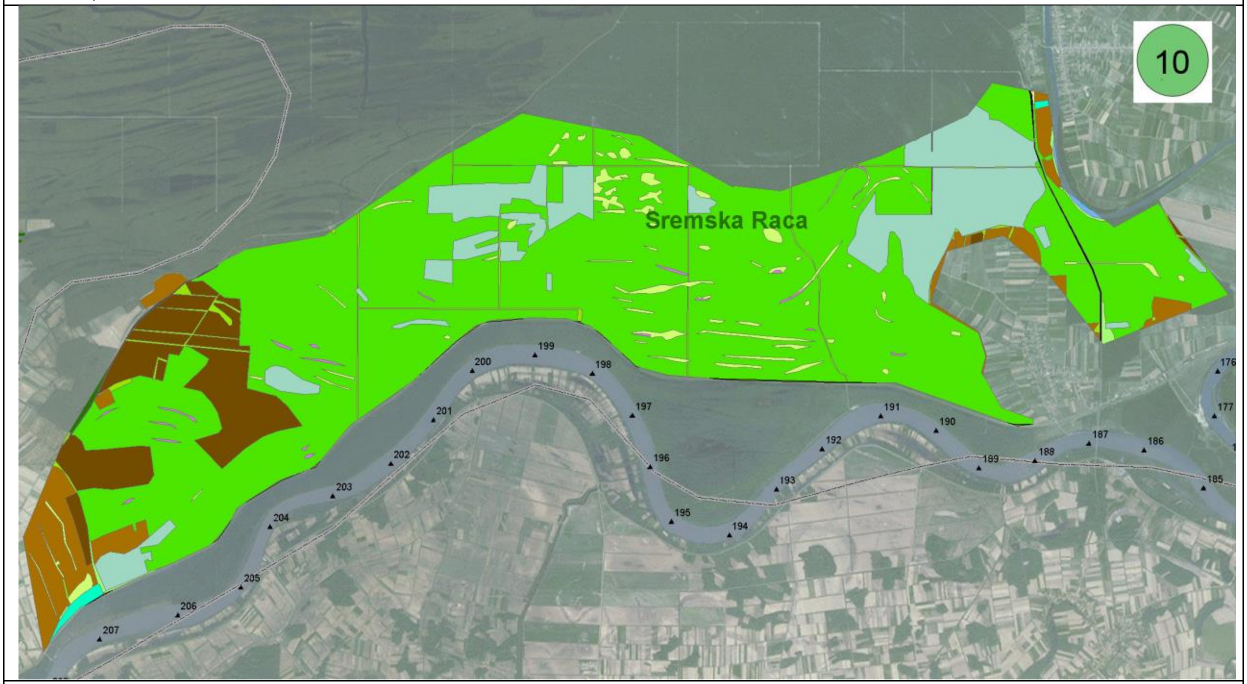
Land structure classification (in ha):



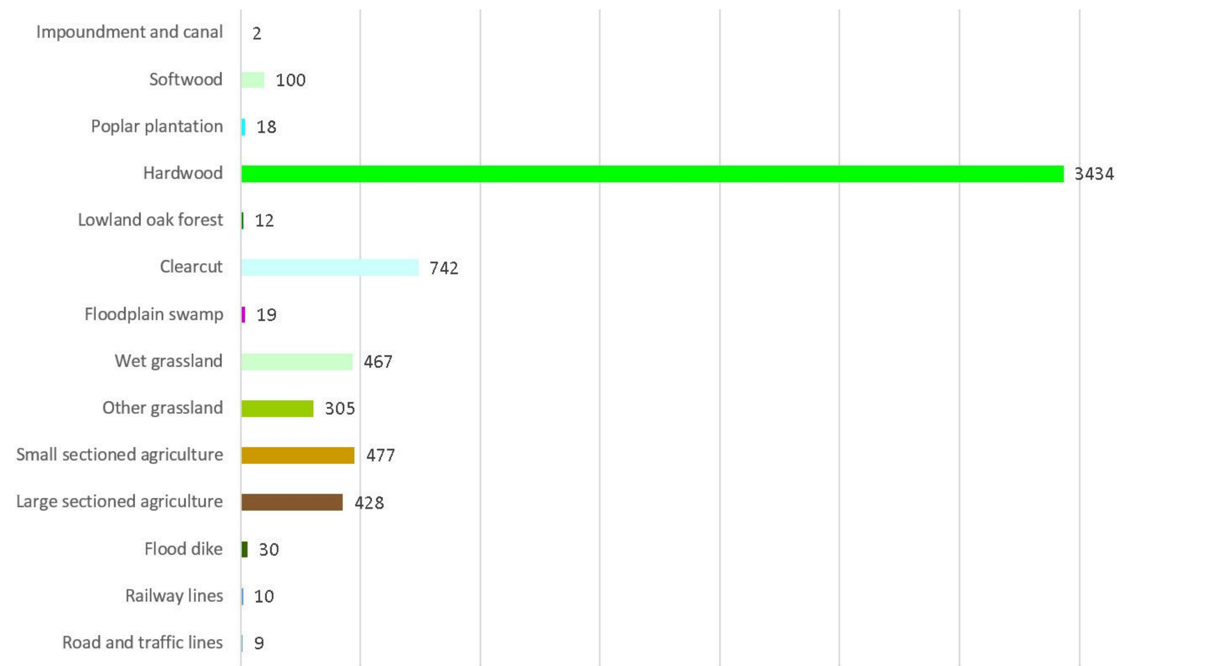
This is a Bosnian polder area, kept flood-free by dikes and pumping stations. Since it contains no settlements, it could easily be reconnected by opening the flood dikes up- and downstream. This would contribute to buffering floods in the Bosna confluence stretch.

☐ *Figures 116 and 117: Potential floodplain restoration site n° 10 – "Sremska Rača" (RS), rkm 207–186*

Size: 6,053 ha



Land structure classification (in ha):



This is by far the largest potential floodplain restoration area. To the north, it borders the central Bosut-Spačva forest, and at present it is partially flooded by the backwater of the Bosut when the Sava weir at the Bosut confluence is closed. There are plans in RS to make this area a flood polder with retention capacity of approximately 130 million m³.

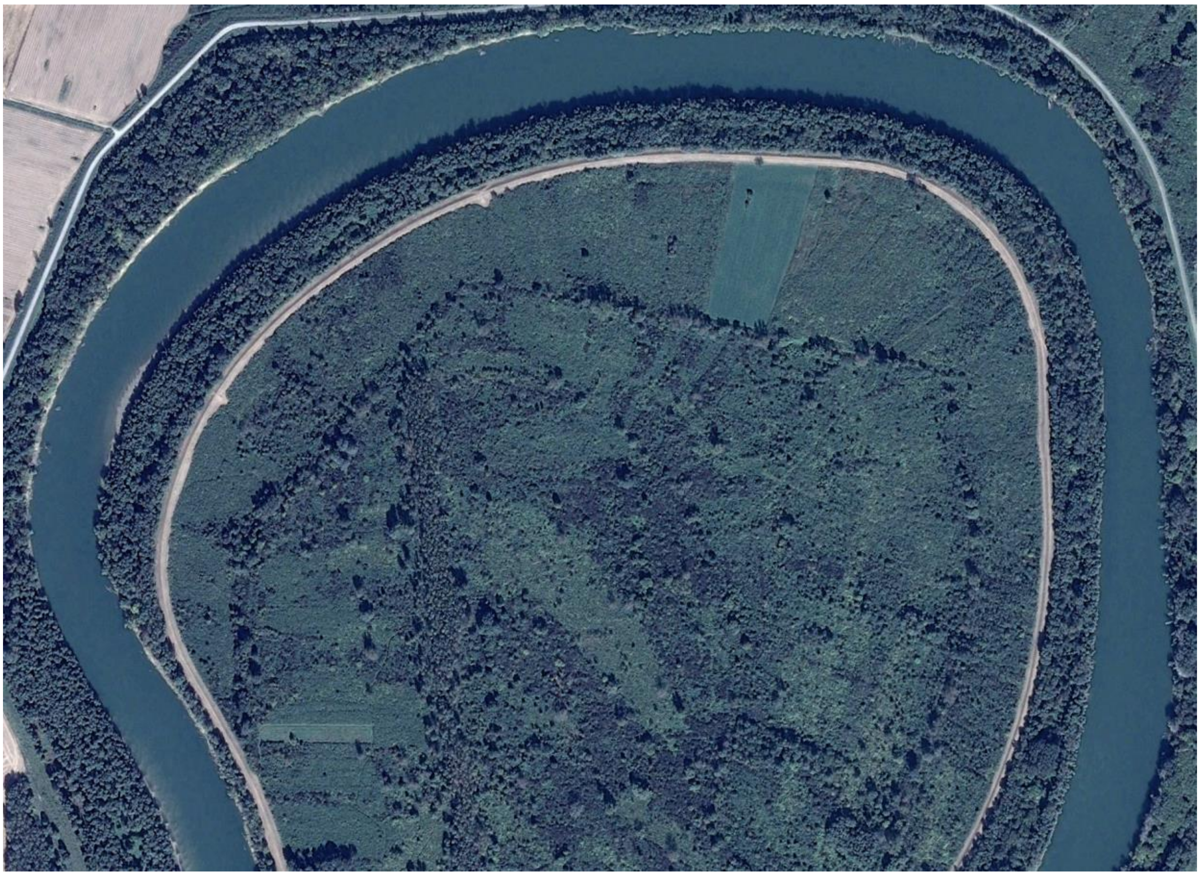
The prioritisation of potential floodplain restoration areas shows the following river stretches and regions as warranting the highest attention in this respect:

1. The Lonjsko polje region, except the areas directly adjacent to river meanders: many smaller areas would enable a lateral shift of the main channel and would allow for the lateral reconnection of the river with the large left and right floodplains. This can be combined and coordinated with flood mitigation management and the filling of polders by existing connections.

2. The areas along strongly regulated and reduced active floodplains between Gradiška and Šamac, including those at the Vrbas and Bosna confluences: flood retention has been a prominent concern along this stretch since the May 2014 flood. Options to allow hinterland flooding as in Lonjsko polje and Odransko polje should be explored and any solution that utilises the storage capacity of these stretches will provide long-lasting and efficient flood mitigation for the entire lower course.

3. The areas attached to the Bosut-Spačva forest area, including the mouth of the Drina: large portions of adapted but disconnected former floodplain are still available in this area and could serve as potential retention areas for the Serbian stretch of the Sava. A large floodable area in the Croatian section also offers considerable local retention capacity, and its reconnection should be considered (similarly to point 2).

4. The areas attached to the Obedska bara near Sremska Mitrovica: extensive areas outside the flood dike south of Mitrovica could provide a continuous retention corridor that includes the Obedska bara area.



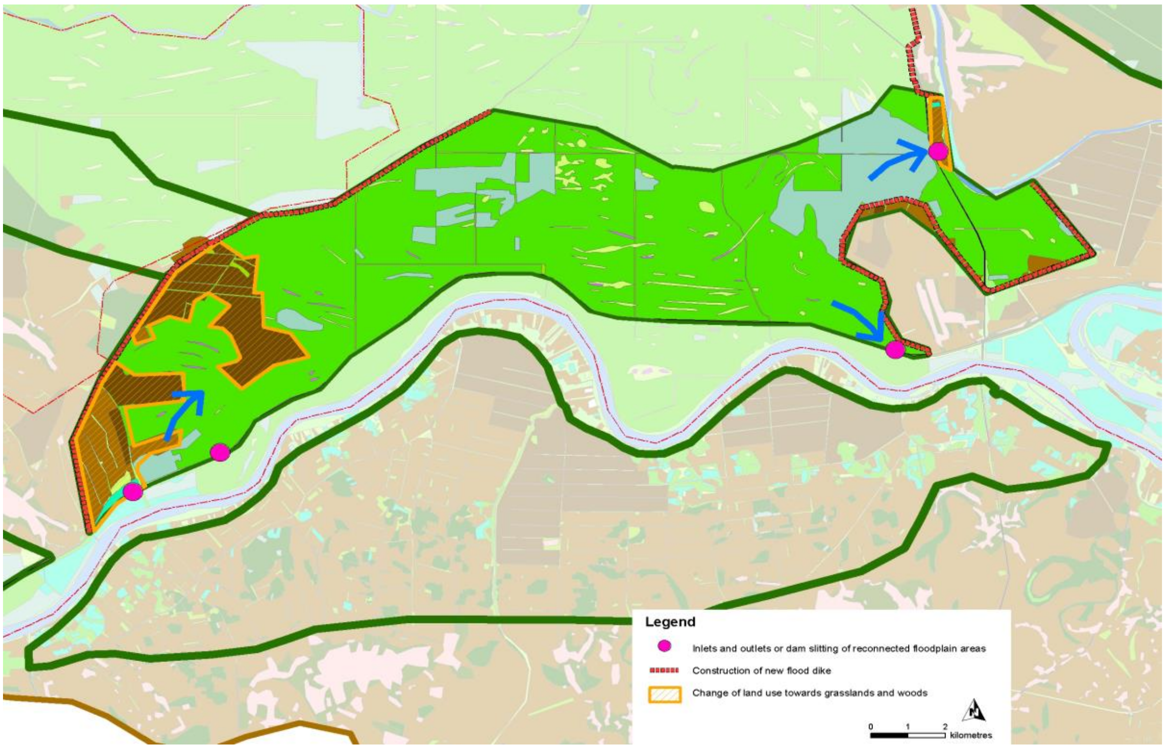
☐ *Figure 118: Floodplain areas disconnected by flood dikes within meander bends provide excellent and cost efficient conditions for reconnection to the river (upstream Jasenovac, HR) [21].*

7-2-3 POTENTIAL FLOODPLAIN RESTORATION PILOT SITES

In addition to the two potential river restoration pilot stretches (Chapter 7-1-3), a third pilot site represents the meandering lower Sava type and a large floodplain restoration area: Sremska Raca (green dot no. 10 in overview map Figure 70).

The proposed area receives one of the highest prioritisation scores and is situated just upstream of the Drina mouth on Serbian territory. The settlements of Sremska Raca and Bosut will remain untouched and profit from a higher level of protection against floods than today. There are several options for implementing flooding, such as slitting the current dike, constructing inlet structures, lowering banks and making permanent connections. New flood dikes are foreseen on the west boundary of the area to protect the settlements. The water would flow back into the Sava via the Bosut confluence.

The area of Semberia lowland between Drina mouth and Sava (i.e. potential restoration site "Novi Grad") on the south bank of Sava (in BA) only reaches restoration priority score 2 (high) due to the intensive agricultural usage of the area. Since the entire area was flooded in 2014, however, it should be part of a wider, transboundary planning process.



☐ *Figure 119: Potential floodplain restoration site "Sremska Rača" (green dot no. 10 in overview map Figure 70). The blue arrows indicate the flow direction. The Bosut is in the right upper corner.*

.Conclusions

- 41 river stretches, with a total length of 251 km are proposed for river restoration.
- 143 restoration areas with a total size of 184,289 ha have been proposed.
- These areas would add a retention capacity of 3.1 billion m³ which is about double the capacity of the near-natural Upper Posavina flood retention system.
- The highest restoration priority was assigned to 15 river stretches and 10 floodplain areas.
- These restoration projects would lead to significant improvement of ecological value, reduce the flood risk and be in line with EU legislation.

8 RECOMMENDATIONS

(1) The Sava White Book underlines the ecological importance of the entire Sava river basin. The huge floodplain forests and regular flooded grasslands are rare among European rivers of comparable size. **Floodplain forests and flooded grasslands together with the dynamic river systems deserve the highest possible protection and guaranteed preservation.**

(2) The evaluation of hydromorphological conditions in this study differs substantially from the findings of the official Sava River Basin Management Plan of the Sava Commission, particularly relating to preliminary designation of Heavily Modified Water Bodies (HMWB). The Sava White Book does not support the Management Plan in designating the entire lower and middle Sava and the southern tributaries as HMWB. **A critical revision of the official hydromorphological status of these rivers is needed.**

(3) Almost the entire river basin is threatened by hydropower developments, navigation plans and gravel excavation projects. It is alarming that neither the existence of highly endangered species nor the status of protected areas seems to pose any limit to the planning of activities causing serious ecological impairments. **The development of protection concepts for free-flowing stretches and catchments is urgently required; so is a reconsideration of the general strategy to maximise energy production by hydropower development.**

(4) Although the overall status of the Sava is good in comparison to other European rivers, many stretches have been strongly (12%) or moderately (31%) regulated and about 77% of former floodplains have been detached from the river. There is a need for a major restoration initiative [51] to improve the ecological quality of the river, boost natural flood prevention and fulfil the requirements of the WFD and the FD. **The White Book lists 41 river stretches totalling 251 km and 143 floodplain sites with a total area of 184,289 ha as having potential for restoration implementation.**

(5) The environmental impact expected from new hydropower plants and navigation developments – even if only a fraction of the plans are realised – will severely diminish or even endanger many protected areas, habitats, and species. **National environmental laws must be strengthened and stakeholders must have the opportunity to appeal decisions.**

(6) Massive sediment excavation is a big problem for the Sava and its tributaries. Furthermore, trapping of sediments in hydropower impoundments increases the sediment deficit. Sediment management is needed to successfully stabilise or stop river incisions. As a starting point, further extraction from the river system has to be stopped. In principle, dredged material has to be fed back to the river. **Sediment excavation from the Sava and its tributaries (especially Vrbas and Drina) must be stopped and a modern sediment management plan deployed.**

(7) In light of the 2014 flood event, there is a need for a new flood prevention strategy that relies much more on natural prevention and retention. The flood protection system of the Upper Posavina is a unique positive example of near-natural conditions that can serve as a blueprint for other river stretches. Any hydrological flood propagation modelling of the 2014 flood event must give special attention to natural flood retention. The analysis must include areas where flood retention can be restored as part of the river system, as identified in this study. **Revised national spatial plans that define limitations on spatial planning with a view to infrastructural and urban developments in areas exposed to floods are urgently required. The inclusion of potential restoration areas in national spatial plans is recommended.**

(8) The Sava river basin would greatly profit from a transboundary restoration master plan for river basin management. This will require the strengthening of international cooperation. The Transboundary Biosphere Reserve Mura-Drava-Danube [52] provides a good example and is mentioned as such in

paragraph 8.1.4.2 of the final Danube River Basin District Management Plan. **Recent LIFE projects along the Drava in Hungary and HR are further good examples of how restoration measures can be funded.**

(9) The currently limited navigation potential on the Sava should not be developed beyond class III. It would require construction of ground sills, correction of several meanders and fixation of the channels by riprap and groynes, all of which would have serious impacts on the entire riparian ecosystem. **The construction of the Danube-Sava canal seems economically unfeasible given all of the other available transport options, and the canal would impair valuable lowland forests.**

(10) The Sava White Book delivers important background data that can be put to use in a powerful new method known as "economic analysis for ecosystem service assessment". This can serve as sound basis for much more accurate cost-benefit analyses when it comes to drawing up future orientated policy and decisions for the Sava river corridor. **Such an analysis of ecosystem services could clearly demonstrate the positive outcome of floodplain restoration, in particular for larger projects [53].**

(11) The Sava White Book presents a vast amount of data and its analysis has exposed shortcomings in the existing scientific basis for decision-making. **Further investigation to support restoration decision processes is required** in the following areas: riparian vegetation in tributaries, functioning of benthos communities, distribution/inventory of birds, long-term changes in forests and grasslands. Also required is an application of standardised hydromorphological assessment considering both river banks separately as well as in situ measurements of dynamic processes.

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10 MAP ANNEX

The Map Annex to this study is provided in an additional document titled „Sava White Book – Map Annex“

TABLE OF FIGURES

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