

Study of Freshwater Ecosystem Services in Croatia



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IMPLEMENTATION FRAMEWORK

The project National Biodiversity Planning to Support the Implementation of the CBD 2011-2020 Strategic Plan in Croatia is being implemented over a period of two years (from 1 July 2012 to 31 December 2014). The Ministry of Environmental and Nature Protection, Nature Protection Directorate (MENP) is the government institution responsible for the implementation of the project and will act as the *Executing Agency*. The main implementing partner of the Ministry is the State Institute for Nature Protection (SINP), which is the central institution carrying out expert tasks of nature protection in Croatia.

UNDP is involved as the *GEF Agency* for the project, and it is accountable to the GEF for the use of funds. The project is nationally implemented (NIM).

The project National Biodiversity Planning to Support the Implementation of the CBD 2011-2020 Strategic Plan in Croatia builds on the current status and achievements of Croatia with respect to its obligations vis-à-vis the Convention on Biological Diversity (CBD), in particular the country's biodiversity planning and Convention reporting processes, and its commitment to implement, at the national level, the CBD's Strategic Plan for the period 2011-2020. The concept of ecosystem services that is directly connected to the Aichi Targets 14 and 15 of CBD, as well as the EU 2020 Biodiversity Strategy, are still quite new for Croatia. Since 2013, three projects in Croatia were dealing with the economic valuation of biodiversity, where ecosystem services were used as a tool for sustainable management of nature protected areas (in Nature Park Vransko jezero and Nature Park Velebit), or for sustainable rural development. However, the concepts of "non-market forest functions" have been used in the forestry sector from the 1990s, as concepts in which the ecological and social benefits of the forest ecosystem were recognized and used in order to ensure sustainable forestry management. This topic has also been indirectly integrated in NBSAP 2008, within the chapters dedicated to the protection of biodiversity and sustainable use of natural resources (strategic objectives and action plans for cooperation with the sectors of agriculture, forestry, hunting, fishing, water management and tourism).

The Study for Freshwater Ecosystem Services (SFES), as a component of the project National Biodiversity Planning to Support the Implementation of the CBD 2011-2020 Strategic Plan in Croatia, constitutes the first institutional initiative related to the assessment of biodiversity values and economic valuation of ecosystem services. It should provide arguments for the protection of freshwater ecosystems, based not only on their biodiversity, but also on other benefits that such ecosystems provide for human society or for the stability of the global ecosystem. These benefits should also be evaluated from the perspective of the economy.

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LIST OF ACRONYMS

CBD – Convention on Biological Diversity
CICES - Common International Classification of Ecosystem Services
DSDF – Drava, Sava and Danube Floodplains
ES – Ecosystem services
GEF – Global Environment Facility
HEP – Hrvatska elektroprivreda d.o.o.
HEPP – Hydroelectric Power Plant
MAES – Mapping and Assessment of Ecosystems and their Services
MAB – Man and Biosphere Reserve
MENP – Ministry of Environmental and Nature Protection
MHS – Multipurpose Hydropower System Osijek
NBSAP – National Biodiversity Strategy and Action Plan
NIM – Nationally implemented
PAHPP North – Production Area Hydropower Plants North
PSA – Pilot Study Area
rkm – River kilometre
SEE River –
SFES – Study of Freshwater Ecosystem Services
SINP – State Institute for Nature Protection
TEEB – The Economics of Ecosystems and Biodiversity
TN – Total nitrogen
TP – Total phosphorus
UNESCO – The United Nations Organization for Education, Science and Culture
UNDP – United Nations Development Programme
VHS Osijek – Višenamjenski hidroenergetski sustav Osijek
WFD – Water Framework Directive
WMS – Web Map Server

1. Introduction

1.1. Concept of ecosystem services in ecosystem evaluation

Increasing damage and devastation of natural ecosystems and the consequential loss of their functions, perceived as a disbalance of natural processes – e.g. the hydrological cycle or nutrient cycles and loss of their productivity – has led to increased awareness of the benefits that ecosystems provide to people. Since the Millennium Ecosystem Assessment (MA, 2005), awareness of the natural capital and efforts to sustain it grew exponentially. The question of economic feasibility of destroying an ecosystem in order to realise a development project has become increasingly insistent.

Declining natural capital poses a direct threat to poor rural communities in developing countries, which directly depend on natural sources. But, ultimately, all humankind depends on nature; therefore, the sustainable use of nature's sources is a question of survival. Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them, sustain and fulfil human life (Daily, 1997). The concept of ecosystem services (ES) has been developed to help evaluate the natural benefits, and to strengthen the arguments for preserving the vanishing ecosystems that we depend upon. After spending a long time to fence off nature from people, conservation has a new vision that emphasises the importance of connecting nature and people (Everard, 2012). The economic perspective, which the ecosystem service concept has brought into the nature protection effort, may serve as a novel argument standing alongside the traditionally perceived values, such as, for instance, the intrinsic value of biodiversity. Such an evaluation becomes increasingly important in the decision-making processes related to development projects with a remarkable impact on ecosystems, or to resource or land use management, optimising the benefits of the ecosystem.

ES evaluations often remain incomplete due to the fact that various services require different methodological approaches (Turner et al., 2008). Moreover, value is often not fully captured in monetary terms, since many evaluations of services are based on non-marketable products. Also, the quantification of processes and products, important for ES evaluation, is often laborious and costly; however, without those evaluations, ecosystem services are invariably undervalued or not valued at all – by governments, businesses, and the public (TEEB, 2010). Promoters of development projects would prepare their own evaluations of project benefits, which can quite easily overlook the value of a lost or damaged ecosystem – simply because its ecosystem services have not been evaluated.

The ecosystem service agenda is an integral part of the European strategy to maintain and protect biodiversity. Pursuant to the EU Biodiversity Strategy to 2020 (Action 5), Member States are obliged to map and assess the state of ecosystems and their services on their national territories by 2014. The assessment of economic values of these services, and promotion of the integration of these values into accounting and reporting systems at the EU and national level, should be completed by 2020. The Mapping and Assessment of Ecosystems and their Services (MAES) report includes indicators that can be used at the European and Member State level in order to map and assess biodiversity, ecosystem condition and ecosystem services, according to the Common International

Classification of Ecosystem Services (CICES v4.3). The completion of this task should consequently improve the knowledge about ecosystems and their services in the EU. One of the essential objectives of Action 5 and the MAES conceptual framework is to support the analysis of preserving the biodiversity benefits and maintaining or bringing ecosystems into a healthy condition for human well-being. These activities both advance the biodiversity objectives and integrate related policies, i.e. on water, climate, agriculture, forest, and regional planning, into the strategy of wise use of ecosystems.

1.2. Values of floodplain ecosystems

River floodplains are frequently analyzed for their multivariate values, functions and benefits. Haslam (2008), for instance, provides an extensive list of lower riverscape values, where numerous landscape, hydrological, chemical, biological, economic and social values are listed. As sites that can potentially mitigate extreme events in the hydrological cycle, floodplains are becoming increasingly important in connection with global climatic change.

The classification of ecosystem services has not been unified yet. Within this study, we will therefore define each ES that will be evaluated, in order to avoid misunderstanding, given the fact some alternative names of ecosystem services do not overlap entirely. Using the list of ecosystem services from the TEEB study (2010), floodplains are important for the following ecosystem services:

- Provisioning services – fresh water provision, wood production, agricultural production;
- Regulating services – moderation of extreme events (flood protection namely), waste water treatment (some authors also refer to this ES as water self-purification or nutrient retention);
- Supporting services – habitat provision;
- Cultural services – tourism.

If floodplains are compared to other ecosystems (Costanza et al., 1989), their overall ecosystem services, expressed as monetary flow per hectare per year, are among the highest (Table 1). Costanza perceived floodplains with their average flow as the second most valuable type of ecosystem, providing ecosystem services in the value of 19,580 USD.ha⁻¹.yr⁻¹. According to his estimate, two very highly ranked ecosystem services contribute the most – water supply (7,600 USD.ha⁻¹.yr⁻¹) and disturbance regulation (7,240 USD.ha⁻¹.yr⁻¹). Given the fact that floodplain ecosystems are also very productive due to the constant supply of river water, provisioning services are also important.

Table 1: Main Ecosystem services of world biomes, expressed as financial flow per ha per year.(Costanza et al., 1989, Nature 387.)

Biome	Area (ha × 10 ⁶)	1 Gas regulation	2 Climate regulation	3 Disturbance regulation	4 Water regulation	5 Water supply	6 Erosion control	7 Soil formation	8 Nutrient cycling	9 Waste treatment	10 Pollination	11 Biological control	12 Habitat/ refugia	13 Food production	14 Raw materials	15 Genetic resources	16 Recreation	17 Cultural	Total value per ha (\$ ha ⁻¹ yr ⁻¹)
Marine	36,302																		577
Open ocean	33,200	38							118			5		15	0			76	252
Coastal	3,102			88					3,677			38	8	93	4		82	62	4,052
Estuaries	180			567					21,100			78	131	521	25		381	29	22,832
Seagrass/ algae beds	200								19,002						2				19,004
Coral reefs	62			2,750						58		5	7	220	27		3,008	1	6,075
Shelf	2,660								1,431			39		68	2			70	1,610
Terrestrial	15,323																		804
Forest	4,855		141	2	2	3	86	10	361	87		2		43	138	16	66	2	969
Tropical	1,900		223	5	6	8	245	10	922	87				32	315	41	112	2	2,007
Temperate/boreal	2,955		88		0			10		87		4		60	25		36	2	302
Grass/rangelands	3,898	7	0		3		29	1		87	25	23		67		0	2		232
Wetlands	330	133		4,539	15	3,800				4,177			304	256	106		574	881	14,785
Tidal marsh/ mangroves	165			1,839						6,696			189	466	162		658		9,990
Swamps/ floodplains	165	265		7,240	30	7,600				1,659			439	47	49		491	1,761	19,580
Lakes/rivers	200				5,445	2,117				665				41			230		8,498
Desert	1,925																		

However, most regulating ecosystem services depend on the ecological state of the floodplain, namely on the extent of natural water pulses – i.e. flooding (Table 1). The river regulation and the loss of connectivity between the river and its floodplain have a negative impact on habitat provision, flood mitigation and water self-purification. Deepening of the river bed and decrease of the water level result in drainage of underground waters, which has adverse effects on drinking water provision and wood and grass production.

River floodplains have been settled as priority localities since ancient times. The rivers represented natural routes and ensured suitable transport conditions, and floods provided nutrient input while increasing the fertility of soils. For this reason, the harmonization of natural processes and human activities has always been a challenge, and history gives us many excellent examples of successful projects of that kind, such as the floodplain management in ancient Egypt. During the last two centuries, most European large floodplains (for instance Rhine, Odra or Loire) have been substantially altered in order to provide agricultural land protected against floods, transport routes and hydroelectricity. This transformation would always follow the same scenario: cutting meanders in order to shorten the river; bank embankments; building dykes to decrease the extent of floods; intensification of agriculture and introduction of settlements, with the loss of flood memory.

With increased knowledge of ecological processes and threats stemming from climate change, people started to reconsider the floodplain transformations and to look for more balanced and harmonised approaches to floodplain management, which would also take into account a number of floodplain functions and services that are now scarce – for instance, water self-purification and the removal of contaminants (Lair et al., 2009); mitigation of climatic extremes (Habersack et al., 2013; Pithart et al., 2010 and 2013); or providing refuge for biodiversity. In general, the role of European wetlands is being reconsidered, often with connection to threats of global climate change (Čížková et al., 2013).

1.3. Background reasons for the ecosystem services study

The background reason for the preparation of this study is a growing awareness of Croatian (floodplain) ecosystems' values, and the need to gain relevant information about them and their importance for the quality of life in this area, and, consequently, their economic importance. Croatian floodplains, same as floodplains in general, have always been a target of a variety of human activities, such as settlement, agriculture, transport or energy production. On the other hand, their potential to provide drinking water, flood protection, habitats for endangered species, hardwood timber, fish and game should be considered as well. In possible future decision processes, information about these values should be at disposal, and should be taken into account.

The aims of the study and its scope are as follows:

- Describe floodplain ecosystems in the Drava, Sava and Danube basin; asses their state and relevant trends
- Identify main threats to these ecosystems
- Identify main ecosystem services which they provide

- Develop alternative scenarios of future development in the selected pilot study area (PSA)
- Evaluate ecosystem services for alternative scenarios in the PSA, together with the evaluation of selected ecosystem services in the entirety of the Drava, Sava and Danube basin floodplains
- Identify governance environment and incentives in connection with economic activities that impact upon biodiversity
- Prepare a set of key messages to decision makers, backed up by credible data from the results of the analysis

2. Character, values and threats of Drava, Sava and Danube floodplains (DSDF)

2.1. Floodplain ecosystems of the Drava, Sava and Danube basin

The rivers Sava, Drava and Danube and their floodplains in Croatia (Figure 1) represent a large, relatively ecologically preserved and interconnected complex of riverine and alluvial ecosystems in the European context (Schneider-Jakobi, 2004). These rivers and their floodplains remained relatively close to their natural state, unlike other large Danube tributaries such as Tisza, Váh, Morava and other rivers, or other parts of the Danube River (for instance in Austria or Slovakia).

River beds of DSDF have undergone partial shortenings (cutting-off of meanders) and fortifications, but, apart from the Sava River in the Zagreb area, they have never been canalised to a large extent. Some 15% of the Drava River in Croatia has been fortified (based on an unpublished analysis by SINP). River beds still kept part of their dynamics, such as meandering, creating or changing side arms, and overbank flooding (Figure1). They have kept their connectivity for fish: downstream of Dubrava accumulation (rkm 160), the River Drava has no migration barriers all the way to its confluence with the Danube, and the same can be said for the Danube and Sava rivers within their entire stretches on the Croatian territory (Mrakovčić et al., 2006).

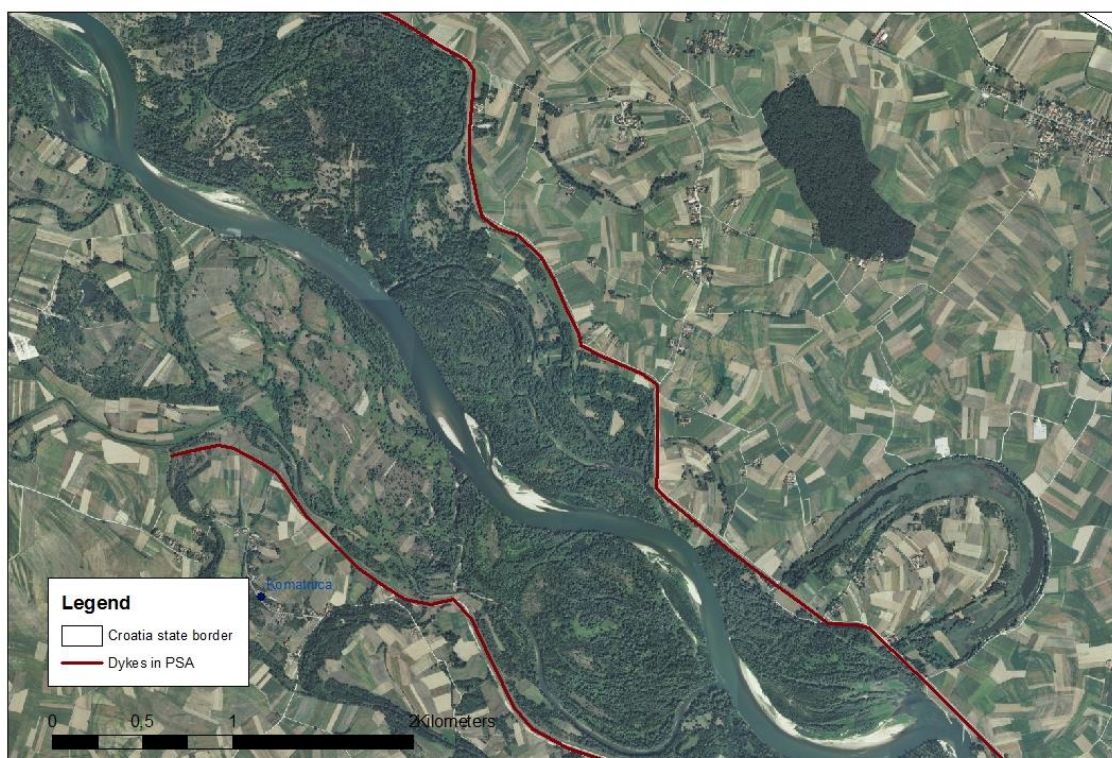


Figure 1: Typical Drava floodplain character and land cover in Gornja Podravina (Podravlje). Active floodplain 1,5-2 km wide is partially delineated by dykes. Some meanders have been cut off (Ješkovo, right). The river can still change its trace, braided channels are partly preserved and connected to the main river bed, and gravel bars are common. Location: 215-220 rkm, north of the Repaš bridge.

A large section of the northern continental part of the Croatian territory has been formed by this river system. Fluvial sediments (both Holocene and Pleistocene) contribute to its total area substantially (Figure 7). The original land cover of these areas was mostly consisting of soft floodplain forests (frequently inundated willow and poplar forests) and hard floodplain forests (less frequently inundated oak, hornbeam, alder and ash forests), but it was lost during the process of land cultivation and conversion of fertile soils to agricultural land (Šoštarić, 2004). The core zones of river corridors remained covered by the soft floodplain forest along most of their stretches, although this zone is quite narrow at the Sava River. On the other hand, extensive areas, such as the Drava forests near Osijek, and also large complexes of hard floodplain forests, have been preserved and successfully managed: among others, we can mention the areas of Turopoljski lug, Spačva, Varoški lug or Repaš forest in this context. In addition, valuable grasslands and other types of wetlands (standing waters, reed beds, tall sedges and others) remained relatively abundant, even though the dominant land cover type of the Drava, Sava and Danube floodplains is cultivated (and mostly arable) land.

Due to the construction of dykes, the inundation zones of DSDF have been reduced substantially, but there are still massive retention spaces in the scale of tens of thousands of hectares, and billions of cubic metres (more on that in Section 5.2.1.1). Due to appropriate distance of the dykes from the active river bed, the River Drava has not lost its contact with the floodplain (also because of sections without any dykes). Hence, overbank flows may reach a width of approximately 1-2 km during high

waters (Figure 1). On the other hand, the Sava River, apart from Gornja Posavina, has been mostly cut off from the floodplain by dykes located quite close to the river bed, allowing only for a corridor up to 1 km wide along its lower section from Gradiška to the Serbian border (Figure2).

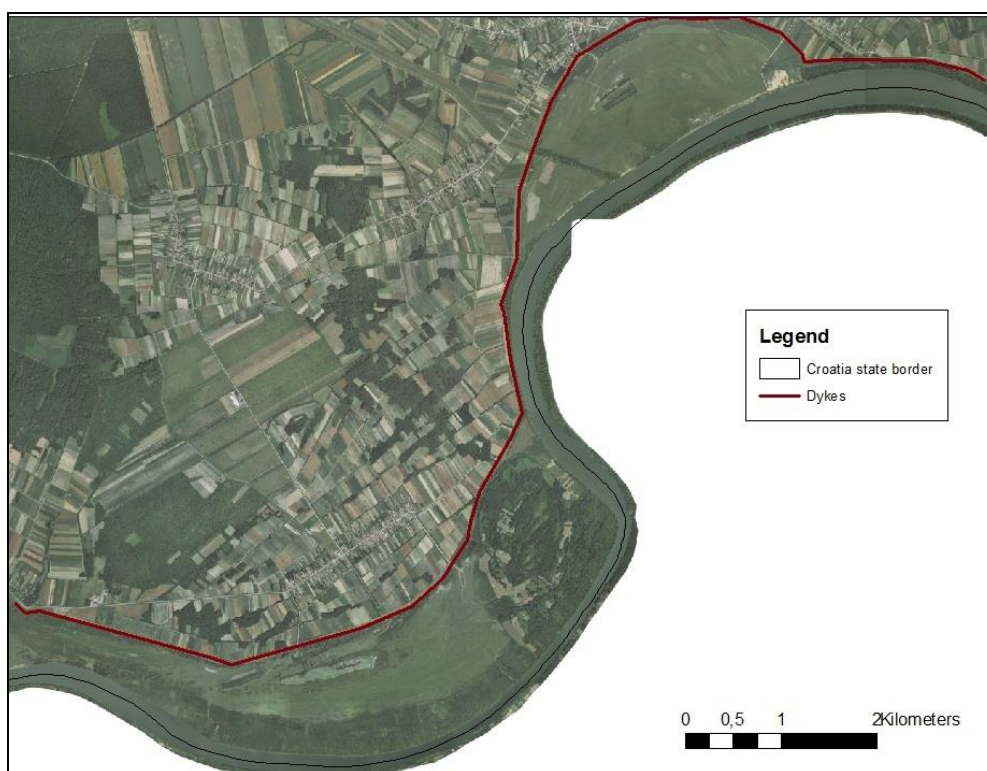


Figure 2: Typical Sava floodplain character and land cover in Donja Posavina. Active floodplain is minimised by dykes, and intensive agriculture almost reaches the river banks. Location: east of Slavonski Brod.

Under the spacious DSDF lowlands, aquifers of intergranular porosity of Pleistocene and Holocene ages were formed. The lithological composition of the aquifers is dominated by gravel and sand in the western parts of the Drava and Sava basins. Sandy aquifers are prevalent in the central and eastern parts. Groundwater accumulated in these aquifers constitutes the basis of the water supply in northern Croatia (Brkić et al., 2010).

The area around the Drava, Sava and Danube rivers contains a variety of wetland habitats, including some of the most threatened habitats in Europe: alluvial forests, wet grasslands, gravel and sand bars, islands, steep banks, oxbow lakes, stagnant backwater, abandoned riverbeds and meanders. They are surrounded by riparian forests and arable land with scattered pastures. The majority of terrestrial habitats of the core area and the buffer zone are covered by softwood or hardwood gallery forests, but there are also extensive grassland areas along the rivers. This variety of habitats provides shelter for a significant number of species (more on that in Section 5.2.2.1).

The river and floodplain ecosystem is vital for the people who live there – it provides them with a number of provisioning services, such as clean water, fish, firewood, timber, game, wood, sand, and gold (more on that in Section 5.2.3.), protects them from floods and droughts (more on that in Section 5.2.1.) and stabilises and maintains key vital cycles such as nutrient, carbon and water cycles.

2.2. Sava, Drava and Danube floodplains and nature protection

The state of rivers, their adjacent land cover types and habitats, partly preserved extensive management and good connectivity that enables the development of an abundance of plant, insect, bird, mammal and fish species and communities, have been recognised as an important issue both at the national and the international level; as a result, different categories of nature protection have been declared in the last decades (for detailed list, see Annex 1):

- Along the Croatian sections of the Drava, Sava and Danube rivers, there are relevant ecological network sites (part of the EU ecological network Natura 2000)¹ (Figure 3)
- Three wetlands of international importance (Ramsar sites)
- Furthermore, the Drava river and its floodplain are part of the core zone of the Transboundary UNESCO Biosphere Reserve "Mura-Drava-Danube" in Croatia and Hungary.² The Biosphere Reserve, together with the riverine areas of Austria, Serbia and Slovenia, will become the first worldwide pentilateral BR and Europe's largest river protected area
- Regional Park Mura - Drava (Mura and Drava Rivers)
- Nature Park Kopački rit (Drava and Danube Rivers)
- Nature Park Lonjsko polje (Sava River)
- 16 Significant Landscape Areas
- 20 Special Reserves
- 9 Natural Monuments
- 5 Park Forests
- 10 Horticultural Monuments

¹<http://natura2000.dzrp.hr/natura/>

² <http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/europe-north-america/croatiahungary/mura-drava-danube/>

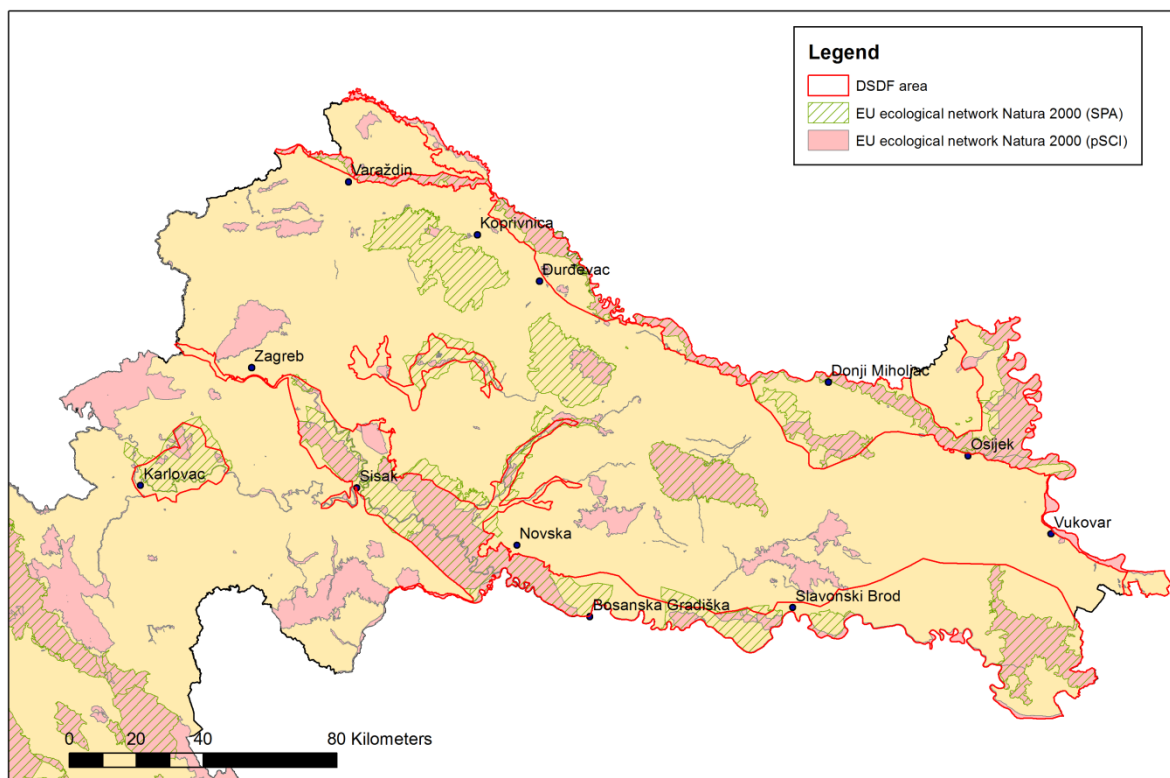


Figure 3: The extent of Drava, Sava and Danube floodplains (DSDF), as they are delineated for this study (see Section 3.1.) and for the EU ecological network Natura 2000. SPA – Areas of Conservation Important for Birds (POP, according to the Croatian legislation); pSCI – Areas of Conservation Important for Species and Habitats (POVS, according to Croatian legislation³). See also: Annex 1. (Source: SINP, 2013).

The proclamation of all these protected area categories is an integral part of the commitments of Croatia stemming from a number of international conventions in the field of biodiversity: the Convention on Biological Diversity (Rio); the Convention on the Conservation of the Wild European Flora and Fauna and Natural Habitats (Bern); Directive 79/409/EEC on the conservation of wild birds; Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora; the Convention on the Conservation of Wetlands of International Importance, Especially as Waterfowl Habitats (Ramsar); the Convention on the Conservation of Migratory Species of Wild Animals (Bonn). All these instruments are fully implemented in the Croatian Nature Protection Act (OG 80/13).

2.3. Evaluation of Drava, Sava and Danube floodplains

The economic importance of DSDF has been recognised by different sectors in particular services, such as timber production (Prpić and Jakovac, 1998) or flood protection (Brundić et al., 2001; Schneider-Jakobi, 2004), although the evaluation mostly did not touch upon the monetary aspects. A complex or holistic evaluation is missing, which is why it is the subject of this study.

³Regulation on ecological network OG 124/13; SINP.

2.4. Threats to Drava, Sava and Danube floodplains

Among the major actual threats with a substantial impact on the ecological state and the ability of providing ecosystem services, one can mention the following:

Canalising rivers for navigation

The rivers Drava, Sava and Danube are already used for navigation⁴. The main water traffic corridor in Croatia is Corridor VII – which includes the Danube River and the Sava River (Figure 4). The Agency for Inland Waters and Regular Maintenance provides measures for the maintenance of navigation corridors, such as the deepening of river beds (gravel and sand extraction); river embankment and structures for diverting the river flow (groynes); and shortening of the river trace by strengthening the curves. For instance, the lower Drava between Osijek and its mouth to Danube has been shortened from the original length of 32 km (in 1784) to the contemporary length of 21 km (in 1988) (Kuspilić et Bekić, 2004). These structures accelerate the water flow and enhance erosion (Kuspilić et Bekić, 2004), and they also have various negative impacts on the ecosystem – namely, they reduce the connectivity of the river and its floodplain.

While the Drava River is not intended for the extension of navigation, plans to construct a new inland waterway, the Danube-Sava Canal from Vukovar to Šamac (61.5 km), are listed in the Croatian strategic documents⁵. This canal should be considered in relation with the Danube-Adriatic traffic corridor, which is a combined river-railroad corridor. This corridor includes the Danube-Sava Canal (61.5 km, Figure 4), the River Sava - IV Navigation Class (345.5 km), and a new Zagreb-Rijeka railroad (160 km). This project would turn 200 km of the Sava River into a reservoir. Scheider-Jacoby (2004) described the details and impact on the Sava river corridor, including the poor economic prospects of this development project.

⁴<http://vodniputovi.hr/en/navigation/>

⁵Strategija prostornog uređenja Republike Hrvatske, 1997; Izmjena i dopuna Strategije prostornog uređenja Republike Hrvatske, 2013; Strategija razvitka riječnog prometa u Republici Hrvatskoj (2008. – 2018.); Srednjoročni plan razvitka vodnih putova i luka unutarnjih voda Republike Hrvatske (2009. – 2016).



Figure 4: Navigation routes and classes for the rivers Drava, Sava and Danube in Croatia (Source: Agency for Inland Waters, 2013).

Eutrophication

Eutrophication of rivers may adversely influence the water quality in permeable sediments from which the drinking water is abstracted, use of water for recreation, and the ecological status of riverine habitats. Moreover, the nutrient pollution in Danube has a strong impact on the Black Sea coastal ecosystems (UNDP, 2006). This nutrient transport and its reduction are perceived as a serious problem, and broad and coordinated international efforts have been made to improve the situation (more on that in Section 5.2.1.). According to Niemayer (1999), the principal sources of surplus nutrient inputs into the Danube basin rivers are the following:

- Insufficient wastewater collection and treatment at the municipal level
- Insufficient wastewater treatment of industrial enterprises
- Water pollution caused by intensive agriculture and livestock breeding
- Inappropriate waste disposal sites

Technical flood protection measures

Technical flood protection measures are partly identical to the measures of support to navigation, described above. The construction of dykes (Figures 1, 2 and 5) and their position have a crucial impact on the extent of the active inundation zone (more on that in Section 5.2.1.).

Fortifications, embankments and other forms of bank stabilisation with the aim of preventing bank erosion have been made on all three rivers (Croatian Waters). According to the internal SINP monitoring and field data collection, Drava has been fortified on 15% of its course (from Dubrava HEPP to the confluence with the Danube River).

The planned flood protection measures have a limited extent, and therefore cannot be taken as a major threat. However, they contribute to the overall negative trend in accelerating the river flows and erosion of the river bed.



Figure 5: Flood protection dyke on the Sava River, Posavina.

Hydroelectricity power plants with accumulations (HEPP)

HEPP facilities in general represent a major impact both on the river corridor, its ecological status (Sørensen, 2004), and the ability to provide ecosystem services. The usual consequences of constructing lowland-type accumulations (with low stratification of the water column) are as follows (Baxter, 1977):

- Destruction of the river and floodplain ecosystem in the locality. New freshwater ecosystem of the reservoir should be expected to have much lower biodiversity, when compared to the original river and floodplain ecosystem complex. The biodiversity would be lower even when compared to the most similar freshwater ecosystem – the lake ecosystem.
- Due to the water level fluctuation needed to optimise throughflow and head (height difference between the reservoir level and the turbines), which is important for electricity production, but also for flood protection, the littoral zone crucial for biodiversity and fish populations cannot develop in full.
- Reservoir dam represents a barrier for fish, and permanent discontinuity throughout the river corridor. Fish passages can mitigate this damage, but cannot fully compensate it.
- Absence of driven material and reduction of flow fluctuations cause the reduction of natural river bed processes, namely of the accumulation of material, trapped in reservoirs. Typical consequences include increased erosion and deepening of the river bed down to the accumulation, with consequent changes in underground water levels.

Numerous HEPPs on the Drava River (11 in Austria, 8 in Slovenia and 3 in Croatia) have a major impact on change patterns in all of the above mentioned characteristics and processes in river and floodplain ecosystems. Namely, the changes in bed load transport dynamics, resulting in river bed

deepening, seem to be the most serious threat to various vital ecosystem services. These impacts are explained and documented in the Section 3.2., dealing with the pilot study area, which is influenced in particular by the three existing HEPPs in Varaždin County.

There are numerous plans to build new HEPPs in order to supply Croatia with electricity; especially on the Drava River, where the chain of proposed HEPPs (Molve 1 and 2 and VHS Osijek) is being planned in the most preserved and ecologically valuable sections of the river (Figure 6). Because of their relevance to the pilot study area, these development projects are described in Section 3.2. There are also plans to build several HEPPs on the Sava River from Zagreb to Sisak (Alerić, S. et al., 2012; MGIPU, 1997).

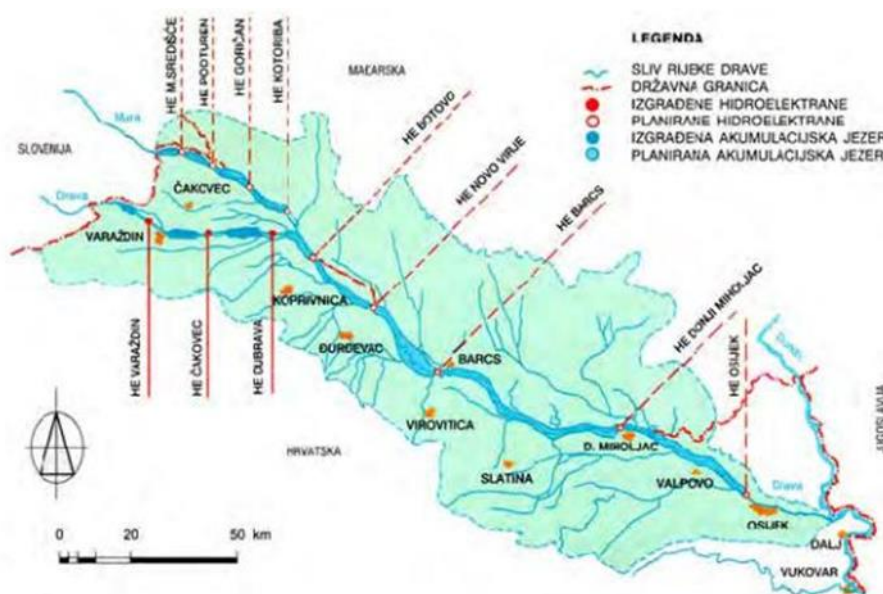


Figure 6: Location of some proposed HEPPs on the Drava River (at present, Novo Virje and Botovo are replaced by Molve 1 and Molve 2). (Višenamjenski hidrotehnički sustav “Osijek”, 2012).

3. Study area delimitation

3.1. Drava, Sava and Danube floodplains (DSDF)

For the purposes of this analysis, one first had to define the extent of the Drava, Sava and Danube floodplains for which ecosystem services would be evaluated. The definitions of floodplain depend on the perspective or the context in which we approach the study. Floodplains in the **geological sense** are formed by alluvial sediments; in this context, the substantial part of northern Croatia is formed by floodplains (Figure 7). However, these extensive floodplains lost their original land cover, and became cultivated agricultural land without direct influence of the river.

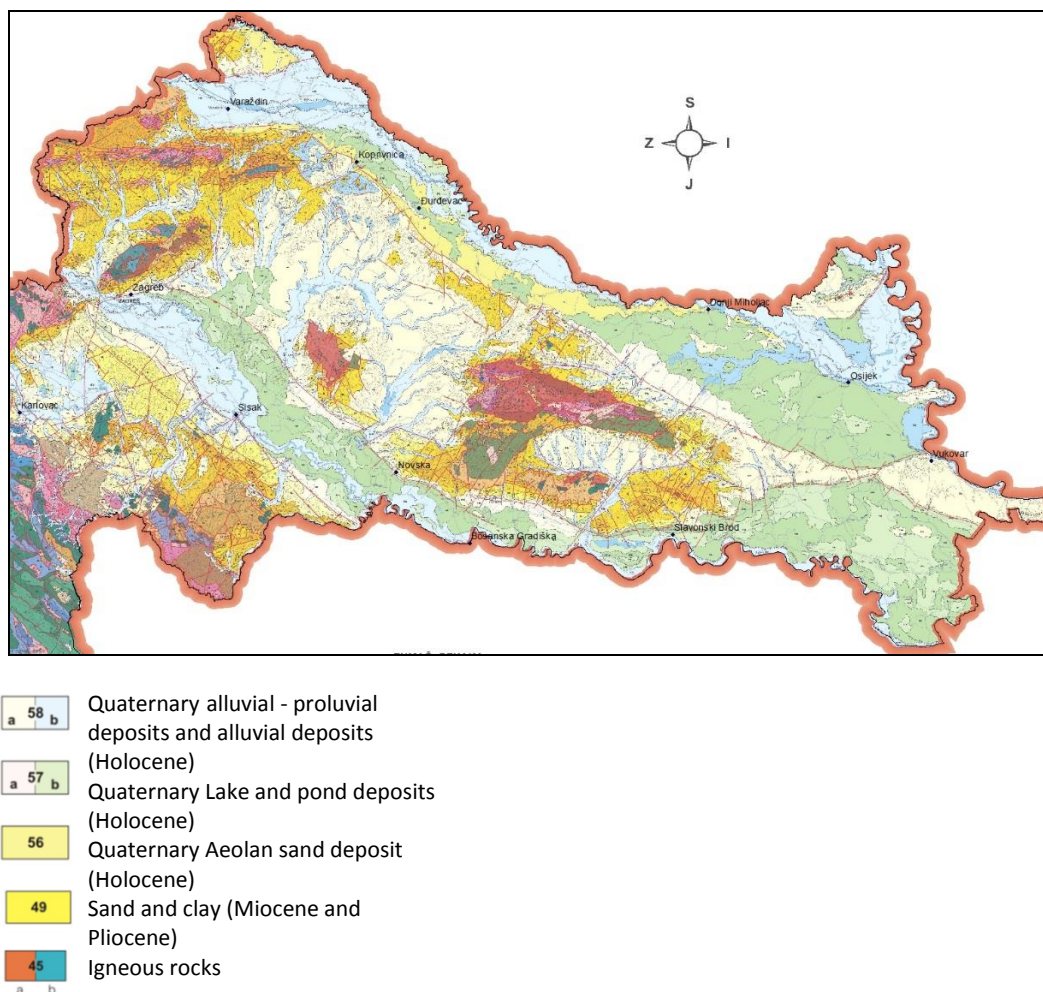


Figure 7: Geological map of Croatia showing the area and location of sediments formed by the river activity: Holocene alluvial sediments, Pleistocene fluvial sediments, Pleistocene swamp forest and Holocene swamp sediment. (Croatian Geological Survey, 2009).

Floodplain (ecosystem) in the **ecological sense** is based on the existence of an interconnected system of the river and its floodplain. This concept has been developed by Junk (1989) in particular, within the theory of the flood pulse concept, where discontinuous flooding is a prerequisite for the existence of the so-called „active floodplain“. The present extent of inundation zones is shown on Figure 8, indicating that long sections of rivers have been transformed and lost their original inundation zones.

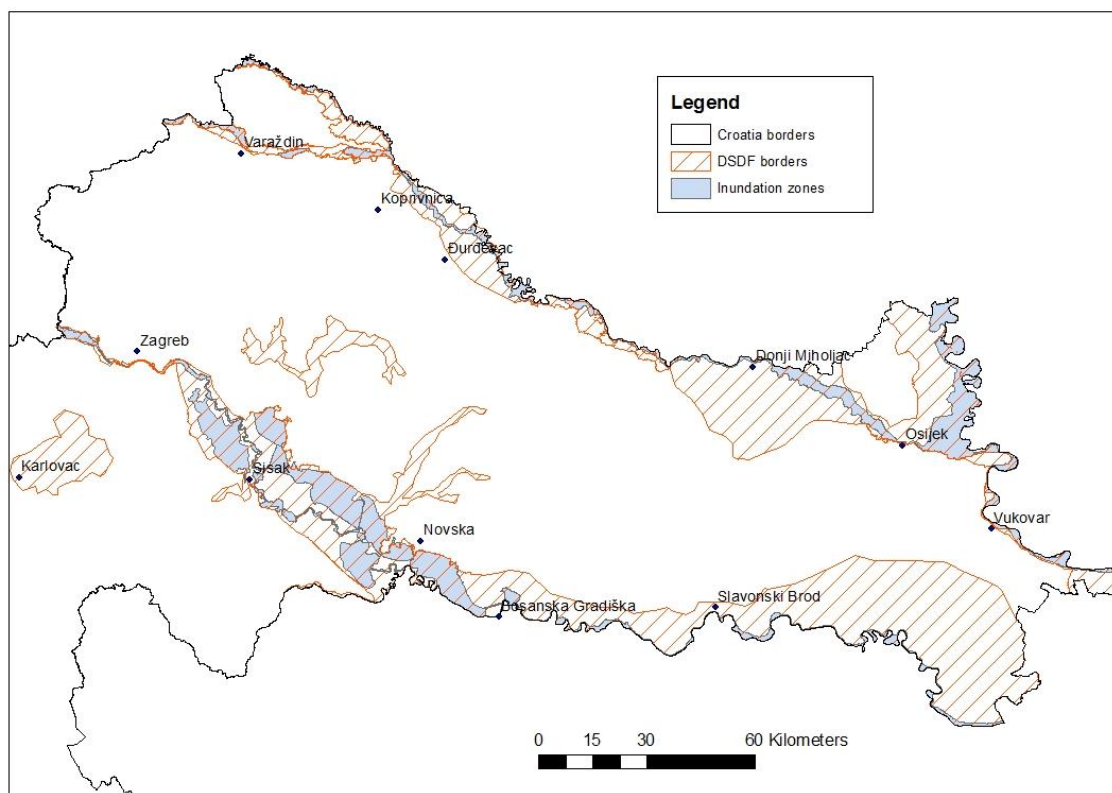


Figure 8: Area of the Drava, Sava and Danube floodplains (DSDF) and the extent of inundation zones (Source: SINP, 2013).

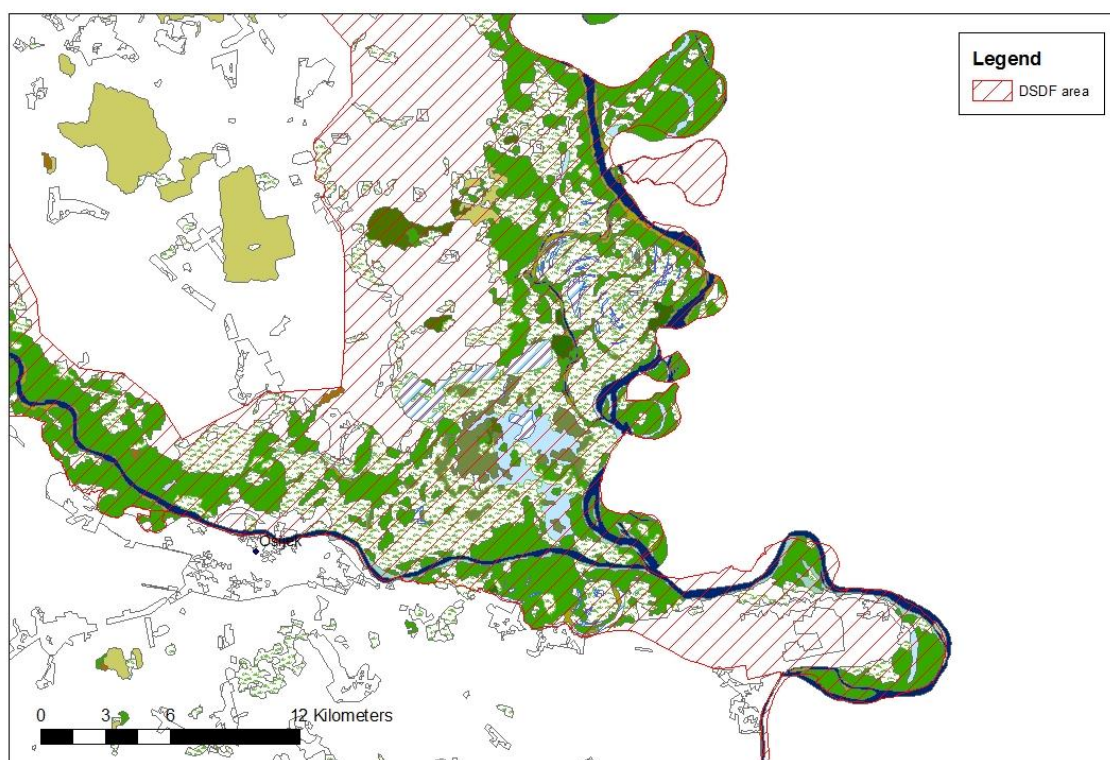
While the geological delineation would be too wide for the purposes of this study, the limitation solely to inundation zones would be too narrow. The main reasons are large complexes of the original floodplain vegetation types, which still correspond to and depend upon the river itself, namely on the regime of underground waters. Being an integral component of the original floodplain ecosystems, these complexes still contribute remarkably to ecosystem services, even in those cases in which they are located behind the inundation zones, outside of the active floodplain (mainly because of their position behind the dykes). Hard floodplain forest is the typical representation of these complexes.

Another criterion for the delimitation of the floodplain providing ecosystem services may be found in its recognition as an area of natural values, which is therefore designated as **protected area** at a different level. However, this criterion was also not satisfactory, for the same reason as the previous one: in such a way, large areas of typical floodplain habitats would be left out of the study area.

In the end, a set of criteria has been defined for DSDF delineation (the extent is shown in Figures 3 and 8, and Figures in Section 5.2.2.).

1. DSDF, as it is defined in this study, includes the entire area of:
 - Inundation zones as they have been declared by the Croatian Waters (Figure 8)
 - Mura-Drava Regional Park located in Croatia (not the transition zone). For detailed description of protected areas, see Annex 1

- Natura 2000 sites declared on the basis of habitats related to floodplain ecosystem (Figure 3)
 - Core and buffer zones of the Biosphere Reserve "Mura-Drava-Danube" in Croatia and Hungary
 - Nature Park Kopački rit
 - Nature Park Lonjsko polje
2. DSDF includes all larger area units of habitats characteristic for floodplains (Figure 9). For that reason, relatively isolated floodplain segments of Drava and Sava tributaries – Kupa, Česma and Ilova rivers - have also been included in DSDF, because of their preserved floodplain habitats.
 3. DSDF covers areas with the following geological subsoil of Holocene sediments: river and creek alluvium, pluvial deposits, Aeolian sands and marsh sediments (Figure 7).



Legend

-  A11 Standing waters
-  A23 Permanent watercourses
-  A27 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A27/A22/A11 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A41/A21 Reed beds, tall sedges and tall rushes / Mosaic of cultivated areas
-  C22 Central Europe humid grasslands
-  C23 Central Europe mesophilous grasslands
-  C23/C22/E31 Central Europe mesophilous grasslands / Central Europe humid grasslands / Mixed oak-hornbeam forests and hornbeam forests
-  D11/E11 Willow thickets on dunes / Alluvial willow forests
-  E11/E12 Alluvial willow forests / Alluvial poplar forests
-  E21 Alluvial forests of black alder and narrow-leaved ash
-  E22 Alluvial forests of pedunculate oak
-  E31 Mixed oak-hornbeam forests and hornbeam forests
-  E31/C22 Mixed oak-hornbeam forests and hornbeam forests / Central Europe humid grasslands

Figure 9: Delimitation of DSDF – detail of the Drava and Danube confluence (Source: SINP, 2009).

3.2. Pilot study area (PSA)

PSA selection

Ecosystem services evaluated within the PSA need to be at least partially transferable to the whole DSDF area. Therefore, PSA should be representative for the entirety of DSDF in terms of the variety of habitats, land cover and management types. On the other hand, PSA selection should also reflect the actual threats to DSDF – so as to enable the definition of different future scenarios within the PSA. For these reasons, we have focused on floodplain areas with both preserved and cultivated (managed) parts, and areas in which development projects with major impact on floodplain ecosystem services are being prepared.

The pre-selection process resulted in two candidate localities: the Drava area in Osijek-Baranja County (Figure 10), and Drava-Molve (between Botovo and Repaš bridges, Koprivnica-Križevci County, Figure 11). There are extensive hydropower projects planned on both sections of the river (for reference, see Section 3.2.2). Both floodplain areas contain segments of non-regulated main river bed, oxbows, wetlands and land cover adapted to periodical inundation.



Figure 10: Drava River in the section where HEPP Osijek is being planned.

Finally, the PSA Drava-Molve has been selected for the following reasons:

1. Drava-Molve is more diverse than Drava-Osijek in terms of land cover (more patchy structure of terrestrial ecosystems); it represents a wider variety of agriculture and forestry management (different types of pastures, arable land, both hard and soft floodplain forest).
2. Higher slope of the river at Drava-Molve enables erosion-accumulation processes to form structures like gravel bars, which are valuable and typical for preserved rivers in DSDF.
3. The shorter distances make the area better accessible, and can result in savings on travel costs.
4. There is no limitation in access to the Drava-Molve locality, unlike the Drava-Osijek area, where minefields prevent access to the left bank of the Drava River.
5. The proximity of existing HEPPs near Varaždin may help to understand the possible impact of proposed HEPPs on the floodplain ecosystem.
6. Drava-Molve is also a pilot study area for the international SEE River project and the proposed LIFE Project, which means that a certain level of synergy can be expected.

Demarcation and description

PSA Drava-Molve covers the area between 192 rkm and 230 rkm, creating a section of 38 rkm. The surface of the area is 201 km²; it is approximately 30 km long and 7 km wide (Figure 11). Politically, it is situated in Koprivnica-Križevci County. PSA is an integral part of DSDF.

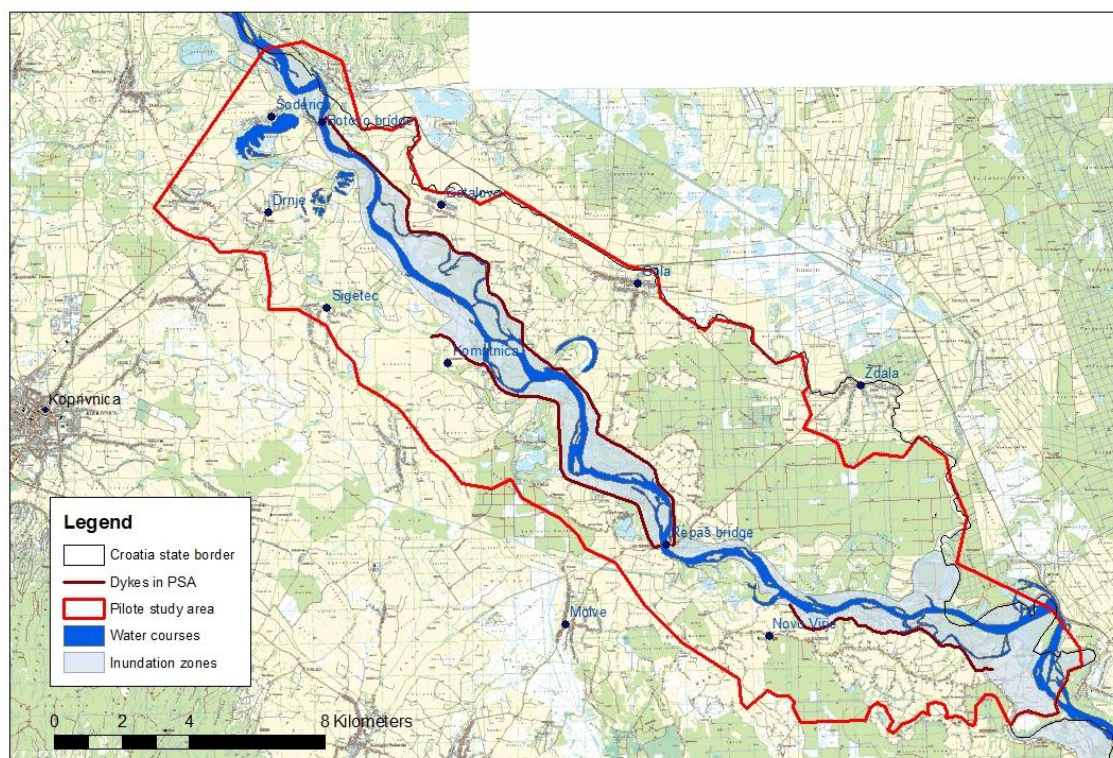


Figure 11: Location and extent of PSA Drava-Molve with the extent of the inundation zone (width ranges from 1.5 to 3 km) and with the position of dykes (Source: SINP, 2013).

Character and state of the river

Long-term average discharges at lower Drava (Table 2) point to a decreasing trend in the period 2008-2012, when compared with the 1963-2012 period.

Table 2: Discharge of the lower Drava river. Blue colour indicates the profiles on inlet and outlet of PSA. (Source: Croatian Waters, 2013)

Profile	Period	Period: 1963- 2012	Period: 2008-2012	Period: 2002-2012			
		Q average $\text{m}^3.\text{s}^{-1}$	Q average $\text{m}^3.\text{s}^{-1}$	Qmax - $\text{m}^3.\text{s}^{-1}$	Date Q max	Q min $\text{m}^3.\text{s}^{-1}$	Date Q min
DRAVA - Donja Dubrava	1983 - 2012		323	2061	7.11.2012	23,1	20.4.2003
DRAVA - Botovo	1926 - 1943 1946 - 2012	496	487	2071	7.11.2012	85,4	14.1.2002
DRAVA - Novo Virje Skela	1977 - 2011		491	1790	25.8.2005	111	9.1.2002
DRAVA - Terezino polje	1961 - 2012	511	503	1680	22.9.2010	111	21.1.2002

DRAVA - Donji Miholjac CS	1926 - 1943 1946 - 2012	525	511	1590	23.9.2010	167	14.2.2002
DRAVA - Belišće	1962 - 1993 2003 - 2012		522	1425	24.9.2010	197	29.9.2003

The Drava River in the PSA has the slope of 0.34 ‰, and its originally high potential for the transport of bed load haulages (coarse and medium-coarse gravel and coarse sand) naturally corresponds to a transitional type between the anastomosing (furcation) and the meandering type (Michor et al., 2013). The main river channel is accompanied by numerous side branches and oxbows with rich macrophyte flora and fish communities (Figure 12). Islands and gravel bars still constitute a typical feature of this section of the river (Figure 13).



Figure 12: Side branch of the Drava River with macrophyte stands (*Nymphaea alba*, *Myriophyllum* sp.)



Figure 13: Gravel bars in PSA

Although the character of the river remained relatively natural, when compared with most of the western European or central European rivers, it has changed remarkably over time, as can be seen from Figure 14. Due to river regulation over the last 250 years, most meanders have been cut off, and the river trace has been straightened and shortened; the width of the river dropped remarkably. Bank stabilisations (Figure 15) are extensive; most banks have remained unsecured, however (Figure 16).

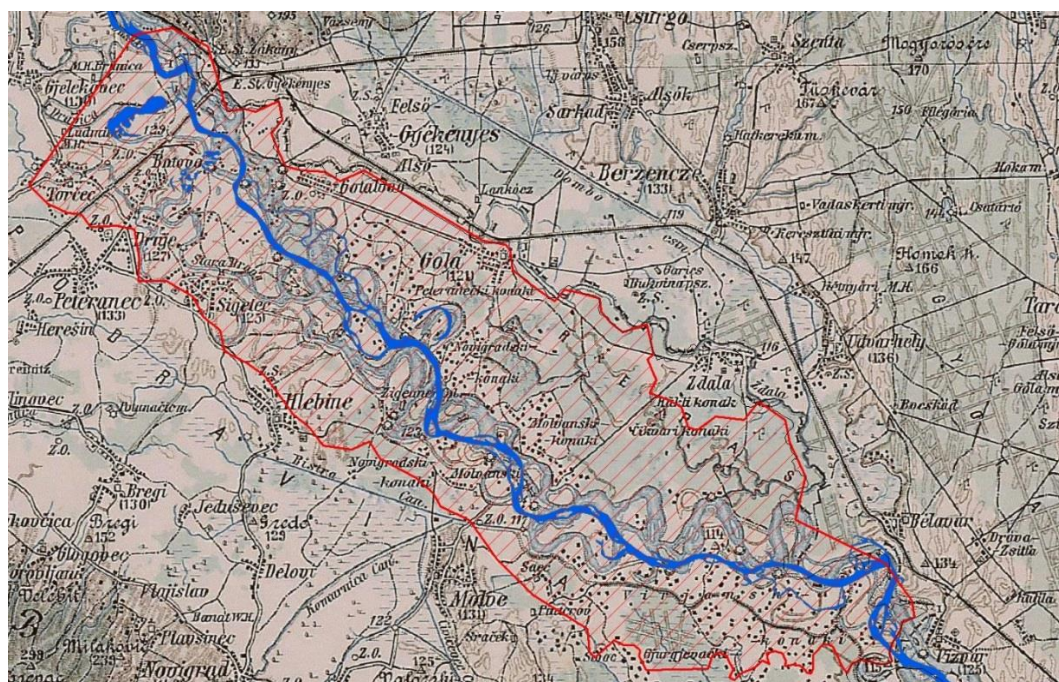


Figure 14: The second military survey map of the Austro-Hungarian Empire in the period 1865-1869 (Croatia and Slavonia). The old extent of the Drava River overlaps with the current watercourse (dark blue); PSA borders are indicated by the red line.



Figure 15: River banks protected by rip-rap structures



Figure 16: Natural river bank with gravel deposits in PSA



Figure 17: Dam disconnecting a river oxbow from the active river bed. The Croatian Waters plan to remove some of these dams.

Some braided river channels were disconnected from the main river (Figure 17), whereas other channels remain active. The active inundation zone is partly bordering the dyke system (Figure 1 on page 10, and Figure 11 on page 23); in areas where dykes have not been built, the extent of inundation is limited by the natural elevation of the terrain.

Land cover, habitats and management

The core zone of the floodplain in the PSA is a mosaic structure of floodplain forests, aquatic habitats, wetlands, meadows and arable land (Figure 1 on page 10). The dominant and typical land cover types in PSA include the following:

Softwood floodplain forest. This type of ecosystem is adjacent to the river and its inundation zone. Willows and poplars are dominating, and providing some extensively harvested firewood (Figure 18). Side arms and permanently flooded oxbows make the accessibility for management difficult.



Figure 18: Extensive harvest of firewood in soft floodplain forest

Hardwood floodplain forest: This type of forest is dominated by oaks or ashes (Figure 19), and it is located at larger distances from the river in areas that are less frequently inundated. A well-known locality is the Repaš forest in the north-eastern part of the PSA. Nowadays, most of the forest is behind the dykes, so the frequency of flooding dropped since the construction of dykes.



Figure 19: Ash dominated hard floodplain forest near Čingi-Lingi sandpits

Floodplain hay meadows (Figure 20). Most of the area with this meadow type has been replaced by abandoned meadows during the previous decades, due to the declining interest of farmers to cultivate floodplain areas.



Figure 20: Hay meadow near Repaš bridge

Abandoned floodplain meadows (Figure 21) are in different state of degradation, and they have been overgrowing with woodland, including invasive species (*Amorpha fruticosa*).



Figure 21: Abandoned hay meadow overgrowing with invasive species *Robinia pseudoacacia*.

Wetlands. Paradoxically, extensive wetlands can also be found on the outer side of dykes (Figure 22), which indicates the possibility of extending the active inundated floodplain, and enhancing its flood mitigation effect.



Figure 22: Oxbow lake disconnected from the active river bed, and consequently silted up with sediments and overgrown by reed (*Phragmites communis*), Komatnica.

Arable land. Arable land inside the inundation zone (between the dykes and the river; Figure 23) indicates that the inundation in some parts is not so frequent so as to prevent this type of land use.



Figure 23: Arable land on the inner side of dykes

Impact of hydropower accumulations on the Drava River on the PSA and the lower Drava section

Existing three HPPs on the Drava River are situated in Varaždin County between 242 rkm and 309 rkm. The reservoirs Ormož (Varaždin), Čakovec and Dubrava (Figure 24; for technical parameters, see Table 2 on page 40) were built in the period from 1975 to 1989. They are components of the Production Area Hydropower Plants North – the PAHPP North system.

Turbines and generators are situated on derivation canals, which outflow from each reservoir; this arrangement makes it possible to increase the head of turbines and consequently the electricity production. In its peak regime, the water level and outflow of the PAHPP North system oscillates in the range of 0.6-1.6 m per day (Schneider-Jacoby, 2004). The old Drava river bed gets the minimum biological throughflow; during the flood waters, it gets the surplus of throughflow which exceeds the throughflow capacity of the derivation canal.

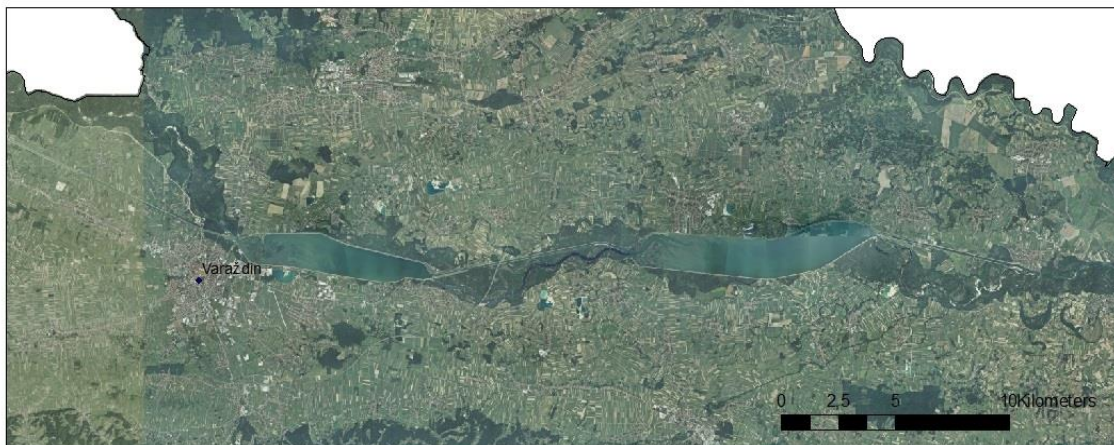


Figure 24: Čakovec (left) and Dubrava (right) HEPP accumulations in Varaždin County. Derivation canals get the majority of Drava discharge.

Various impacts on the environment, ecosystem services, and local community have been described. Some of these impacts are consequences of all upstream HEPPs in Slovenia and Austria; however, the access of impact has mostly limited reach, because of the fact that the river processes (erosion and accumulation) are gradually restored at a certain distance from the accumulation. Therefore, the strongest impact on the lower Drava section is posed by the HEPP North system at Varaždin. The details are explained in the continuation.

Detected impacts can be summarized as follows:

Changes in the underground water regime

Increase of underground water levels in the vicinity of accumulations. Due to the pressure of aboveground water body in the accumulations, and permeability of both the alluvial sediments and dams, the underground water in close vicinity of the reservoirs increased to adverse levels. It flooded some basement areas of houses in nearby villages. To compensate for these effects, additional investments were therefore needed - canals or holes have been made to drain this surplus water. Along the dams, drainage canals derive the water permanently leaking through dams, having the discharge of about $5 \text{ m}^3 \cdot \text{s}^{-1}$. At the Čakovec reservoir, this permanent water level increase was about 0.5-1.2 m; the level of oscillations also decreased partially (Grdan and Kovačev-Marinčić, 1992).

Drainage of underground water by derivation canals. The inlet part of the derivation canal leading the water into the power plant is made from impermeable concrete and has no contact with underground waters. The outlet (or discharge) derivation canal (Figure 24), leading water from power plants to the old river Drava, is deepened – water table of the

power station is 9 m below the ground (Čakovec accumulation), and permeable, and it efficiently drains its surroundings. The ground water level along the power plant station is lowered by about 8 m. The influence drops with distance from the river, but is still detectable at a distance of 4.5 km (Grđan and Kovačev-Marinčić, 1992).

Drainage of underground water around the old river Drava. Average discharge of the Drava River is $335 \text{ m}^3 \cdot \text{s}^{-1}$ in the HEPP. The biological minimum discharge which has to be released by HEPP to the old river bed is $8 \text{ m}^3 \cdot \text{s}^{-1}$. This value is far from an ecologically acceptable flow, which has never been defined (Bonacci and Oskoruš, 2010). Apart from own HEP monitoring, there is no independent monitoring of this biological minimum flow. Such a dramatic decrease of discharge resulted in drainage of the original floodplain, and a remarkable decrease of wood increment in soft floodplain forests (see Section 5.2.3).

Bed load and suspended sediment transport situation

The chain of Hydropower Plants North at Varaždin has a massive influence on the free-flowing stretch of the Drava in the PSA, by trapping the suspended sediment load (Figure 25). This phenomenon is present, of course, on all upstream Drava HEPPs, and depends on the length of the upstream free-flowing river stretch and other hydrogeomorphological conditions. Due to the construction of hydro power plants, there is a deficit of bed load downstream. The bed load input is limited to sideways erosion or to the transportation of its tributaries (Mura, for instance).

Bonacci et al. (1992) and Bonacci and Oskoruš (2010) have quantified the decrease of suspended sediment load at different Drava profiles (Varaždin, Botovo and Donji Miholjac) in different time periods. At the Varaždin profile, sediment load decreased 2.3 times after the sub-period 1960-1967 after the construction of Zlatoličje accumulations (Figure 25). In the same period, there was no decrease on the Donji Miholjac profile, showing the limited extent of Zlatoličje impact on the sediment regime. At the Botovo profile, suspended sediment load decreased by 17% after HEPP Varaždin was constructed. After the construction of HEPP Čakovec, transport decreased 2.7 times, and, after the construction of the Dubrava facility, another decrease of 28% has been detected. Today, only about 28% of the suspended sediment measured during the years 1968-1974 flows through the Botovo profile, and 20% through the Donji Miholjac profile.



Figure 25: Accumulation of sediments in Varaždin accumulations (left) and Zlatoličje (right) in Slovenia. On the left side of the picture, one can distinguish the sediment (in the upper part of the lake) and reflexion of the sun.

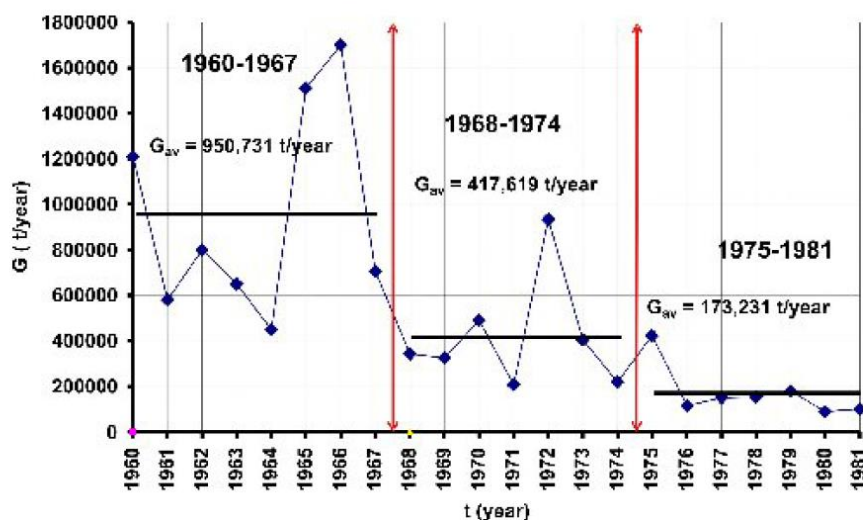


Figure 26: Suspended sediment load decrease in three sub-periods on the Drava profile Varaždin. 1960-1981: before the construction of HEPPs. 1968-1974: after the construction of Zlatoličje. 1975-1981: after the construction of the Varaždin facility. Source: Bonacci and Oskuruš (2010).

Drainage of underground waters by deepening of the river bed down to HEPPs.

This process is caused by a permanent lack of bed load trapped in accumulations, and increased erosion potential of river water down to the accumulations. In addition, the narrowing of the river bed, and the shortening of its trace due to technical flood protection and local erosion prevention measures, are accelerating the overall erosion. In the PSA, the average deepening of the river bed was approximately 1.7 cm per year between 1926 and 1991, with reference to the mean annual water level, and 2.56 cm with reference to the minimum annual water level. Overall, the Drava deepened by 1.1 m between 1926 and 1991 at the flood marker in Botovo (Mohl, 1998; Bonacci and Oskoruš, 2010). More recent analyses in the downstream area, at the flood marker in Terezino Polje at rkm 152.5, show that the deepening of the river bed since 1875 amounts to about 3 m (Kuspilić et Bekić, 2004); degradation processes in the Drava river bed near the mouth to the Danube resulted in the deepening of the river bed by about 3 m in the period from 1960 until the present times. The following consequences can be noted:

- An increasing separation of the river and soft alluvial forests (visible in the form of river banks that are unnaturally high in long stretches); deficit of flood and underground water.
- Deficit of underground water for more distant hard floodplain forests.
- Formation of new open gravel bars is reduced, and, due to the larger contribution of fine sediment, the increased sedimentation rate can be found in old branches of the river (Michor et al., 2013). Also, the structure of

gravel bars has changed in favour of smaller fractions, which means that gravel bars can be siltated, and their permeability decreases.

- Decreasing river discharge. This trend has also been proven by Bonacci and Oskuruš (2010), but it cannot be attributed solely to the construction of accumulations causing the deepening of the river bed. Decrease of discharges started in the Botovo profile in 1981, and it points to a statistically significant difference between the annual average discharge of $529 \text{ m}^3\text{s}^{-1}$ in the period 1926-1980, and the discharge level of $463 \text{ m}^3\text{s}^{-1}$ in the period 1981-2006. Climate change and other measures resulting in the acceleration of the outflow of river water are responsible as well.

Changed patterns of groundwater recharge. Reduction of inundation zones by limiting the flood water in the accumulations causes the weakening of this process. The contribution of regular flooding to groundwater recharge (together with precipitation and recharge from river beds) is beyond dispute. Babbitt et al. (2006) estimate the rate of groundwater recharge at 1 mm per day in the Lonjsko polje flood detention area. Moreover, natural river beds are more permeable when compared with mostly colmatated bottoms of accumulations.

Siltation of accumulations

Suspended load trapped in accumulations (Figure 25) causes their siltation, resulting in decrease of the reservoir volume. Varaždin accumulation is facing the biggest threat of that kind. The thickness of sediment is changeable and hard to predict. Thick sediment layers derive the water current towards the banks (form and inner river bed in the accumulation), which enhances erosion of the banks. The analysis of sediment thickness is not available. Every large flood splashes one part of the sediment (fine particles) out towards the old river Drava.

Discharge oscillations

Due to the daily peak regime in electricity production, oscillations occur in the discharge of outlet from HEPP (Figure 27). These oscillations may have an adverse effect on fish populations (Mrakovčić et al., 2006), in particular during the reproduction phases.

The HEPP Dubrava, which is situated upstream, often operates in a hydropeaking mode with two daily peaks. The variations in water levels have an impact on discharges in the PSA.

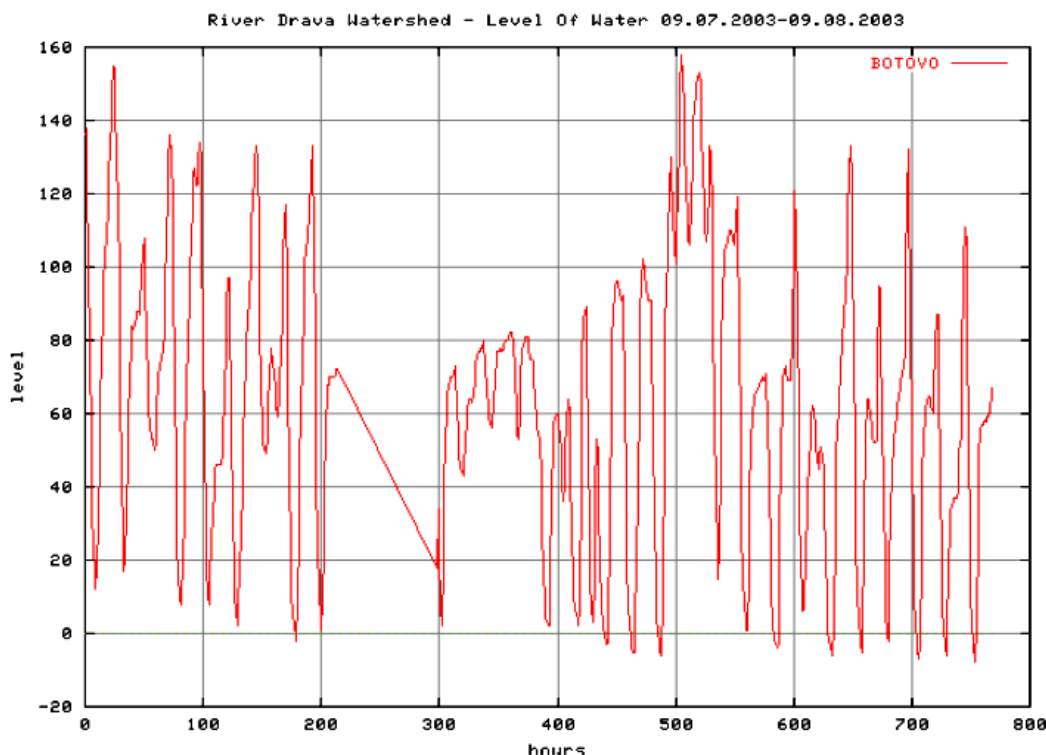


Figure 27: Water level oscillations caused by hydropеaking of Dubrava HEPP (dependent on the operation regime of the entire interconnected HEPP North system). Data from: Michor et al., 2013 (Source: Croatian Waters).

Changes in nutrient transport and cycles

Proper analysis of changes in nutrient transport would require a more detailed analysis, which is outside of the scope of this study. In general terms, natural floodplains and river systems can serve as nutrient sinks (Lair et al., 2009); however, during the extreme floods, they also serve as nutrient sources. As far as phosphorus is concerned, this is true for reservoirs as well, given the fact that phosphorus binds with suspended solids sediment on the bottom, where it can be resuspended in the water column and cause eutrophication of the water body.

According to the saprobity index, HEPP Varaždin (Figure 28) and Čakovec are eutrophic water bodies, while Dubrava is moderately eutrophic. (Mrakovčić et al., 2006). Algal cell volumes in all the three lakes were stable in the period 1999-2012 (showing a decreasing trend since 2008, and an increasing trend until 2005). Trophical diatom index is exhibiting an increasing trend, the saprobic index is stable, and the Shanon Wiener Index of Diversity has been stable since 2002. These data point to a mildly prevailing eutrophic status of accumulation waters.

In contrast to standing water bodies, where the nutrients are stored in sediments, the nutrients in active floodplain are processed in biofilms covering wet surfaces like gravel, sand and plants, and are transformed to a much larger extent into plant biomass, which causes a relative slowdown of nutrient transport until the biomass is decomposed again (more on that in Section 5.2.2.).



Figure 28: Eutrophic water in the Varaždin accumulation, with colouring caused by algal biomass.

Changed patterns of flood protection

Decrease of the old Drava river bed discharge capacity. During high discharges or flood water (with the discharge at HEPP Varaždin exceeding $450 \text{ m}^3 \cdot \text{s}^{-1}$, coupled with the release of $2,000 \text{ m}^3 \cdot \text{s}^{-1}$), the capacity of the derivation canal is exceeded, and water is released into the old Drava river bed. (Figure 29)



Figure 29: Overgrowing gravel beds in the old Drava river bed at Varaždin, caused by the decline of throughflow to the derivation canal.

Decrease of retention space. The retention volume of accumulations is limited due to constant electricity production, keeping the water at the maximum level. As a rule, this volume is not larger than the original extent of the floodplain. On the other hand, assuming that the flood is predicted on time, the retention capacity can be enlarged by water

manipulation. The mitigation effect on larger floods is limited, which is clearly visible in Figure 30, taken during the floods of 2012.



Figure 30: Extensive flood down to the Dubrava reservoir in 2012 (Photo: Darko Grlica).

Decreased attractiveness for recreation. Adverse bank structure (Figure 30) allows access to water only in the areas of inflow. As a result, the attractiveness for tourists is low, and cannot be compared to the original river corridor.



Figure 31: Čakovec reservoir dam with the outlet to the derivation canal (right), and the old Drava river bed (left).

Loss of connectivity for fish populations. Fish passages, which were built at the same time as the accumulations (Figure 32), have not provided sufficient alternative for fish migration (Mrakovčić et al., 2006; Witkowski et al., 2013). As a result, HEPP Dubrava represents the upper end of the Drava river section in which fish can migrate without limitations.



Figure 32: Fish passage at the Čakovec reservoir. Weak current at the inlet may not attract fish sufficiently to enter the passage. High slope (right) results in low efficiency of this device.

Impact of proposed HEPP on the PSA and the lower Drava

The proposed HEPP system on the Drava River (Figure 6 on page 17) has been designed in several versions (including, for instance, HEPP Novo Virje in the past). The latest version consists of the proposal for HEPP Molve 1 (Figure 33), and HEPP Molve 2 and VHS Osijek (Figure 34). The technical parameters are shown in Table 3 (on page 41), including a comparison with the technical parameters of existing HEPPs.⁶

HEPPs Molve 1 and 2 are envisaged as run-of-the-river hydroelectric stations, i.e. stations with small or no reservoir capacity. This typology is not clear, because the area of accumulations reaches 870 and 1,006 ha (volume data is not available). The head should be at about 6 m, so one should assume that the whole extent of accumulation will be flooded permanently (with oscillations of water level due to the peak regime). In general terms, typical run-of-the-river hydroelectric stations have a lower impact on river ecology; however, the proposed projects should rather be classified as a transient type between the run-of-the-river and classical hydroelectric stations.

⁶ Alerić, S. et al. (2012): Program iskorištenja slobodnog hidropotencijala u Republici Hrvatskoj. Hrvatska komora inženjera građevinarstva, Zagreb-Opatija.

Hrvatska elektoprivreda d.d., Sektor za strategiju, planiranje investicija i korporativni razvoj (2013): Podloga za izradu prostornih planova. Opis HE Molve 1 i HE Molve 2.

Višenamjenski hidrotehnički sustav „Osijek“ (2012): Studija – Projekt više struka. Studija utjecaja na okoliš i ekološku mrežu, Osječko-baranjska županija, Osijek.

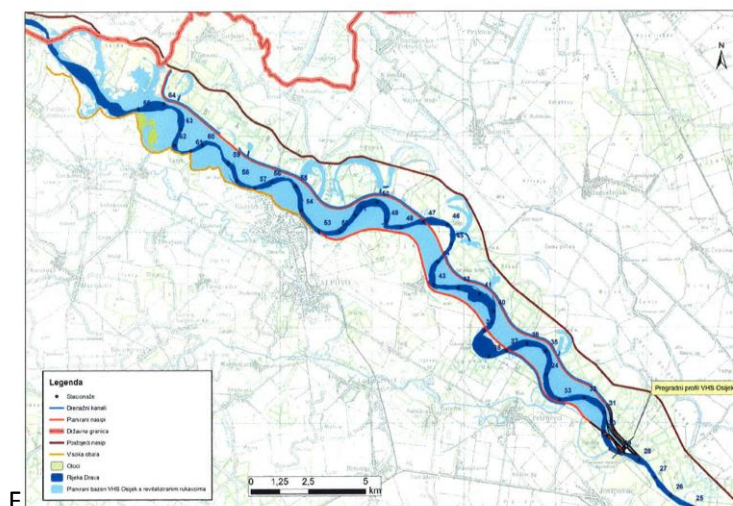


Figure 33: VHS Osijek extent of accumulation. From: Višenamjenski hidrotehnički sustav „Osijek“ (2012), HEP study.

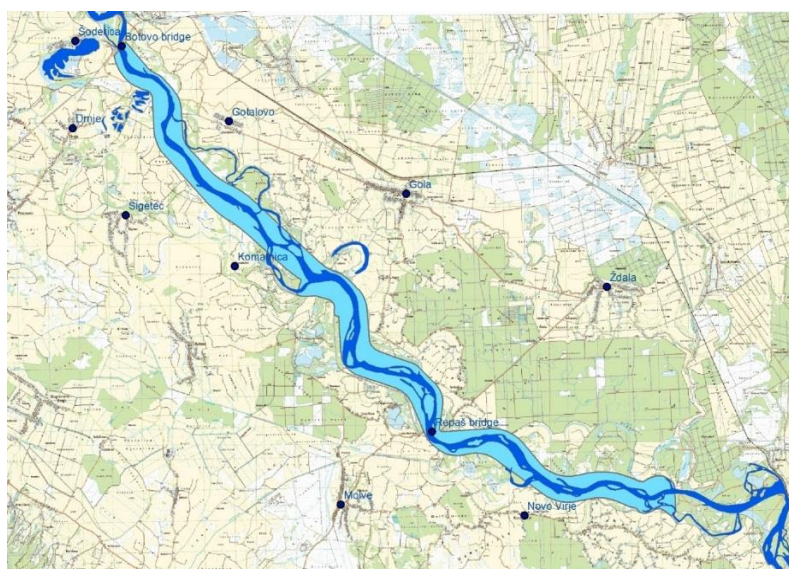


Figure 34: HEPP Molve 1 and 2 extent of accumulation. Alerić, S. et al. (2012): Program iskorištenja slobodnog hidropotencijala u Republici Hrvatskoj. Hrvatska komora inženjera građevinarstva, Zagreb-Opatija.

All projects are presented as multipurpose projects (see footnotes on page 39), with the following benefits:

- Flood protection
- Stabilisation of the Drava river bed
- Electricity production
- Protection of the surroundings – provision of both surface water and underground water of good quality
- Opening of the possibilities of preserving and restoring natural assets on the Drava River
- Recreation and sports
- Transportation
- Agriculture, fishery

Technical comparison of proposed and existing hydroelectric power plants (HEPPs) on the Drava River.

The proposed and existing HEPPs (Production Area Hydropower Plants North – PAHPP North) on the Drava River in Croatia have been compared in terms of their selected technical parameters relevant for the environmental impact of the construction.

A simple formula for approximating electric power production of a hydroelectric plant is:

$P = \rho h r g k$, where:

- P is the power in watts;
- ρ is the density of water ($\sim 1000 \text{ kg/m}^3$);
- h is the height in meters;
- r is the flow rate in cubic meters per second;
- g is the acceleration due to gravity of 9.8 m/s^2 ;
- k is the coefficient of efficiency, ranging from 0 to 1. Efficiency is often higher (i.e. closer to 1) with larger and more modern turbines.

The height in metres, also stated as *head*, depends of the difference of water level between the accumulation and the turbine inflow. To get a sufficiently high *head* in a relatively flat countryside, where the river slope is small, it is necessary to build reasonably long accumulations in order to ensure substantial water surface above the level of the surrounding terrain, or to combine accumulation with the derivation canal, where the *head* can be increased via the positioning of the power plant in this canal. Such a solution also requires lateral dams, which influence the cost of investment and make this type of HPP less economically favourable than the HPPs situated in steep valleys (canyons).

Because the proposed HEPPs are situated in river segments with lower slopes (when compared to PAHPP North), and they do not have derivation canals, they have to be relatively longer (14, 15 and 35 km, whereas PAHPP North accumulations are 3, 8 and 10 km long) and larger in area (5,616 ha compared with 3,069 ha; Table 3). Despite these construction projects, the total installed power of 114 MW represents only 46% of PAHPP North (246 MW).

As a consequence of these technical solutions, one can conclude that the proposed HEPPs would require larger areas of floodplain ecosystems to be altered, when compared with the HEPP North. We can roughly estimate such impact from the length of the river that would be lost under the accumulations, or from the area of the floodplain ecosystem that would be destroyed. This impact would not be compensated by higher electricity production; quite to the contrary, the installed electricity production is substantially lower due to the geomorphological limitations.

Table 3: Comparison of technical parameters of existing accumulations of PAHPP North and the proposed accumulations on the river Drava in Croatia.

Technical data of Drava Hydroelectricity power plants					
	Parameter	Value	Unit		
HE Varaždin	Location	309-298	river km	HE Molve 1	213
	Area	259	ha		870
	Length, width	3 x 1	km		12,6 x 0,7
	Volume at average throughflow	8	mil.m3		
	Head	20-24	m		5,85
	Installed power	2 x 47 (94)	MW		47
	Annual average production	435	GWh		235
HE Čakovec	Location	288-267	river km	HE Molve 2	199
	Area	1150	ha		1006
	Length, width	8,6	km		14,2 x 0,7
	Volume at average throughflow	51	mil.m3		
	Head	16-19	m		6,30
	Installed power	2 x 38 (76)	MW		51
	Annual average production	340	GWh		248
HE Dubrava	Location	267 - 242	river km	VHS Osijek	29 - 65
	Area	1660	ha		3740
	Length, width	10,2	km		35,5 x 1
	Volume at average throughflow	93,5	mil.m3		190
	Head	16-20	m		3.3 - 7.4
	Installed power	2 x 38 (76)	MW		16,3
	Annual average production	340	GWh		237,4
PPHE north in total	Installed power	246	MW	Proposed HE in total	114,3
	Annual average production	1428	GWh		720,4
	Total area	3069	ha		5616

The impact of proposed HEPPs on biodiversity and ecosystem services will be the subject of the following chapters.

3.3. Alternative scenarios for ES evaluation in PSA

For the purpose of ES evaluation in comparison with alternative development opportunities for the PSA, three scenarios have been defined:

- A – state *as-is*
- B – state with hydropower accumulations
- C – state of sustainable use

3.2.1. State as-is

This scenario corresponds to the present state of the PSA, and it is described in previous sections. It should be understood having in mind the present trends, given the fact that it includes the deepening of the Drava river bed, and the consequential decrease of floodplain forest growth.

3.2.2. State with hydropower accumulations

The position of HEPP Molve 1 and 2 is shown on Figure 33, and its technical parameters are provided in Table 3. The variety of impacts of this scenario on floodplain ecosystems and ecosystem services will be described in the following chapters.

3.3.3. State of sustainable use

This scenario is based on measures aimed at the harmonisation of ecosystem services, economic development and nature protection. This scenario is based on the following:

- Extension of the area of active floodplain, i. e. the inundation zone, into the areas that contain the original and still preserved floodplain land cover (wetlands, meadows and floodplain forests). This extension and land cover changes are not related to the ownership structure, and no assessment has been done about the feasibility of this scenario; however, it corresponds to the proposed LIFE project (Michor et al., 2013); Figure 35.
- Support to extensive agriculture management (grazing, hay production);
- Improved access for visitors and support to tourism.

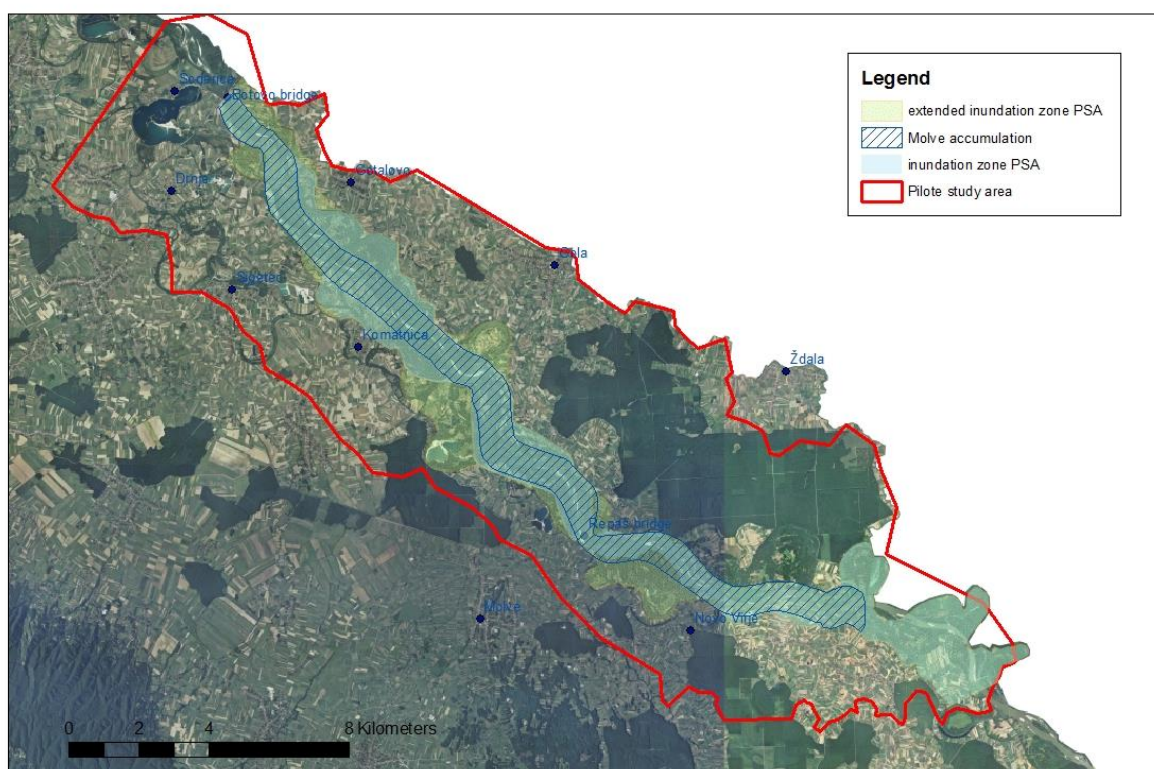


Figure 35: Location of Molve 1 and Molve 2 accumulations (scenario B), the present inundation zone (scenario A), and the extended inundation zone (scenario C).

4. Meetings with relevant stakeholders and experts

Stakeholders have been identified for the purposes of contacting them, and they have been asked to participate in the process of analyzing the use of services and benefits of the river and floodplain ecosystems. They have also been asked about their opinions and attitudes to the proposed development projects. Given the fact that electricity production was not taken into account as an ecosystem service in this study (because of the need for total alteration of the existing ecosystem that all other services are related to), HEP was not included as a typical stakeholder.

The following set of meetings with stakeholders and relevant experts took place:

State institutions – national level

Ministry of Environmental and Nature Protection – April 2013; April 2014 – *introduction of SFES, support of the Ministry, establishment of regular reporting about the project progress; incentives and subsidies in the floodplain area, study presentation and finalisation.*

Croatian Waters, Zagreb, July 17, 2013. Present: Zoran Đuroković, B.Sc.C.E, Head of the Flood Defence Department; M.Sc. Sanja Barbalić, Head of the Water Management Institute; Darko Barbalić, B.Sc.C.E and Vesna Grizelj Šimić, B.Sc.C.E from the Development Sector; Nataša Tomić-Strelec, B.Sc.C.E and Tomislav Šlehta, B.Sc.C.E from the Water Management Department Varaždin; Samra Polić, B.Sc.C.E and Tomislav Novosel. *Flood protection aspects, floods in Croatia – trends, risks.*

SINP, Zagreb, June 27, 2013. Present: Biljana Barić, B.Sc.Biol. (Senior Advisor, Department for Nature Impact Assessment – SEE River Project) - *Project for Sustainable Integrated Management of International River Corridors in SEE Countries.*

SINP, Zagreb, July 16, 2013. Present: M.Sc.Vet.Med. Jasna Jeremić, Head of the Domesticated Taxa Section, Department for Wild and Domesticated Taxa and Habitats. *Indigenous breeds in Croatian floodplains.*

SINP, Zagreb, July 17, 2013. Present: M.Sc.Geol. Neven Trenc, Head of the Evaluation of Admissibility of Intervention to Nature Section, Department for Nature Impact Assessment. *Hydrogeomorphology of river Drava and impact of HPP Varaždin.*

SINP, Zagreb, July 18, 2013. Present: Vida Posavec Vukelić, M.Biol. Head of the Flora Section; dr.sc. Igor Boršić, Expert Advisor, Department for Wild and Domesticated Taxa and Habitats. *Botanical aspects of PSA Molve.*

SINP, Zagreb, July 19, 2013. Present: M.Sc. Vlatka Dumbović Mazal, Head of the Vertebrates Section, Department for Wild and Domesticated Taxa and Habitats. *Ornithological aspects of PSA Molve.*

SINP, Zagreb, July 19, 2013. Present: Aljoša Duplić, M.Ed., Head of the Introduction and Reintroduction Section, Department for Nature Impact Assessment. *Ichthyological aspects of PSA Molve.*

Institute for tourism and the Ministry of Tourism, Zagreb, February 6, 2014. Present: Dr.sc. Hrvoje Carić (Institute for Tourism) and M.Ec. Jelena Šobat (Head of the Department for Protection of

Tourism Resources and Sustainable Development in the Ministry of Tourism) – Ecotourism issue in continental Croatia.

State institutions – regional level

Croatian Waters Varaždin, Varaždin, June 2013. Present: Emil Flajšman, B.Sc.Biol. (Biologist, Croatian Waters, branch office Varaždin) – *monitoring of water quality in Varaždin County, data acquisition, functioning of existing hydropower reservoirs, maintenance of old Drava river bed, hydrological monitoring.*

HEP Proizvodnja Ltd PP HE Sjever, Varaždin, June 2013. Present: Ivančica Somođi, B.Sc.C.E. (Environmental Coordinator) – *positive and negative impact of Varaždin reservoirs on environment and people, water manipulation in the system, sediment deposition, water quality, environmental activities of HEP, functioning of hydropower accumulations. Full day excursion around the lakes, technical facilities, flood experience, recreation at the reservoirs.*

Agricultural Advisory Service, Branch-office of Koprivnica-Križevci County in Križevci, June 20, 2013. Present: Slavko Kopilović, B.Sc.Agr. (Head of the Branch Office in Križevci) – *Prospect of agriculture in Koprivnica-Križevci County.*

Croatian Forests (CF), Regional forestry office in Repaš, Repaš, June 18, 2013. Present: Zvonimir Ištvan, B.Sc.in Forestry (Head of the Forestry office in Repaš) and Đurđica List, B.Sc. in Forestry (Head of the Forest Ecology Department in the Forestry Administration in Koprivnica) – *Forest management, sustainability, impact of HP Molve.*

CF, Regional forestry office in Varaždin, Varaždin, June 18, 2013, Present: Mario Vlašić, B.Sc. in Forestry (Head), Zvonko Kranjc B.Sc. in Forestry (Forester) – *Forest management, sustainability, impact of HPP Molve.*

Croatian Sport Angling Union, Association of Sport Angling Clubs (ASAC) in Đurđevac, Đurđevac, June 21, 2013. Present: Ivica Vrabec (President) and Siniša Filipović (Secretary) – *Fish angling in Drava River, impact of the proposed HPP Molve.*

CW (Hrvatske vode), Zagreb, July 17, 2013. Present: M.Sc. Marija Marjanović Rajčić, Head of the Central Water Management Laboratory. *Water chemistry and quality monitoring and reporting.*

Regional administrative and local inhabitants

Institute of Physical Planning Koprivnica-Križevci County, Koprivnica, May 2013. Present: M.Sc. Mladen Matica (Assistant Director) – *future visions for Koprivnica-Križevci County, positive and negative impacts of planned hydropower plants on environment and people, need of sustainable development strategies, GIS data sources.*

Public Institution for Management of Protected Areas in the Varaždin County, Varaždin, May 2013. Present: Sanja Kopjar, B.Sc.Agr. (Head of Expertise department) – *history and functioning of the Regional Park Mura-Drava, nature protection, positive and negative impacts.*

Molve local inhabitants, Molve, June and July 2013. Present: Tihomir Jakopović (member of family providing private accommodation in Molve) – *social problems in the Molve area, sustainable*

development of the area and its future prospects, costs and benefits of hydropower projects for the local community. Zdravko Ivančan Mag.ing. (Agriculture Engineer, candidate for the Head of the Municipality Molve) – prospects of sustainable development.

Molve catholic parish: Molve, May and June 2013: Tomislav Glavnik, OFM Conv (catholic priest in Molve) – *social problems in the Molve area, sustainable development of the area, modernisation of agriculture, irrigation, use of renewable energy sources, benefits of hydropower projects for the local community.*

Municipality of Molve, Molve, June 21, 2013. Present: Zdravko Ivančan (Mayor), Nevenko Jakopović (President of the Hunting Union of Koprivnica-Križevci County), Mijo Kovaček (Head of the Angling Club Šaran in Molve), Mirko Paša (Mayor Deputy) – *attitude of the Municipality to the planned HPP Molve, hunting and angling in PSA, sustainable development in the Molve area.*

Naive Art Gallery Hlebine, Hlebine, June 24, 2013. Present: Sanja Vrgoč (museum technician) – *naive art and its inspiration in Drava Floodplain ecosystems, economic importance of naive art.*

Non-government organisations and independent experts

NGO Prirodoslovno društvo Drava. Ivan Darko Grlica, Virovitica, April 2013, March 2014 – *Flood dynamics, flood mitigation of the Drava river in Koprivnica-Križevci County, nature values and protection, illegal cottages at the river, present river management and its alternatives.*

UNDP, Zagreb, April 2013. Present: mr.sc. Sandra Vlašić (Programme Officer) – *project introduction and progress, sustainable development in Croatia, renewable energy sources, social aspects in rural areas.*

UNDP-Croatia, Zagreb, June 19, 2013, Present: M.Sc. Robert Pašičko (Project Development Specialist) – *renewable energy production in Croatia, prospects for PSA.*

CEE Bankwatch, Prague, July 3. 2013. Present: Petr Hlobil – *construction aspects of the proposed hydroelectric power plants on Drava River.*

Goran Šafarek, B.Sc.Biol. (Freelance Biologist, various NGO's, Koprivnica), Molve, June 22, 2013 and March 2014 – *Drava River floodplain, possible prospects for its future, ecosystem services.*

Mijo Kovačić (painter), Gornja Šuma near Molve, June 24, 2013 – *naive art and its inspiration in Drava Floodplain ecosystems, economic importance of naive art.*

Private companies

Komatnica Horse Riding Club, Komatnica, June 22, 2013 – *sustainable tourism in the Molve area.*

Universities

Faculty of Science, University of Zagreb, Zagreb, April 2013. Present: prof. dr. sc. Milorad Mrakovčić (Faculty of Science, University of Zagreb), dr. sc. Marko Čaleta (Assistant Professor, Faculty of

Education, University of Zagreb) – *hydrobiological monitoring of Varaždin reservoirs, impact on fish communities, water quality in Varaždin reservoirs, angling.*

Faculty of Forestry, Zagreb, June 2013. Present: dr. sc. Stjepan Mikac (Senior Assistant Research Fellow) – *floodplain forest management, monitoring of underground waters, impact of underground water levels on wood increment and timber production. Alternative scenarios for ES evaluation in PSA.*

5. Ecosystem services of DSDF and PSA

5.1. Identification of relevant ecosystem services

Ecosystem services relevant and/or important for Drava-Sava-Danube floodplain (DSDF) ecosystems and the PSA have been indicated and formulated during the stakeholder meetings and the final brainstorming session in SINP, and are listed in Table 4. Ecosystem services are divided according to the classification used in the Millennium Ecosystem Assessment (2005). Among the ecosystem services identified as relevant, eight have been chosen for evaluation. Those not evaluated were in the end omitted for a variety of reasons, but mainly because of inaccessible data (carbon sequestration), unclear methodology (air purification, climate stabilisation), or simply because of time constraints and limited financial resources for this study. Electricity production was not taken into account as an ecosystem service in this study (because of the need for total alteration of the existing ecosystem that all other services are related to).

During the stakeholder meetings, we discovered that timber production is the most clearly perceived ecosystem service. That is due to the fact that decrease of that service is detectable, it has an economic impact, and it is understood as an ecosystem service – i.e. it is connected with the state of the river and interconnected underground water dynamics.

Table 4: Ecosystem services identified as relevant for DSDF and PSA.

List of Ecosystem services relevant for Drava Sava Danube Floodplains					
	Ecosystem service	Highly relevant	Relevant	Evaluated	Not evaluated
Regulating	Flood mitigation	•		•	
	Balance of erosion and accumulation		•		•
	Nutrient retention and water self purification	•		•	
	Carbon sequestration		•		•
	Local climate regulation		•		•
	Air purification		•		•
	Drought mitigation, water storage	•			•
Supporting	Habitat and biodiversity provision	•		•	
	Biocorridor provision		•		•
Provisioning	Timber production	•		•	
	Biomass energy		•		•
	Fish production	•	•		
	Game animals production		•	•	
	Drinking water supply	•		•	
	Irrigation water supply		•		•
	Agriculture production		•		•
Cultural	Esthetic value of landscape	•	•		
	Recreation/Tourism	•		•	
	Naive art inspiration		•	•	
	Raw material for local crafts		•		•
	Habitats for indigenous breeds		•		•

5.2. Evaluation of particular ecosystem services

5.2.1. Regulating ecosystem services

5.2.1.1. Flood mitigation

Definition of service, its importance and relevance for the ecological status

Flood mitigation is the ability of ecosystem to decrease the flood hazards by transforming the flood wave. A prerequisite of this function is overbank flow; i.e. the possibility of flooding within the floodplain area. Other parameters, like river bed structure or route, cease to have an impact on larger flood dynamics. The parameters of flood dynamics, which can be influenced by the floodplain ecosystem (or any man-made retention space), include the value of maximum discharge (peak of the

flood wave in the hydrogram) and time shift (delay) of maximum discharge. The most important factors influencing peak reduction include the slope, width and roughness of floodplain (Habersack et al., 2013). Within the schematic floodplain model, doubling the width of the floodplain results in changes to peak reduction of approximately 25%; change in roughness (light shrubbery to dense willows) results in peak reduction of up to 50% (Habersack et al., 2013). Whereas the slope is constant for any given river section, the width of the active floodplain is frequently determined by dyke position (Figure 1 on page 10) and the roughness of the vegetation cover. These parameters also have an effect on flood wave translation (water retardation), which is important in flood risk management because of the prolongation of time required for the preparation for flood (Valentová et al., 2010). Both of these latter parameters can be influenced by the river and floodplain planning and management.

If the flood mitigation effect is expressed as a percentage of lowering the peak discharge per one kilometre, floodplains of the similar character as DSDF can reach up to 2.25 % (the value of that indicator is 1.64 % HQ₁₀₀ flat type at the 40 km section of the upper Danube to Vienna near Tullnerfeld; Schober et al., 2013). Dostál et al. (2013) calculated this effect for three floodplains in the Czech Republic, with the values for Q₁₀₀ in the range of 0.2% to 0.6%. These calculations show that a sufficiently long section of floodplain with the mitigation potential can remarkably reduce the peak discharge.

Good ecological state of floodplain is mostly corresponding with the flood mitigation potential, because ecosystem connectivity is ensured in case that flood pulses reach the floodplain area; it is beneficial if agriculture management in the area is adapted to regular inundation.

The economic importance of flood protection is growing with climate change. The need to mitigate hydrological extremes is growing rapidly, and using ecosystems as a tool for such mitigation is in accordance with the EU Floods Directive 2007/60/EC, requiring space for rivers and the use of near-nature measures to tackle this problem (Pedersen et al., 2007).

Situation in DSDF and PSA

DSDF area includes relatively large and preserved floodplain areas, where the floods can be mitigated (Figure 8 on the page 19). Brundić et al. (2001) evaluated the central Sava basin and quantified the potential of both the existing and planned sub-basins, in terms of their area and volume (116,775 ha; 2,124 billion m³), which makes this area the largest floodplain ecosystem in the Danube river basin. The largest complexes include Kopački rit, Odransko polje, Lonjsko polje (23,700 ha; storage capacity 634 billion m³), Mokro polje (22,294 ha; storage capacity 611 billion m³), Kupčina (22,242 ha; 203 billion m³), and the lower section of the Drava River upstream of Osijek, where the dykes keep their distance from the river and form a corridor 2.5-3.5 km wide. Babbist et al. (2006) compared the present state and two different plans of enlargement and operation of the Lonjsko polje detention system, which also includes the proposed derivation canal protecting the capital city of Zagreb from extreme floods, and they concluded that this system is advanced at the European level, and that it may serve as an example of good practice for other countries.



Figure 36: Flood storage capacities in Gajna nature reserve near Slavonski Brod, April 2012.

Applying the FEM method (floodplain evaluation matrix; Habersack et al., 2013), it can be concluded that DSDF areas are mostly floodplains with a good potential of flood mitigation along their entire stretches. This is the consequence of combination of their low slope, large width and high roughness (with preserved floodplain forests in core zones). This is also the case with the floodplain in the PSA (Figure 1 on page 10 and Figure 12 on page).

When it comes to the hydrological regime of the rivers Drava, Sava and Danube, one should note that the rivers Sava and Danube have a pluvio-nival regime, with the discharge that peaks in winter and spring. The Drava River has a nivolo-pluvial regime, with peaks in summer. Extreme discharges are driven by the precipitation upstream, in Austria and Slovenia, with the precipitation in Croatia being of minor importance.

Drava hydrological regime is strongly influenced by a set of hydropower accumulations – 3 in Croatia, 8 in Slovenia and 12 in Austria.

Flood risks around the Drava, Sava and Danube rivers are not very high, given the fact that village settlements mostly respect the extent of inundation, while the towns such as Varaždin and Osijek are relatively well protected. The river segment without dykes is also naturally protected, and one cannot argue that the settlements in such areas are more vulnerable, because the houses are built on naturally elevated sites.

However, possible enlargement of active floodplain (inundation zone) is being considered by the Croatian Waters. Some cut-off meanders might be reconnected and revitalised, which could result in an enlargement of inundation. That would be in accordance with the European policy “more space for the river”. The replacement of dykes should also be considered in the future.

During the meeting with the representatives of the Croatian Waters, these representatives expressed the opinion that the river Drava is in a good state, both ecologically and in terms of the preparation for hydrological extremes; therefore, it should be taken into account as part of the natural heritage, and preserved in such state.

Mitigation of the flood of 7th November 2012 on the Drava River

In November 2012, extensive flood wave came from the upper Drava section (in Austria and Slovenia). At its inflow to Croatia, the discharge of the Drava River was $2,800 \text{ m}^3 \cdot \text{s}^{-1}$; however, after the partial transformation in the Varaždin accumulation, it was reduced by reservoirs and intersected floodplains (around the old Drava river bed) to $2,000 \text{ m}^3 \cdot \text{s}^{-1}$. The duration of the flood wave was not long (it lasted one day), so the flood wave was gradually mitigated to harmless discharges, and did not cause substantial damage. Down to the Dubrava accumulation, the flood wave was still extreme, having the peak discharge of $1,639 \text{ m}^3 \cdot \text{s}^{-1}$ at the Donja Dubrava profile (Figure 36). After the confluence with the Mura River (Figure 37), peak discharge increased to $1,925 \text{ m}^3 \cdot \text{s}^{-1}$ at the Botovo bridge profile. Since that time and profile, the peak discharge was gradually lowering (Figure 38) to 70% of its value, which was measured at Belišće with five days delay (Table 5). After that, the flood wave outflow moved in the direction of the largest storage area on the Drava River, Kopački rit.

Table 5: Flood mitigation along the Drava River, reaching 30% decrease in 5 days delay at 172 rkm; November 7-12, 2012. Source: Croatian Waters, raw data.

Flood mitigation	Peak Discharge	Unit	Date	river km
Botovo	1925	m ³ /s	7 11 2012	226
Belišće	1364	m ³ /s	12 11 2012	54
Lowering of the peak	30	%		
Flood wave translation	5	days		
River km	172	km		
Lowering of the peak per km	0,17	%		



Figure 37: Flood of November 7, 2012, under the Dubrava reservoir (rkm 241). Selnica Podravska village can be seen in the front (Photo: Darko Grlica).



Figure 38: Flood of November 7, 2012 – dykes at the confluence of Mura and Drava (rkm 237) in the front (Photo: Darko Grlica).

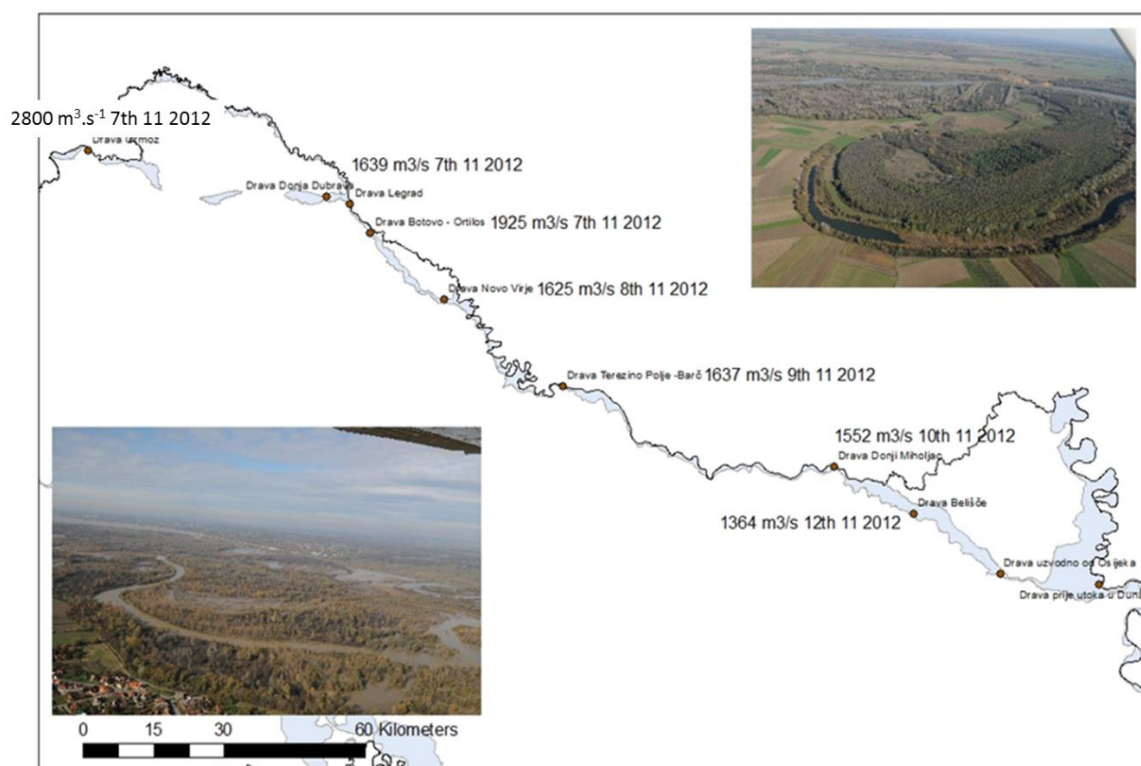


Figure 39: Flood mitigation along the Drava river, showing the peak discharges at monitoring profiles and peak discharge days. Photo below left – flood under Dubrava on 7th November. Upper right – the Drava River at Ferdinandovac on the day before the flood came (Photo: Darko Grlica).



Figure 40: Flood of November 7, 2012, river km 220 – extended floodplain with a large flood storage capacity, near Sigetec (Photo: Darko Grlica).

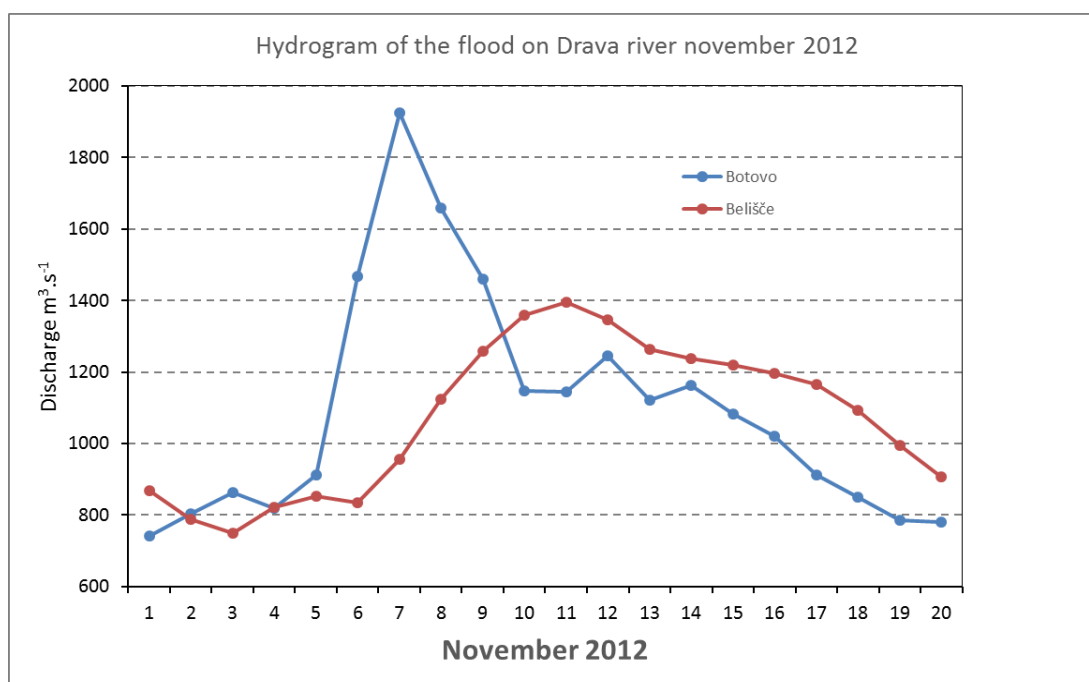


Figure 41: Hydrogram of the flood wave on the Drava River for November 2012. The transformation of the flood from the profile at Botovo to Beliše took place via the lowering of the peak by 30% and translation for 5 days.

The dynamics of the flood of November 2012 clearly show the effectiveness of Drava floodplains in the lowering of peak discharge and the translation of the flood wave (Figure 37). Sufficient flood storage capacities and a high level of roughness (Figure 38) are prerequisites for this ecosystem service.



Figure 42: Flood of November 7, 2012, rkm 207; photographed downstream of the Repaš bridge. High roughness of the floodplain surface positively influences the flood wave translation (Photo: *Darko Grlica*).

There is no doubt that different sections (compartments) of the river and its floodplain contributed to the final transformation in highly diverse ways (Schober et al., 2013), and that proper evaluation should distinguish between these areas in order to define the most important flood storage capacities, so as to protect them or enlarge their capacity.

Quantification of flood storage capacity and economic evaluation

Proper evaluation of the floodplain mitigation effect should be done via 1D, rather than 2D hydrological modelling (Dostál et al., 2013, Valentová et Valenta, 2003). This requires a 3D model of terrain and specialised software (David et Dostál, 2013); however, such an analysis would be outside of the scope of this study. For that reason, we focused on calculating the area and volume of inundation zones in the PSA for scenarios A and C, together with Molve 1 and Molve 2 accumulations for scenario B.

In scenario C, we extended the floodplain in the PSA by a virtual transfer of dykes to the areas where:

1. Land cover was formed by wetlands, standing waters, or meadows
2. There were sharp curves of dykes, which were smoothed
3. There were no settlements (Figure 38). The area of inundation increased from 3,811 ha in scenario A to 4,617 ha in scenario C (Table 6 on page 56).

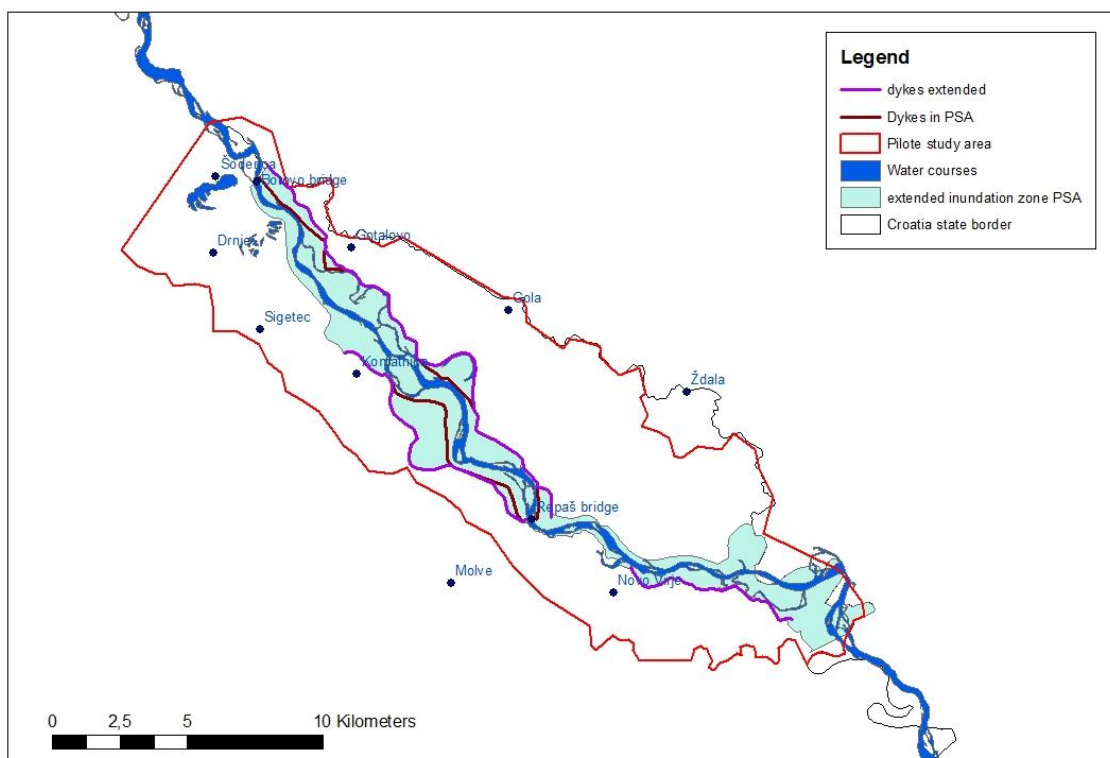


Figure 43: Extended floodplain in scenario C. The existing dykes are in brown, and they delineate the extent of the floodplain in scenario A; extended dykes are in violet.

To calculate the areas, we obtained data on the extent of inundation zones (Source: Croatian Waters, 2013) (Figure 43); the depth of inundation was estimated from the longitudinal profile of the Drava River as a difference between the basic water level and the water level for regulation (capacity of the river bed), and as a difference between the water level for regulation and the height of banks and dykes (capacity of inundation).

For economic evaluation, we used the *shadow project* method, based on the comparison with the cost of technical structure (the proposed accumulation) that would provide a comparable flood storage volume in Croatia. We took into account the cost of retention of cubic meter in the planned VHS Osijek (the cost of the whole project without the electric power station, i.e. including land purchase), which is at 2,269 million HRK (408 million USD). The proposed total volume is 190 million m³. The retention volume is not stated in this study; this volume also depends on the manipulation order and on the particular situation in a given moment. Providing that the manipulation can decrease the volume to 50% of the total volume (which is a very optimistic scenario, given the fact that the available volume would be much lower due to the need to produce electricity), we can assume that the retention volume would be 95 million m³ (Višenamjenski hidrotehnički sustav „Osijek“, 2012). In such a case, the cost of storage in this accumulation would be 4.29 USD per m³. By comparison, the median cost per m³ in polders in the Czech Republic is 7.1 USD (Černý, 2011). The costs vary very much based on the size and technical components of the project.

Dividing the total value by area and discount rate (Seják et al., 2003), we can also express the value in the form of monetary flow per hectare per year (Table 6).

	Inundation scenario A	River bed storage	Scenario A in total	Scenario B	Inundation scenario C	Scenario C in total	VHS Osijek
Area (ha)	3811	706	3811	1876	4617	4617	3740
Max depth (m)	4	2		2,5	4		2,5
Volume (mil.m ³)	152,4	14,1	166,6	46,9	184,7	198,8	93,5
Cost of m ³ €	3,17	3,17	3,17	3,17	3,17	3,17	3,17
Value €.ha ⁻¹ .yr ⁻¹	6340	3170	6927	3963	6340	6825	3963
Value \$.ha ⁻¹ .yr ⁻¹	4594	2297	5020	2871	4594	4945	2871
Total value mil. \$.yr ⁻¹	24,16	2,24	26,40	7,43	29,27	31,51	14,82

Table 6: Area, volume and value of ecosystem service – flood mitigation – in scenarios A, B and C. Note that the numbers in red would be paid by taxpayers, whereas the values in black are obtained from the ecosystem in its present state.

The comparison of volumes of inundation with volumes of accumulation can provide only an approximate idea on how a particular flood can be transformed. The transformation in accumulations is always managed by regulating the outflow – maximising the outflow before the expected peak discharge, and then minimizing it during the peak. Using this measure, the peaks of floods can be sufficiently lowered. The efficiency of transformation depends on the time for preparation, retention volume of the accumulation, and – which is very important – on the character of the flood wave. With increasing length of the flood wave, effective manipulation of the discharge will be increasingly limited. In addition, floodplain storage capacities can be fully used during long floods; in such a case, the roughness of the floodplain can be an important factor in terms of slowing down the movement of the flood wave.

The value of flood mitigation service, if expressed in monetary flow per ha per year (5,020 USD), is comparable with the estimate of Costanza et. al. (1989, Table 1) for the service referred to as disturbance regulation, which is evaluated at 7,240 USD on average. Pithart et al. (2010) evaluated this service in a near nature preserved floodplain of the river Lužnice at 12,000 USD; in both cases, this service belongs to economically most important services in floodplains.

The evaluation of DSDF is outside of the scope of this study. The only figure available at the moment is the area of inundation zones (1,588 km²) in DSDF. Calculation of the volume without a proper 3D model of terrain could be misleading, and on top of that, as has been said, it would not necessarily correspond with the real transformation effect. It is beyond dispute that the definition of important storage capacities within DSDF, their protection and possible enlargement should constitute a priority for future water management.

The floodplain inundations are also very important for groundwater recharge, as will be discussed in Section 5.2.3. This process has not been studied in great detail, but it will surely be in the focus of researchers given the climate change and continuous decrease of aquifer levels. Among the issues of

future high importance, we can also mention the comparison of groundwater recharge in floodplains with permeable river bed and flood pulses with overbank flows, and groundwater recharge in the area of reservoirs with bottom permeability colmated (blocked) by fine sediments.

5.2.1.2. Nutrient retention

Introduction. Nutrient retention is the ability of an ecosystem to store the excess of nutrients (nitrogen and/or phosphorus) via biological, biochemical and geochemical processes in biomass (both living and dead) and soil mineral compounds (Turner et al., 2008). Slowing down the adverse nutrient transport within the watershed by nutrient retention provides the benefit of improving the water quality downstream and preventing the eutrophication process in rivers and their recipients (lakes, reservoirs and seas). Wetlands and natural floodplains are reported as important nutrient sinks, but their capacity to store nutrients is limited; if the potential is exceeded, such areas can be degraded, coupled with the release of nutrients.

Nutrient retention in rivers and floodplains depends on their geomorphological and ecological state. Contact of water with surfaces such as gravel, sand and plants is crucial, as well as sufficient delay of water in flood detention areas. Overbank flows cause remarkable decrease of flow velocity and sedimentation of suspended particles (Figure 44), which may in turn serve as a natural fertilizer for floodplain meadows. The sufficient delay allows the growth of periphytic algae (Figure 45), which take up nutrients from the water and complete the sedimentation of all suspended particles (Figure 46). Succession stages of vegetation growth enable natural absorption of available nutrients: Kiedrzyńska et al. (2008) quantified the increase of TP retention after the planting of fast growing patches of willows at 30%.

The overall nutrient balance in natural floodplains and floodplains converted to agriculture may be totally different. Pedersen et al. (2007) quantified the nutrient transport before and after revitalisation (conversion of agriculture floodplain into wetland areas) on the Danish river Skjern (a 40 km segment). Before revitalisation, the annual discharge of TN of this entire floodplain was 132 tN.year⁻¹ and 10.6 tP.year⁻¹; after the revitalisation, the discharge was negative – i.e. retention was 13 tN.year⁻¹ and 5 tP.year⁻¹, which represents approx. 10% of the annual river transport.



Figure 44: Fine sediment deposition of river suspended sediment on the surface of Drava floodplain near Molve.



Figure 45: Periphytic algae overgrowing the surfaces of flooded plant vegetation. The growth of these algae requires dissolved nutrients from water, and represents a component of self-purification system. After the retreat of flood, the algal biomass will be incorporated into the floodplain soil. Posavina, April 2014.



Figure 46: Standing water after complete sedimentation (compare Figure 45 left) during spring inundation, with growing freshwater algae mats. Posavina, April 2014.

Situation in DSDF. The Danube River is an important source of Black Sea pollution. High nutrient loads and their consequences have been recognised in a number of studies and articles. Schreiber (2005) quantified the total emission of the Danube to the Black Sea as 756 kt TN.year⁻¹ and 68 ktP.year⁻¹. The proportion of background natural emission constitutes only about 10% of this amount, pointing to the fact that human activities are remarkable drivers behind this transport. The Croatian rivers Drava and Sava belong to important contributors, due to their high annual water discharges. Their average water quality classifies them into the second water quality class (individual sections of the Sava River are on the border between the second and the third class), according to Croatian water quality standards⁷. The negative impact of transformed floodplain segments

⁷Izveštaj o stanju površinskih voda u Republici Hrvatskoj u 2010. i 2011. godini. (Source: Croatian Waters).

(including intensive agriculture and reduced active floodplain – down from Terezino Polje to Višnjevac, and in the Varaždin area as well) are illustrated in Figure 47.

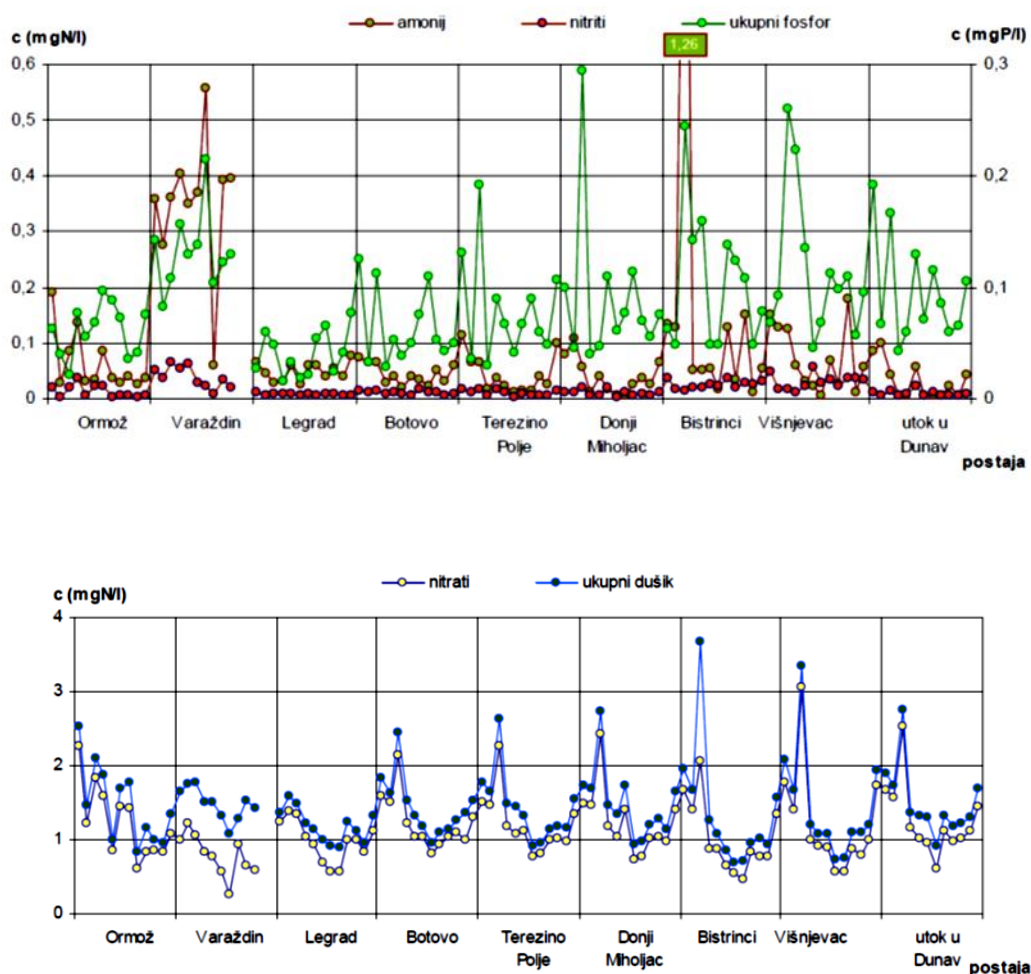


Figure 47: Annual course of ammonia nitrogen, nitrites and total phosphorus (top), and nitrates and total nitrogen (bottom) on profiles of the Drava River in 2010⁸.

There is an overall agreement among all the countries concerning the nutrient loads from the Danube basin to the Black Sea: all Danube river basin countries contribute nutrient loads to the Black Sea, as demonstrated by the results of various water quality model simulations (Figure 48). Pollution reduction is a common task of all Danube river basin countries⁹. This means that all countries agree to strengthen their efforts in order to implement the necessary steps for reduction of water pollution, not limited to the local hot spots, but also covering the reduction of water pollution by nutrients which have adverse transboundary effects and a negative impact on the water quality in the Black Sea (Niemayer et al., 1999).

⁸ Izvjestaj o stanju površinskih voda u Republici Hrvatskoj u 2010. i 2011. godini. (Source: Croatian Waters) .

⁹ Convention on Cooperation for the Protection and Sustainable use of the Danube River (Danube River protection Convention, 2008).

Danube River Basin District: Risk of failure to reach the Environmental Objectives - Nutrient Pollution

MAP 13

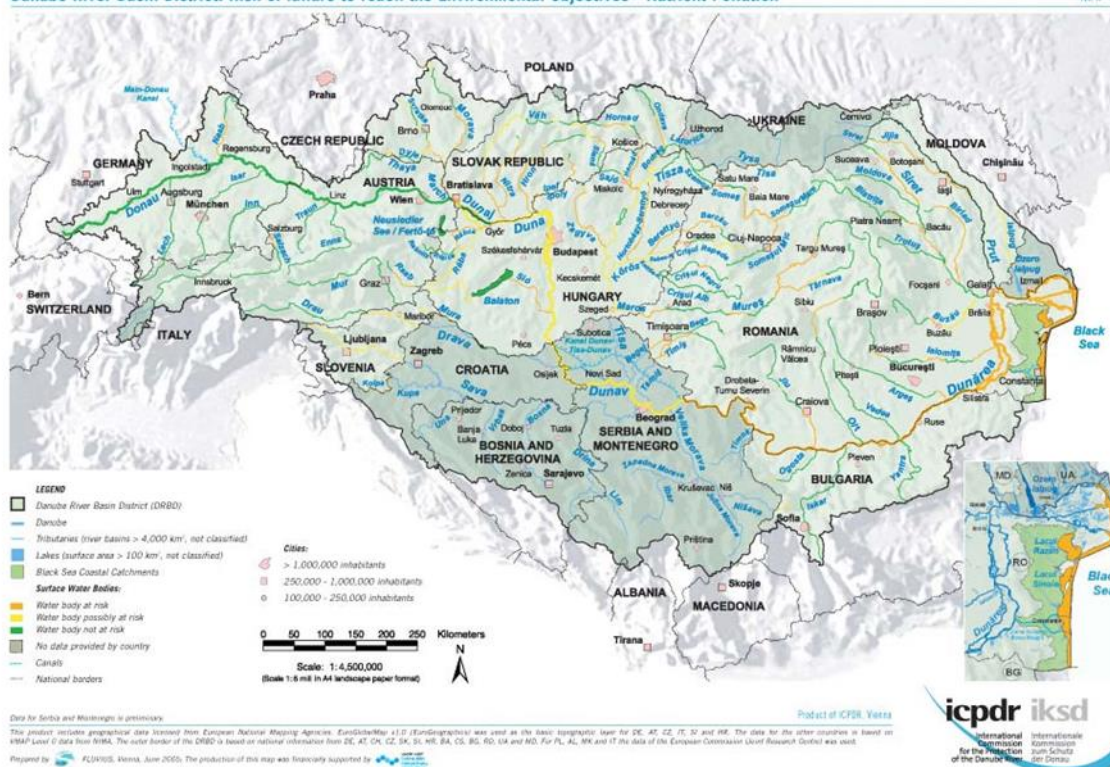


Figure 48: Segments of the Danube basin rivers according to nutrient pollution (Niemayer et al., 1999).

In order to reduce nutrient loads in the Danube basin, the preservation and restoration of wetlands represent one of the principal tools (together with investments in wastewater cleaning stations, etc.), and international strategies have also been developed (Niemayer et al., 1999). The Transboundary Analysis Workshop identified "Significant Impact Areas" in the Danube river basin (Niemayer et al., 1999), as areas that are most intensively receiving pollution emissions, and are valuable from an environmental and/or conservation point of view. So far, 51 Significant Impact Areas have been identified, including the Croatian transboundary areas Gemenc-Kopački rit (1,980 km²), Middle Drava (450 km²), Lower Mura Drava (1,410 km²), Middle Sava Kupa (2,820 km²), Middle Sava Una and Vrbas (1,770 km²) and Lower Sava (1,320 km²), with the total surface of newly proposed wetlands at 262,000 ha.

Quantification of nutrient retention. Retention of nutrients is quantified by means of direct measurements of annual balances and the use of various models, including calibrated models and models used in combination with direct measurements. Usually, the amount of transported nutrients in a canal is based on regular monitoring, with the titrating of lateral inflows. Revitalised segment of the river Skjern floodplain in Denmark (Pedersen et al., 2007) had the retention of 3-4 kg TP.ha⁻¹.year⁻¹ and 90 kgTN. ha⁻¹.year⁻¹. Pithart (2013) estimated the retention in the floodplain of the river Lužnice (Czech Republic) at 3 kg TP.ha⁻¹.year⁻¹ and 66kgTN. ha⁻¹.year⁻¹, and Babbist et al. (2006) modelled the retention in the Lonjsko polje flood retention area (237 km²) at 31 kg TP.ha⁻¹.year⁻¹ (using different retention times under the scenario in a plan from 1972 (UNDO, 1972), the result was 19 kg TP.ha⁻¹.year⁻¹). Finally, Gren et al. (1995), reviewing different studies, proposed the values of 100-150 kgTN. ha⁻¹.year⁻¹ and 10-20 kg TP.ha⁻¹.year⁻¹ for wetlands and natural floodplains in the Danube basin. This

estimation was used for the study Evaluation of Wetlands and Floodplain Areas in the Danube River Basin (1999), as well as for all the calculations in the Danube pollution reduction programme (Niemayer, 1999).

Economic evaluation. Economic evaluation can be performed by a variety of methods (Turner et al., 2008), for instance via the replacement cost method (analysing the cost of artificial removal of nutrients by wastewater treatment stations). Gren et al. (1995) estimate the economic value of this ecosystem service at 250 USD/ha/year.

Results

For the purpose of this study, we used the economic evaluation according to Gren (1996), taking into account the area of active floodplains delineated by inundation zones (Figure 8 on page 19 for DSDF – 1,588 km²; Figure 35 on page 44 for PSA – 3,811 ha for the as-is state, and 4,617 ha for the extended inundation zone).

The analysis of these areas within the DSDF points to the value of nutrient retention as an ecosystem service in the amount of 40 million USD per year. In the PSA, this indicator would be at 953,000 USD for scenario A, and 1,28 million USD for scenario C.

To evaluate scenario B, we would need additional analyses based on the amount of transported nutrients in the Drava River, discharges, and water residential time in the accumulation. The volume of Molve 1 and Molve 2 accumulation is not at disposal, but it can be estimated from the area and depth of the accumulation (Table 3). Water residential time would be approx. 2.7 days, which would result in an approximated maximum TP retention of 8-17%, and TN retention of 1-3% (Hejzlar et al., 2006). To compare retention in scenario B with scenarios A and C, more precise data on morphological parameters of accumulations should be ensured, and the annual amount of nutrient transport in Drava river should be calculated, which would require an additional specialised study.

5.2.1.3. Carbon sequestration

Carbon sequestration (this service can also be called carbon dioxide removal) is the ability of ecosystem to uptake CO₂ from the atmosphere during the process of photosynthesis. Carbon is incorporated into the plant biomass and released during the reverse process, respiration. This carbon cycle is crucial for climate stabilization; its misbalance (surplus of emissions over sequestration) is reported as a main reason of climate change (Gore, 1993).

Ecosystems which can store carbon can be important carbon sinks – wetland soil is an important carbon sink; 14.5% of the world's soil carbon is found in wetlands, while only 6% of the world's land is composed of wetlands (Nelson, 1999). Wet soils tend to accumulate carbon due to the limited ability to mineralize the decomposing biomass. Also, growing forests incorporate carbon dioxide into the wood biomass, which is a carbon sink. For these reasons, reforestation – replanting of trees on marginal crop and pasture lands – has been proposed to incorporate carbon from atmospheric CO₂ into biomass (Newell et Stavins, 2000). Reforestation with long-lived trees (>100 years) will sequester carbon for a more gradual release, minimizing impact during the expected carbon crisis of the 21st century.

While sustainable forest management may be neutral in terms of carbon sequestration – emission (harvested trees are replaced by growing new trees accumulating wood biomass with carbon),

irreversible deforestation can, on the other hand, cause carbon emission connected with the conversion of stored carbon into carbon dioxide (both from wood and soil).

For precise evaluation of the source or sink character of an ecosystem, the annual balances of CO₂ exchange between the ecosystem and atmosphere are being measured and modelled, for instance by the eddy-covariance technique (Marek et al., 2011), which is not at disposal for the DSDF area. Consequent economic evaluation can be done by evaluating the amount of sequestered carbon in the ecosystem, using an analogy with the market of emission limits. However, forests and wetlands are generally better carbon storages and/or sinks compared to lakes or reservoirs; hence, this service would be positively influenced by scenario C, and negatively by B. To validate this presumption, a more detailed study should be done.

5.2.2. Supporting ecosystem services

5.2.2.1. Habitat provision

Mapping of floodplain habitats

Due to the relatively preserved river and floodplain ecosystems, Croatian floodplains provide a unique set of habitats (Annex 2) for a variety of endangered species (Schneider-Jacoby, 2004; Grlica et Razlog-Grlica, 2007). The functional relationships and prerequisites for the existence and good ecological state of these habitats, as well as their nature protection, are described in Section 2 – Character, values and threats of Drava, Sava and Danube floodplains. For pictures of typical floodplain habitats in lower Drava, see Section 3.2.

DSDF habitats are interconnected with various species which simultaneously form their structure and get the environment suitable for their existence. Floodplains have also been understood as ecosystem complexes, due to a variety of aquatic (both lentic and lotic, permanent or periodic), semi-terrestrial and terrestrial habitats (ecosystems). Not surprisingly, these complexes support and enable the occurrence of a number of protected and rare species.

Very diverse plant and algal communities occur in standing oxbows and braided river channels; *Wolfia arrhiza* (Figure 49), *Nymphaea alba*, *Stratiotes* sp., *Carex bohemica* can be found in wetlands, and rare *Myricaria germanica* on gravel bars (Grlica et Razlog-Grlica, 2007; Purger 2008.).



Figure 49: Tiny and rare aquatic plant *Wolffia arrhiza* near the Repaš bridge on the Drava River in Molve area, July 2014. *Salvinia natans* on the right.

A variety of habitats suitable for fish result in a very rich community: 65 species have been found in the river Drava in total (Mrakovčić et al., 2006). Some species' prosperity depends on preserved flood pulses, such as the European mud-minnow (*Umbra crameri*), weatherfish (*Misgurnus fossilis*), crucian carp (*Carassius carassius*). Others are dependent on gravel bars, such as zingel (*Zingel zingel*), streber (*Zingel streber*) and *Sabanejewia balcanica*.

Birds are typical and most visible representatives of preserved DSDF ecological values. White tailed eagle (*Haliaetus albicilla*) can be seen high above the river, while the rich community of waders, herons and cormorants inhabit its banks: pygmy cormorant (*Phalacrocorax pygmaeus*), purple heron (*Ardea purpurea*), great white egret (*Egretta alba*). Very endangered little tern (*Sterna albifrons*) nests on gravel bars with other tern species and plovers; sand martin (*Riparia riparia*, Figure 50) and kingfisher (*Alcedo attis*) nest in eroded steep banks, while bittern (*Botaurus stellaris*), black stork (*Ciconia nigra*) and willow warbler (*Phylloscopus trochilus*) belong to the rarer wetland inhabitants.

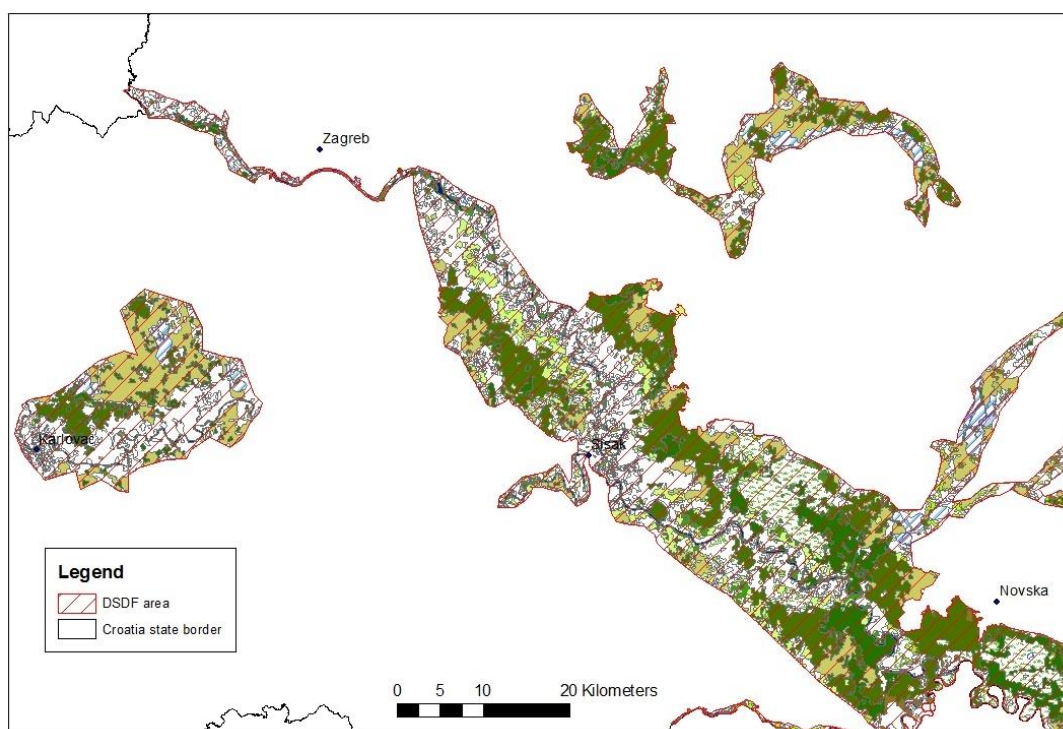


Figure 50: Nesting colony of sand martin (*Riparia riparia*) on the lower Drava near Gotalovo.

Amphibians and mammals are also diverse, and we can mention at least the Danube crested newt (*Triturus dobrogicus*), otter (*Lutra lutra*), beaver (*Castor fiber*), and pond bat (*Myotis dasycneme*) among the rare and endangered species.

It is important to realise that most of the typical floodplain habitats evaluated in this chapter depend on a specific water regime, characteristic for floodplains in a natural or semi-natural state. This regime is mostly stated as flood pulse regime in ecological literature (Junk et al., 1989). Its importance for wetlands (Middleton, 2002; Čížková, 2013) and river-floodplain (Bailey, 1991) functioning and restoration is widely accepted (Pithart et al., 2013).

In the evaluation of habitats, the National Habitat Classification (Source: SINP, 2009) was the principle source of information. Intersection of DSDF area and habitats shows the landscape patterns, location and variety of floodplain habitats – for a detailed view of Kopački rit, see Figure 9 (on page 20); for other areas of DSDF, see Figures 51-54. Gravel bars in the PSA have been mapped according to satellite images, in order to define their area (Figure 56).



Legend

-  A11 Standing waters
-  A23 Permanent watercourses
-  A27 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A27/A22/A11 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A41/A21 Reed beds, tall sedges and tall rushes / Mosaic of cultivated areas
-  C22 Central Europe humid grasslands
-  C23 Central Europe mesophilous grasslands
-  C23/C22/E31 Central Europe mesophilous grasslands / Central Europe humid grasslands / Mixed oak-hornbeam forests and hornbeam forests
-  D11/E11 Willow thickets on dunes / Alluvial willow forests
-  E11/E12 Alluvial willow forests / Alluvial poplar forests
-  E21 Alluvial forests of black alder and narrow-leaved ash
-  E22 Alluvial forests of pedunculate oak
-  E31 Mixed oak-hornbeam forests and hornbeam forests
-  E31/C22 Mixed oak-hornbeam forests and hornbeam forests / Central Europe humid grasslands

Figure 51: Floodplain habitats in Posavina and Sava tributaries (Source: SINP, 2009).

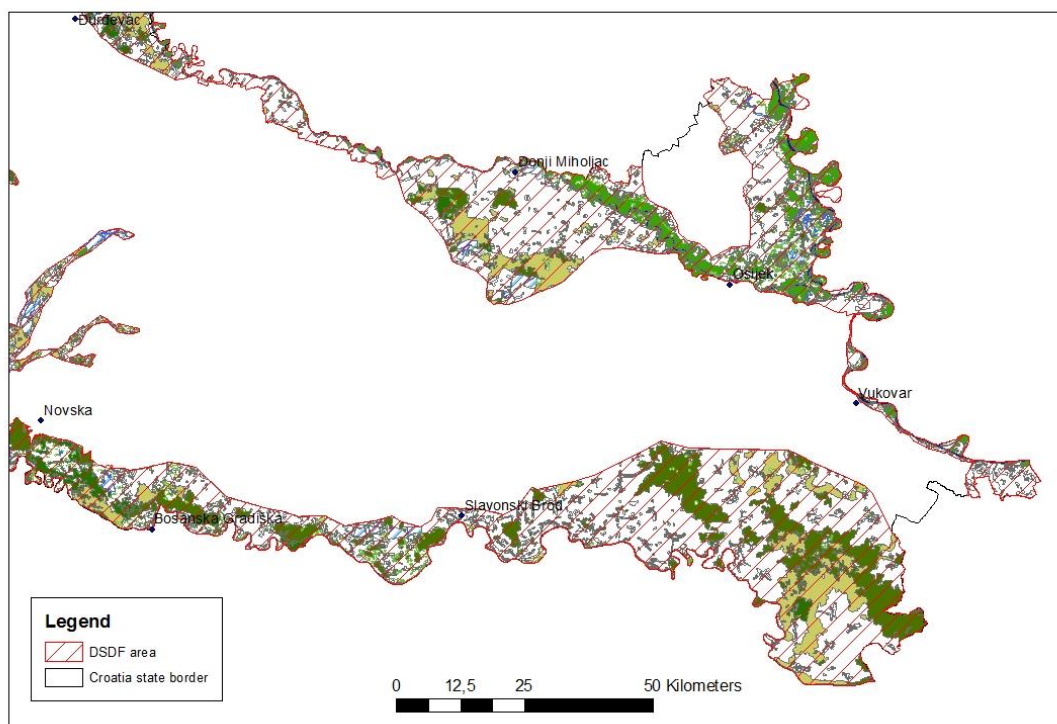


Figure 52: Floodplain habitats in north-eastern Croatia. For legend, see Figure 51 (Source: SINP, 2009).

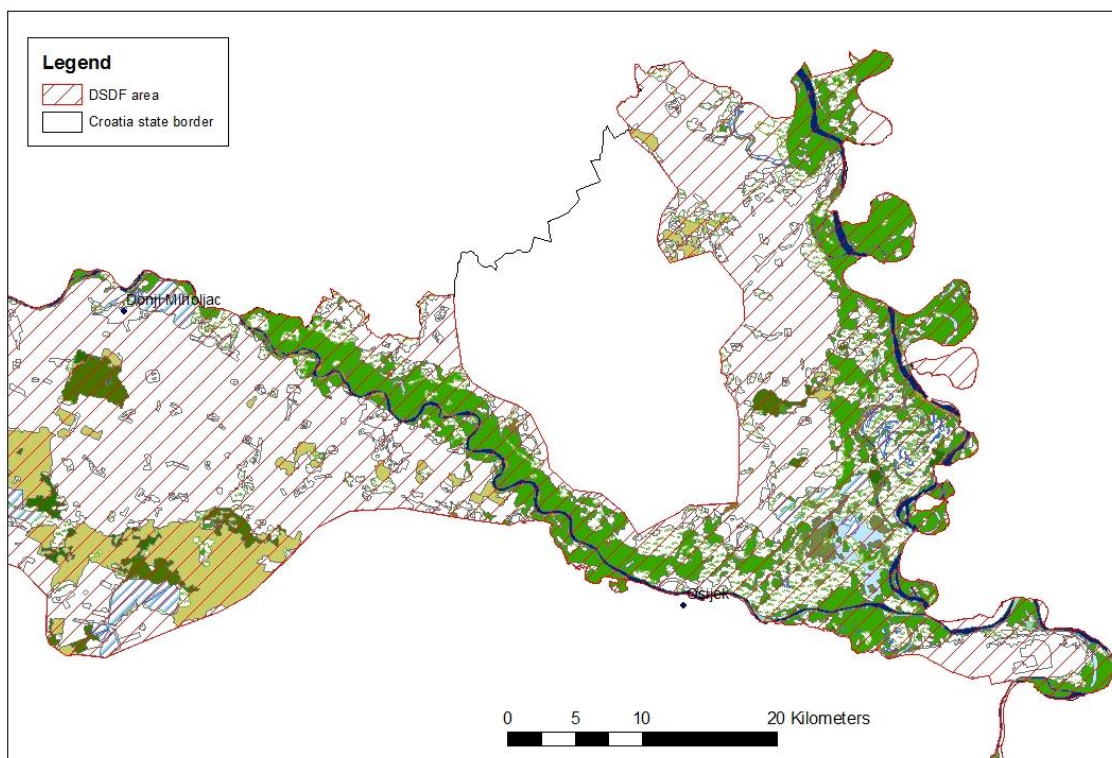
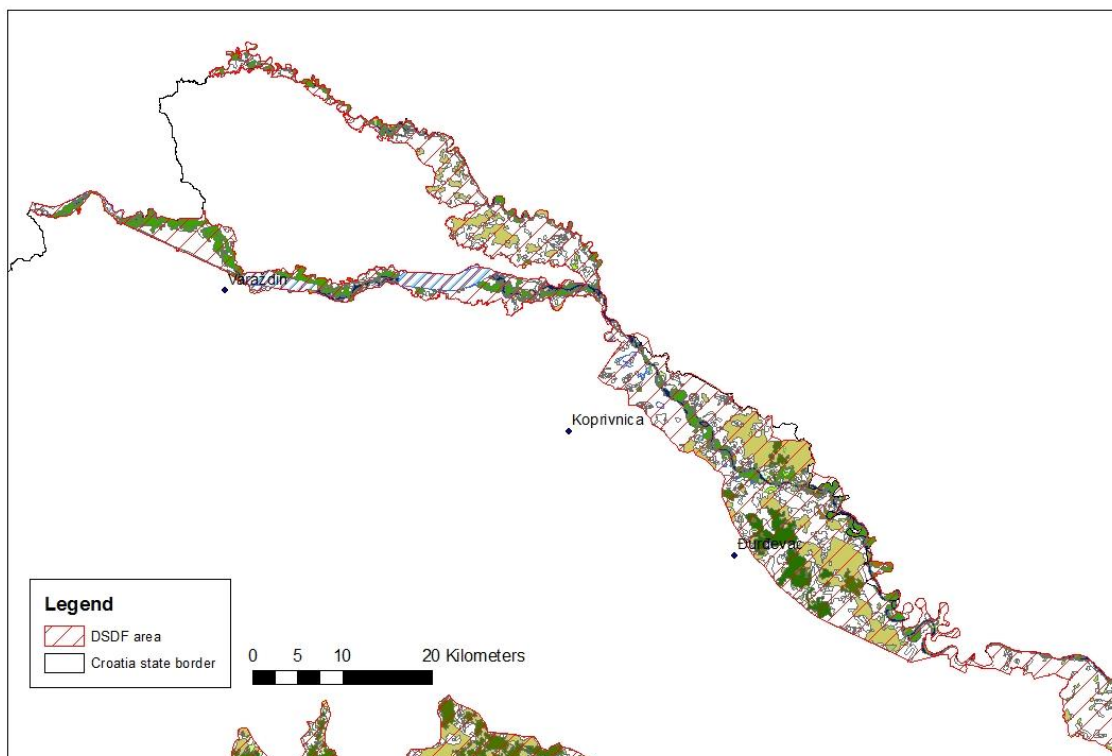


Figure 53: Floodplain habitats at the lower Drava and Danube. For legend, see Figure 51 (Source: SINP, 2009).



Legend

-  A11 Standing waters
-  A23 Permanent watercourses
-  A27 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A27/A22/A11 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A41/A21 Reed beds, tall sedges and tall rushes / Mosaic of cultivated areas
-  C22 Central Europe humid grasslands
-  C23 Central Europe mesophilous grasslands
-  C23/C22/E31 Central Europe mesophilous grasslands / Central Europe humid grasslands / Mixed oak-hornbeam forests and hornbeam forests
-  D11/E11 Willow thickets on dunes / Alluvial willow forests
-  E11/E12 Alluvial willow forests / Alluvial poplar forests
-  E21 Alluvial forests of black alder and narrow-leaved ash
-  E22 Alluvial forests of pedunculate oak
-  E31 Mixed oak-hornbeam forests and hornbeam forests
-  E31/C22 Mixed oak-hornbeam forests and hornbeam forests / Central Europe humid grasslands

Figure 54: Floodplain habitats of the north-western part of the Drava River (Source: SINP, 2009).

Method of evaluation. For each habitat type, the area and its contribution to the total area of DSDF were calculated (Table 7 on page 68). For evaluation, we used the so-called Hesen method (Sejak et al., 2003), reflecting the average cost of investments necessary for the creation of natural habitats. First, each habitat was given a value in points according to the classification reflecting a set of criteria, such as maturity, structural and species' diversity, habitat rareness, anthropogenic impact, and vulnerability (Table 7). According to this classification, most valuable habitats are floodplain forests; on the opposite end of the scale are anthropogenic habitats like intensively cultivated arable fields or urbanised rural areas. Since such a national classification is not at disposal for Croatia, we have used the Czech national classification (Sejak et al., 2003), given the fact that the Czech Republic is a central European country with landscape and habitat types comparable with those that can be found in northern Croatia.

For monetary evaluation, each point obtains a value (per unit of area), calculated on the basis of average cost of accomplished revitalization projects, which increases the point value of the area via the creation of more valuable biotopes. This value has been calculated at 0.62 USD per m², on the basis of analysing the cost of more than one hundred revitalisations in the Czech Republic. Multiplying the area, value in points and monetary value of one point, and by applying the 5% discount rate, we get the value of the habitat type (Table 7).

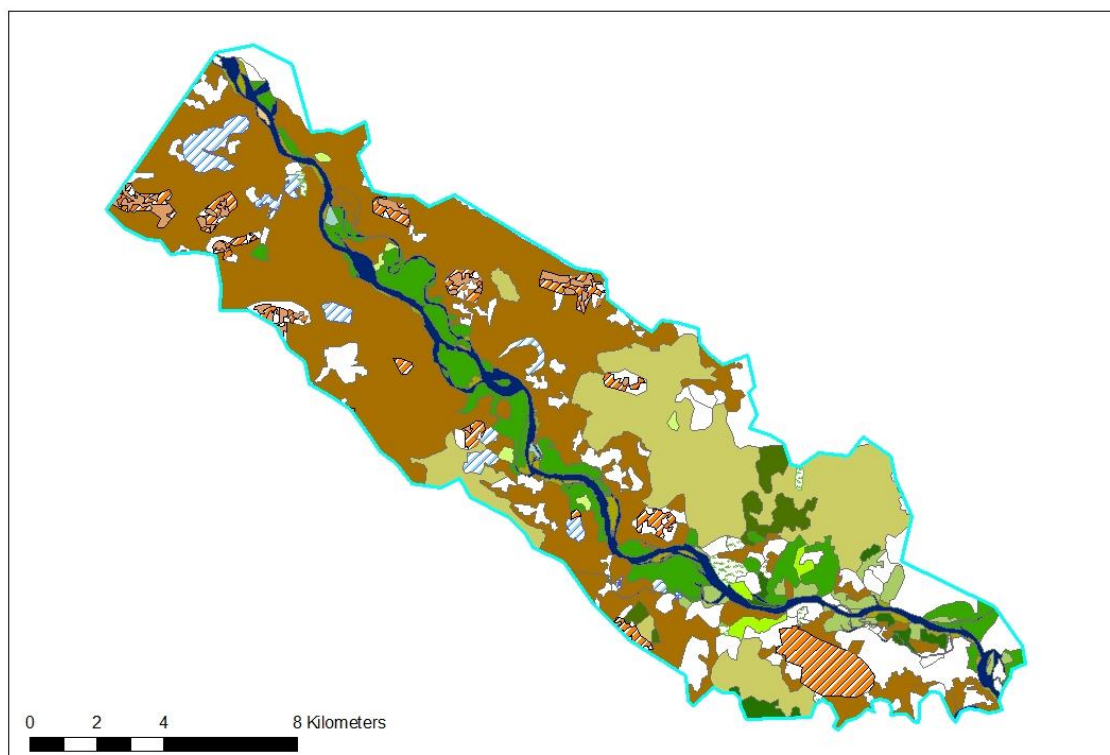
Table 7: Floodplain habitats in Croatia according to the national classification; area, contribution to floodplain area (DSDF), point value and monetary value.

Code	Habitat name	Area (ha)	Contribution to DSDF area	Point value	Value total mill.\$
A11	Standing waters	17836	2,3	47	259,9
A23	Permanent watercourses	17455	2,3	52	281,4
A27/A22	Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses	379	0,0	43	5,1
A27/A22/A11	Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters	733	0,1	45	10,2
A41/I21	Reed beds, tall sedges and tall rushes / Mosaics of cultivated areas	741	0,1	21	4,8
C22	Central Europe humid grasslands	57172	7,5	66	1169,7
C23	Central Europe mesophilous grasslands	2406	0,3	33	24,6
C23/C22/E31	Central Europe mesophilous grasslands / Central Europe humid grasslands / Mixed oak-hornbeam forests and hornbeam forests	13285	1,7	53	218,3
D11/E11	Willow thickets on dunes / Alluvial willow forests	4527	0,6	52	73,0
D12	Mesophilous hedges and thickets of continental, exceptionally coastal areas	2537	0,3	33	26,0
E11/E12	Alluvial willow forests / Alluvial poplar forests	37907	4,9	65	763,8
E21	Alluvial forests of black alder and narrow-leaved ash	28110	3,7	42	366,0
E22	Alluvial forests of pedunculate oak	105722	13,8	66	2163,1
E31	Mixed oak-hornbeam forests and hornbeam forests	83223	10,9	61	1573,7
E93	Plantations of broadleaf trees	9084	1,2	20	56,3
I21	Mosaic of cultivated fields	77238	10,1	15	359,2
I21/J11/I81	Mosaic of cultivated fields / Active rural areas / Public	2628	0,3	13	10,6
I31	fields on consolidated land	252098	32,9	10	781,5
J11	Active rural areas	19515	2,5	10	60,5
J11/J13	Active rural areas/Urbanised rural areas	4622	0,6	14	20,1
J13	Urbanised rural areas	1067	0,1	18	6,0
In total		738285			
In total natural habitats		372033			6939,5

Value of habitats in DSDF. The total value of near-nature floodplain habitats in Croatia (Table 7 in bold) was calculated as **6.9 billion USD**, which would be the cost needed to create these habitats by renaturation or revitalisation projects. Hard floodplain forests (both alluvial forest of pedunculate oak and mixed oak-hornbeam forest and hornbeam forest) contribute the most to the total value, which is the result of a high point score (65 and 66 point respectively) and large areas (1,057 and 832 km²). Among other important habitats, one can also find central European humid grasslands (area 571 km²), soft floodplain forest – willow and poplar (379 km²), alluvial forest or black alder and ash (281 km²), and standing waters (178 km²) and watercourses (176 km²). The average value of natural habitats is 18,650 USD per ha.

Valuation of habitats in PSA

For scenario A (Figure 54), we mapped and evaluated habitats in the same way as for DSDf. Given the fact that shp files of the national habitat mapping do not include gravel bars, which are valuable and key habitats for the Drava river ecosystem, these habitats were mapped additionally (Figure 55) and their area was calculated. The actual visible area of gravel bars depends on the water level, which is why mapping should be related to a particular hydrological situation. Due to the hydrological regime of the Drava River, gravel bars most frequently appear during the late summer and autumn.



Legend
























-  A11 Standing waters
-  A23 Permanent watercourses
-  A27 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A27/A22/A11 Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters
-  A41/I21 Reed beds, tall sedges and tall rushes / Mosaic of cultivated areas
-  C22 Central Europe humid grasslands
-  C23 Central Europe mesophilous grasslands
-  C23/C22/E31 Central Europe mesophilous grasslands / Central Europe humid grasslands / Mixed oak-hornbeam forests and hornbeam forests
-  D11/E11 Willow thickets on dunes / Alluvial willow forests
-  D12 Mesophilous hedges and thickets of continental, exceptionally coastal areas
-  E11/E12 Alluvial willow forests / Alluvial poplar forests
-  E21 Alluvial forests of black alder and narrow-leaved ash
-  E22 Alluvial forests of pedunculate oak
-  E31 Mixed oak-hornbeam forests and hornbeam forests
-  E31/C22 Mixed oak-hornbeam forests and hornbeam forests / Central Europe humid grasslands
-  E92 Conifer plantations
-  E93 Plantations of broadleaf trees
-  I21 Mosaic of cultivated fields
-  I21/I11/I81 Mosaic of cultivated fields / Active rural areas / Public unproductive cultivated green areas
-  I31 Intensively cultivated arable fields on consolidated land
-  J11 Active rural areas
-  J11/J13 Active rural areas / Urbanised rural areas
-  J13 Urbanised rural areas

Figure 55: Habitats of the PSA (Source: SINP, 2009)

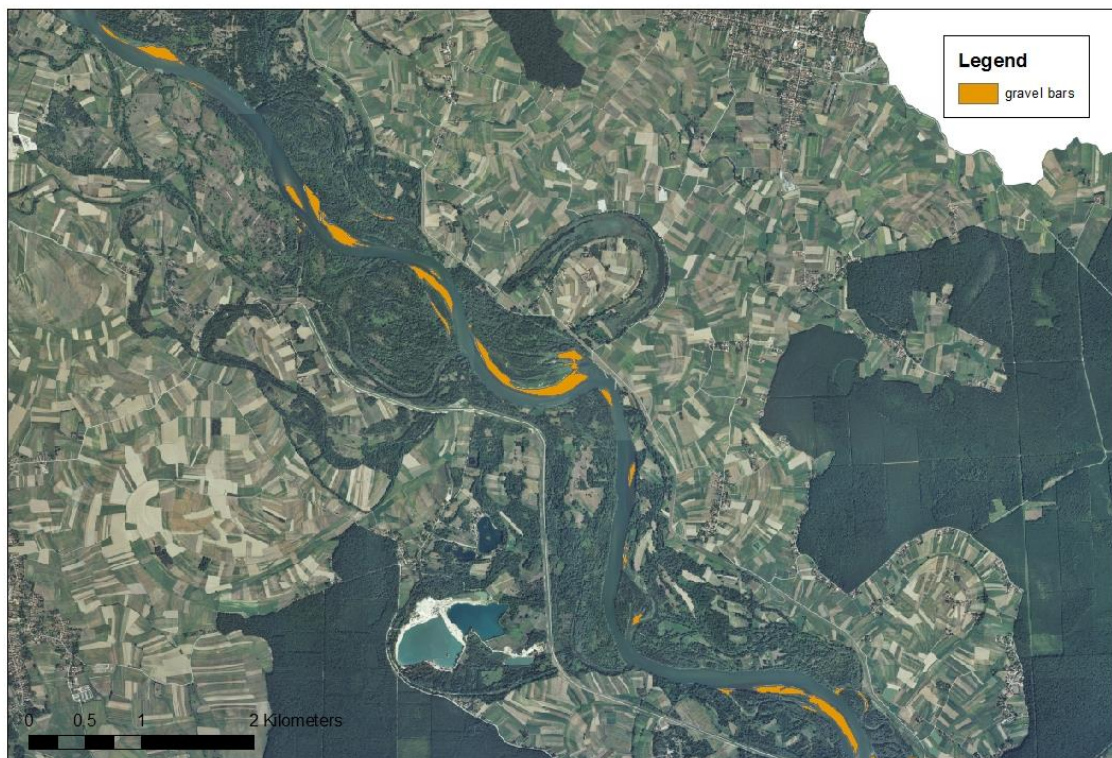


Figure 56: Gravel bars in the middle part of the PSA, mapped according to digital ortophoto map from the WMS of the Republic of Croatia State Geodetic Administration (2011).

For the scenario B, the extent of the proposed Molve 1 and Molve 2 accumulations was intersected with habitat maps, in order to quantify the loss of natural floodplain habitats under the accumulation (Figure 52 and Figure 53). The resulting decrease of areas of particular habitats is shown in Table 8. These habitats were replaced by the habitat of standing water without macrophytes and with artificial banks (with a relatively low point value). The possible and probably negative effect on other adjacent habitats (located next to the accumulation) was not evaluated due to its complexity.

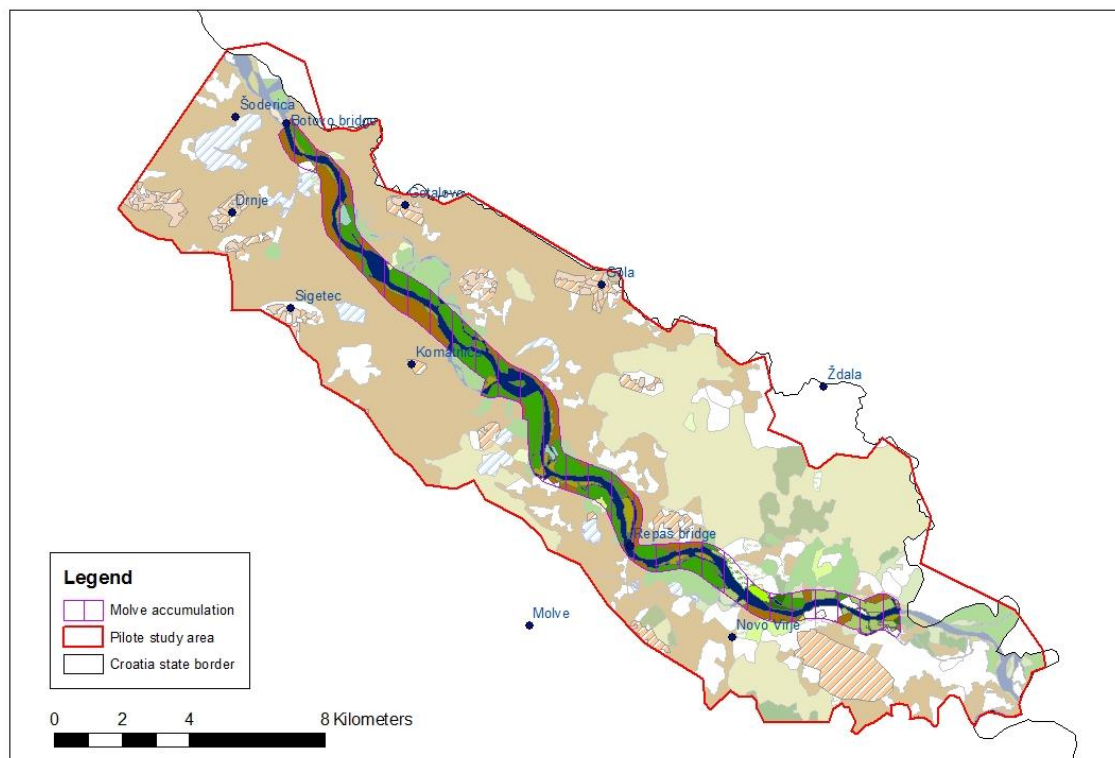


Figure 57: Habitats under the proposed Molve 1 and Molve 2 accumulations. For habitat legend, see Figure 55.

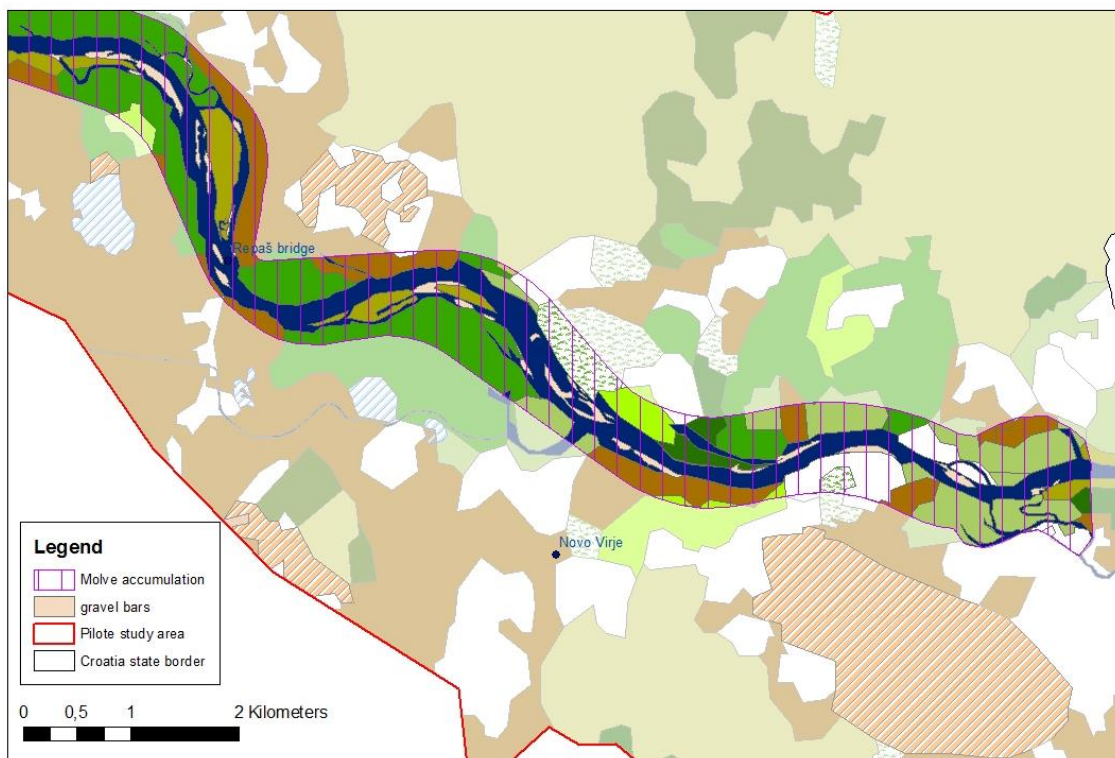


Figure 58: Habitats under the proposed Molve 1 and Molve 2 accumulations, detail with gravel bars. For habitat legend, see Figure 55.

For scenario C the structure and extent of habitats within the extended floodplain (replacement of dykes) was changed: the area of valuable floodplain habitats as namely alluvial willow forest and central Europe humid grassland was enlarged in the area between the dykes (Figure 59).

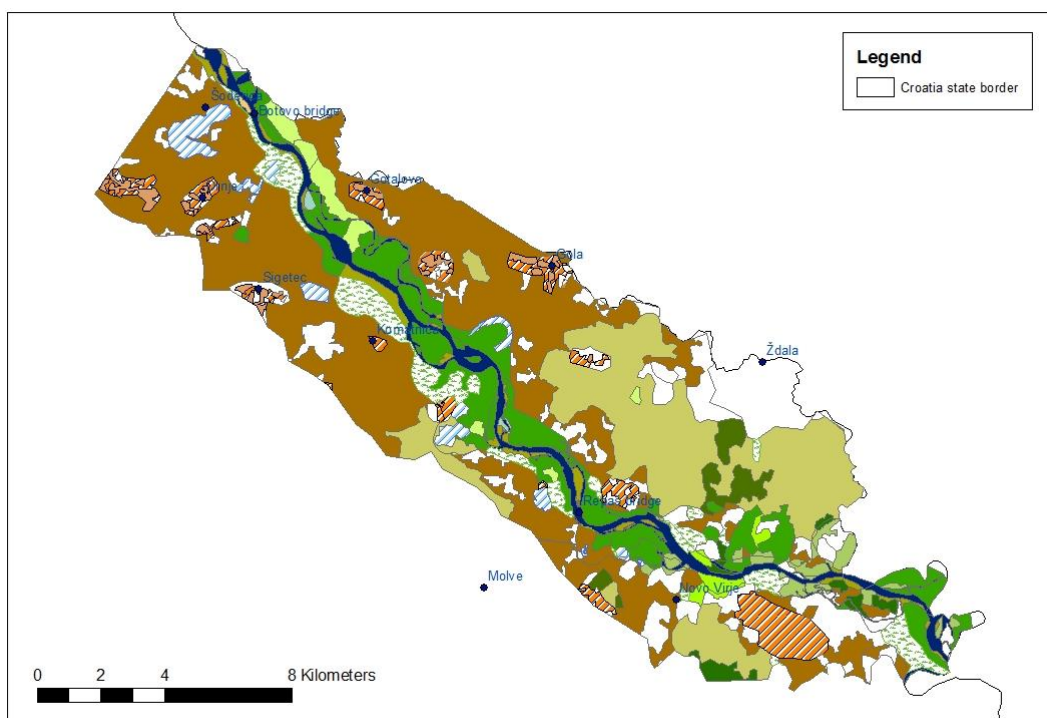


Figure 59: Habitats in the PSA in scenario C – the extended active floodplain. For habitat legend, see Figure 55.

Table 8: Area of habitat type, its contribution to the PSA area, point value and monetary value for natural floodplain habitats in scenarios A, B and C in the PSA.

Code	Habitat name	Scenario A				Scenario B				Scenario C			
		Area (ha)	Contribution to PSA area %	Point value	Value total mill.\$	Area (ha)	Contribution to PSA area %	Point value	Value total mill.\$	Area (ha)	Contribution to PSA area %	Point value	Value total mill.\$
A11	Standing waters	423	2,1	47	6,2	2268	11,3	6	4,2	425,0	2,1	47	6,2
A23	Permanent watercourses	973	4,8	52	15,7	304	1,5	52	4,9	976,2	4,9	52	15,7
A27	Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters	9	0,0	43	0,1	9	0,0	43	0,1	9,3	0,0	43	0,1
A27/A22/A1	Unvegetated and sparsely vegetated banks of running waters / Temporary watercourses / Standing waters	26	0,1	45	0,4	0	0,0	45	0,0	25,3	0,1	45	0,4
A41/I21	Reed beds, tall sedges and tall rushes / Mosaics of cultivated areas	228	1,1	21	1,5	228	1,1	21	1,5	229,3	1,1	21	1,5
C22	Central Europe humid grasslands	148	0,7	66	3,0	90	0,4	66	1,8	1105,0	5,5	66	22,6
C23	Central Europe mesophilous grasslands	110	0,5	33	1,1	110	0,5	33	1,1	135,0	0,7	33	1,4
C23/C22/E3	Central Europe mesophilous grasslands / Central Europe humid grasslands / Mixed oak-hornbeam forests and hornbeam forests	98	0,5	53	1,6	86	0,4	53	1,4	305,2	1,5	53	5,0
E31/C22	Central Europe humid grasslands / Mixed oak-hornbeam forests and hornbeam forests	66	0,3	64	1,3	13	0,1	64	0,3	77,0	0,4	64	1,5
D11/E11	Willow thickets on dunes / Alluvial willow forests	187	0,9	52	3,0	65	0,3	52	1,0	266,8	1,3	52	4,3
D12	Mesophilous hedges and thickets of continental, exceptionally coastal areas	94	0,5	33	1,0	84	0,4	33	0,9	94,0	0,5	33	1,0
E11/E12	Alluvial willow forests / Alluvial poplar forests	1544	7,7	65	31,1	882	4,4	65	17,8	2145,1	10,7	65	43,2
E21	Alluvial forests of black alder and narrow-leaved ash	186	0,9	42	2,4	165	0,8	42	2,1	485,3	2,4	42	6,3
E22	Alluvial forests of pedunculate oak	298	1,5	66	6,1	298	1,5	66	6,1	298,0	1,5	66	6,1
E31	Mixed oak-hornbeam forests and hornbeam forests	3391	16,9	61	64,1	3391	16,9	61	64,1	3391,1	16,9	61	64,1
E93	Plantations of broadleaf trees												
	In total	7781	38,7		138,6	7993	39,8	702	107,4	9968	49,6		179,5
	Percentage of A				100,0				77,5				167,1
	Difference from A				0,0				-31,2				72,1

To compare scenarios A-C, the total monetary value, area and contribution to the total area of the PSA were calculated (Table 8). The total value of natural habitats decreased in scenario B by 22.5% compared to scenario A. This relatively low decrease is a consequence of the large area of the PSA, which also includes large units of hard floodplain forest (Repaš forest) that would not be replaced by the accumulation – and the impact of the accumulation on them is not a subject of this evaluation method. The enlargement of active floodplain and replacement of some cultivated arable fields by natural habitats (namely soft floodplain forests and humid grasslands) in scenario C have led to an increase of the area, and consequently also to the value of 67% when compared with the scenario A.

The area of gravel bars in scenario A was calculated at 47 ha. Given the fact that their point value is identical to the point value of this category of watercourse, they had no influence on monetary values in this type of evaluation.

A comparable evaluation, also based on the cost of revitalisation, can be made using the estimates of future revitalisation costs in the Danube floodplains, prepared by the WWF¹⁰. According to this estimate, the long-term Danube floodplain restoration would be needed, with the investment costs

¹⁰http://awsassets.panda.org/downloads/wwf_restoration_potential_danube.pdf

of around 6,000,000,000 EUR shared by 13 countries in order to replace the lost floodplains. A study carried out on the lower Danube after the 2006 floods (Schwarz et al., 2006) calculated the costs at about 20,000 EUR/ km²; this estimation does not include large technical structures, such as polder in- and outlets, and compensation for land users. By comparison, costs in Germany and Austria can be estimated at some 1-2 million EUR/km². Based on the DRB-wide average of 500,000 EUR/km², this data would result in a value of 0.69 million USD per km² for the existing Croatian natural floodplains; using the prices in Germany and Austria, the value would be 2.07 million USD per km², compared with 1,7 million USD per km² resulting from the Heszen method results in the previous calculations.

5.2.3. Provisioning services

5.2.3.1. Wood production

Introduction

Unlike in other central European countries, floodplain forests still cover remarkable areas of floodplains in Croatia (Prpić et al., 2005). The well-known forests are in Spačva, the lower section of the river Drava upstream of Osijek, the Danube at Kopački rit, Turopoljski lug, Repaš forest, Sunjsko and Lonjsko and Odransko Polje, Žutica, Varoški lug and others. Four main types of forests and their area and contribution to the entirety of DSDF are shown in Table 9. According to Klepac et al. (1996) and Schneider Jacoby (2004), forests dominated by pedunculate oak cover the area of over 201,000 ha, with wood storage of 55.6 million m³ (wood increment 7.1 m³.ha⁻¹ year⁻¹). By comparison, floodplain forests in the Czech Republic have been reduced to the contemporary 33,000 ha (Klimo et al., 2008).

Pedunculate oak wood is highly priced in the furniture industry, and top-quality timber can be sold for approx. 672 USD per m³ (according to the price list of the Croatian Forests Ltd. of 2012), which makes it one of the most valuable timber products provided by the Croatian Forests Ltd. (Figure 63).

Table 9: Area and contribution of four main forest types in DSDF

Code	Habitat name	Area (ha)	Contribution to DSDF area %
E11/E12	Alluvial willow forests / Alluvial poplar forests	37907	4.9
E21	Alluvial forests of black alder and narrow-leafed ash	28110	3.7
E22	Alluvial forests of pedunculate oak	105722	13.8
E31	Mixed oak-hornbeam forests and hornbeam forests	83223	10.9

The growth and existence of pedunculate oak forests depend on the access to underground water table. If the underground water table permanently falls, plain forest trees die sooner or later. Massive dieback of pedunculate oak usually appears five to ten years after the change (Prpić, 2005). Factors endangering the water table stability, which is necessary for the prosperity of floodplain forest, include (according to Prpić, 2005) the shortening of river trace (cross cutting meanders), construction of dykes, construction of accumulations and navigation channels, gravel and sand excavation, and other factors.

The Croatian Forests Ltd. manages most of the hard floodplain forests and a substantial part of the soft floodplain forests in Croatia. Representatives of the company are aware of the negative impacts, and report losses due to the decrease of underground water table.

Forestry in Varaždin County manages the soft floodplain forest in the old river Drava floodplain (willow 22%, poplar 33%, oak 3%, elm 5%; 1,500 ha in total; Figure 60). These forests have a special research forest status, and the level of underground water table is being monitored since the construction of accumulations (monitoring is financed and managed by HEP). Underground water has dropped remarkably in this area, due to the abstraction of water from the river Drava bed to derivation channels. Wood production dropped from 25,000 m³ (before accumulation) to the contemporary level of 12,500 m³; i.e. by 50% (with wood increment dropping from the original level of 8 m³ to 4 m³ per ha per annum) (Croatian Forests, Forestry Varaždin, personal communication).

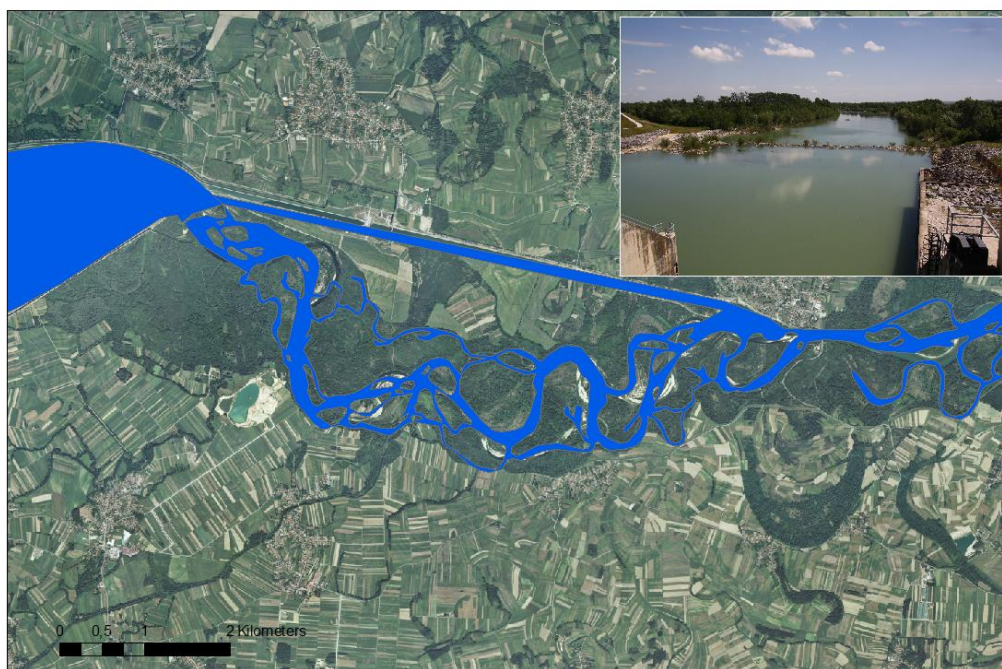


Figure 60: Soft floodplain forest down to the Dubrava accumulation, where the old river Drava guaranteed the biological minimum discharge of 8 m³.s⁻¹.

Forests in the PSA. Soft floodplain forest, dominated by willow, poplar and alder, covers a substantial part of the active floodplain (Figure 56), and it is owned by small private owners who are using it extensively, mainly for firewood (Figure 57). Due to the character of ownership, there is no data concerning the harvest, storage or increment. According to Vukelić (2008), the economic benefits stemming from privately owned floodplain forests can reach approximately 2/3 of benefits stemming from state forests.

Hard floodplain forest is located in the north-eastern part of the PSA (Figure 57 and Figure 58), and it forms the forest management unit called “Repaš”, which covers the area of 4,216 ha. This forest is dominated by pedunculate oak (production 66%, area 77%), while other important species include common hornbeam (*Carpinus betulus*), common ash (*Fraxinus excelsior*) and black alder (*Alnus glutinosa*). The southern part of the forest adjacent to the river Drava is dominated by willows and poplars. A characteristic management practise is seed felling (Figure 65). Management plans are prepared for 10-year periods. Rotation (harvest cycle) for pedunculate oak in favourable conditions is 140 years. Sufficient wood increment in Repaš forest depends on access to the underground water table; the southern part of the Repaš forest is exposed to regular flooding due to the absence of dykes (Figure 59).

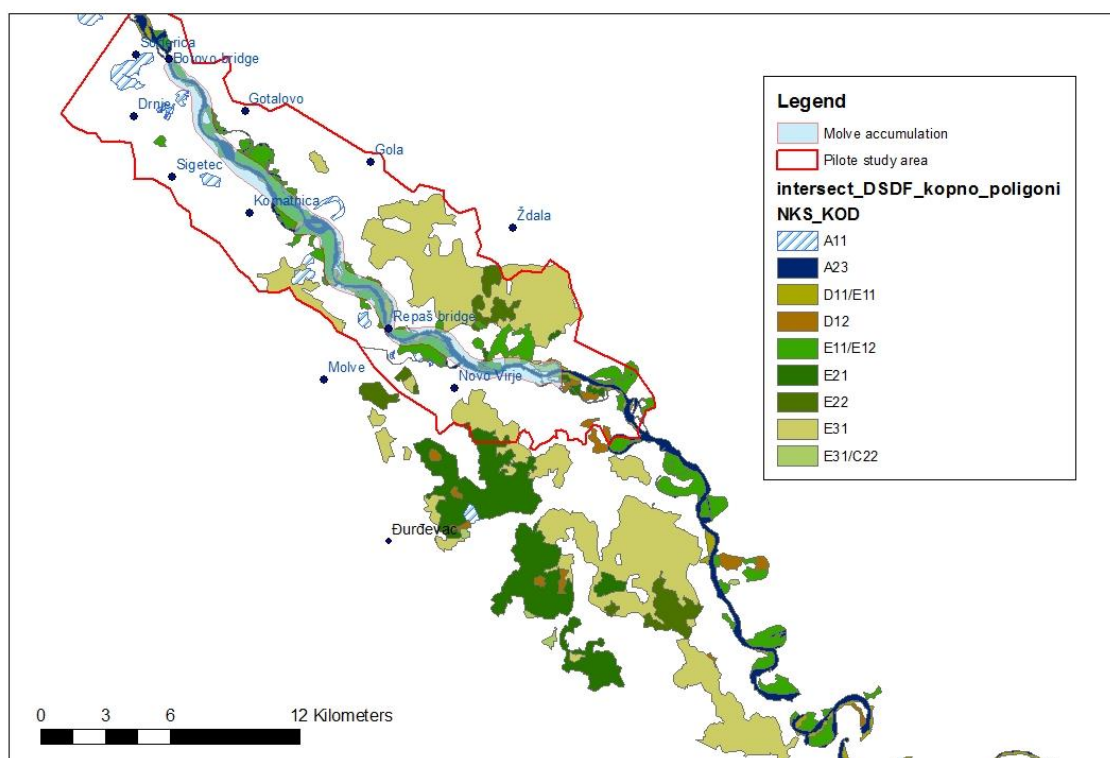


Figure 61: Forest types in the wider area of Molve 1 and Molve 2 accumulations. (Source: SINP, 2009)



Figure 62: Soft floodplain forest in the PSA is used extensively for firewood.



Methodological approach. For the purposes of evaluation of hard floodplain forest, we used the contemporary data from Repaš (Table 10 on page 81). In order to evaluate other functions (services) of forests as well, the foresters routinely apply the methodology of calculating the so-called non-productive forest functions, which is based on the methodology¹¹ in which forests functions such as soil protection, impact on water regime, support for soil fertility, impact on climate, protection from erosion, oxygen production, recreation and hunting are evaluated by applying a point scale, where one point is equal to a defined monetary value. In floodplain forest, this non-productive value is 5.7 times higher than the productive value (Prpić, 2005). This valuation is reflected in the final price of forest, if it is subject to market operations. This methodology is actually a predecessor of the

¹¹Metodologija ocjenjivanja općekorisnih funkcija šuma, year

ecosystem services approach, and it originates in a holistic understanding of forest functions and roles. According to this method, the value of Repaš forest is 97,000 HRK/ha (17,446 USD/ha). In the final overview of ecosystem service values, we used only the productive value of forests, in order to avoid doubling the value by adding non-productive forest values to the values of other ecosystem services (which are in fact already incorporated in this non-productive value).



Figure 63: Sufficient wood increment in Repaš forest depends on access to the underground water table. Regular flooding contributes to groundwater recharge; the southern part of Repaš forest is exposed to regular flooding due to the absence of dykes.



Figure 64: Oak forest Repaš managed by seed felling, leaving the top-quality trees to provide acorns for the next generation.



Figure 65: Ash-dominated section of Repaš forest.

For final calculations for scenarios A, B and C, we used forest type areas in connection with the habitat mapping (Figure 53 on page 66). In order to calculate the values for hard floodplain forest, we used the Repaš forest data (Table 10) as reference (having been informed by the Croatian Forests Ltd. that these values are transferable to other forest management units in the lower Drava). In order to calculate the values for other forest types, we used the references from published literature (see Table 9 on page 75).

Value of the service. Data on forest area, wood storage in m^3 , productive and non-productive values (according to the Croatian Forests Ltd. evaluation method), annual wood increment, and values of these parameters related to the area, are provided in Table 10. The productive value of floodplain forests in DSDF is 2.5 billion USD, whereas the non-productive value reaches 14.6 billion USD.

Table 10: Data on the total and proportional value (per ha), storage in m³, productive and non-productive forest values, and annual wood increment for DSDF and PSA (scenarios A,B,C).

Location	Source	area	storage mil. m ³	storage mil. \$	storage/ha \$	usual price per m ³	productive value mil.\$	productive value/ha \$	non prod. value mil.\$	total value mil. \$	total value /ha \$	increment m ³	increment /ha	increment /ha \$	increment total mil. \$
Repaš forest	Croatian Forests 2011	3200	1,16	40,52	362,65	34,91	40,52	12662	234,19	274,71	85846	25999	8,12	284	0,908
Repaš forest	Croatian Forests 2012	4218		44,91			44,91	10647	328,32	373,23	88475				
Mura Drava Regional Park	Vukelić	57216													
State owned		47393	9,38		197,91	36,29	328,19	6925	1896,95	2225,14	46951	356000	6,22	226	10,702
Private		9823													
Forests impacted by NV	Prpić a Jakovac 1998	12224	3,50	176,00	286,32	26,50	92,70	7583	535,81	628,51	51416				
Varaždin soft floodplain forests	Croatian Forests	1456										6206	4,26		
Forests DSDF	Habitat map of Croatia	256962					2534		14644	17177			8,12	284	72,891
Soft (E11/E12+E21)		66017					500,64	7583	2893,68	3394,31	51416		8,12		
Hard (E22+E31)		190945					2032,92	10647	11750,25	13783,17	72184		8,12		
Scenarion A	Habitat map of Croatia	5419					60		346	406			8,12	284	1,537
Soft (E11/E12+E21)		1730					13,12	7583	75,83	88,95	51416		8,12		
Hard (E22+E31)		3689					46,71	12662	269,98	316,69	85846		8,12		
Scenarion B	Habitat map of Croatia	4736					55		316	371			8,12	284	1,343
Soft (E11/E12+E21)		1047					7,94	7583	45,89	53,83	51416		8,12		
Hard (E22+E31)		3689					46,71	12662	269,98	316,69	85846		8,12		
Difference to A							-5,18			-35,12					-0,19
Scenario C	Habitat map of Croatia	6320					67		385	452			8,12	284	1,793
Soft (E11/E12+E21)		2630					19,95	7583	115,30	135,25	51416		8,12		
Hard (E22+E31)		3689					46,71	12662	269,99	316,70	85846		8,12		
Difference to A							7			46					1,79

Differences between scenarios A-C are stemming only from changes in the areas covered by various forest types. In scenario B, the forests covered by the accumulation are being replaced; as opposed to that, in scenario C the area covered by forest would be enlarged (Figure 35 on page 44). The productive value of forest in scenario A is 60 million USD (1.53 million USD increment annually), whereas this value for scenario B is at 55 million USD, and for scenario C at 67 million USD.

In order to evaluate the impact of accumulation on forests less adjacent to the river corridor, in terms of underground water changes, a special methodology and datasets would be required, which are outside of the scope of this study. However, this impact would be important, from both the economic and the ecological point of view. For instance, the study of Novo Virje impact by Prpić and Jakovac (1998) estimated that the overall loss due to the proposed Novo Virje accumulation would be at the level of 663 million USD (900 million EUR). It should be expected that the impact would be stronger on forest units located downstream of HEPP Molve 2 (Svibovica, Đurdevačke nizinske šume), where the increase of river bed deepening would cause drainage of the underground water table. In close vicinity of HEPP Molve 1 and Molve 2 we can expect an increase of underground water (Grđan and Kovačev-Marinčić, 1992) which may also have an adverse effect on forest growth, whereas the effect at further distances is unknown (there are no forests close to the existing HEPP North at Varaždin that would be comparable with the Repaš forest). AntoniĆ et al. (2001) modelled the acceptable range of underground water table for the locality of Repaš forest, and concluded that pedunculate oak would probably end up extinct from the area within several decades, under the existing environmental changes. According to these authors, the proposed HEPP (Novo Virje at that time) could improve the conservation and reconstruction of this forest – however, this argumentation is ignoring the fact that other forests down the river would face an even higher risk of extinction.

5.2.3.2. Fish provision

Introduction. Natural freshwater fish production and diversity depend on the ecological state of the river ecosystem: namely, heterogeneity of the habitats and water quality (pollution) are crucial factors affecting these variables. Similarly as the game animals attract hunters, fish attracts anglers, which means that this service is interconnected with the ability of the ecosystem to provide recreational activities. Good natural productivity of the ecosystem and developed angling activities impact upon the final economic output of this service.

Situation in DSDF and PSA. Fish production in DSDF is based on natural production potential of these three rivers, which are forbidden to stock (only man-made water bodies, such as sand pits adjacent to the river but not connected to, it may be stocked). This potential is relatively high compared with other European rivers which have lost the habitats crucial for fish reproduction. That is the reason why the richness of species is very high: Mrakovčić et al. (2006) report about 65 fish species in the Drava River, which makes this river the most diverse in Croatia. Relatively high productivity of the Drava River and its adjacent aquatic water bodies (oxbows) depends on:

- Relatively good connectivity of the river with side arms (although there are also numerous barriers and blinded connections of side arms). The side arms and their variety of lotic and lentic ecosystems provide habitats for breeding and foraging of fish species
- Absence of migration barriers on the main river bed

- Presence of gravel bars as crucial habitat for breeding of salmonid fish
- Preserved flood pulses with overbank flows, which is especially important for limnophilic fish species
- Good water quality

The impact of planned HEPPs should be expected, in the form of a decrease or even disappearance of rheophilic fish species, and their replacement by limnophilic species. A drastic decrease of total fish diversity and adverse effect on holobiotic migratory species (trout, pike, nase, barbel, vimba, starlet, danubian roach and others; Mrakovčić et al., 2006) should be expected, due to the disruption of river integrity, changes in physical and chemical conditions, and disappearance of crucial habitats. Water level pulses, caused by peak regime of electricity production, will adversely affect the fish populations downstream as well.

In terms of angling, the Drava section in the PSA is managed by the Fishing Clubs Association Koprivnica and Fishing Clubs Association Đurđevac, consisting of 10 fishing clubs with 900 members. The management plan is prepared for a 6-year period¹², and it includes estimates of potential fish production and allowed limits for fish catches in registered localities.

There are 200 visiting anglers per annum, with the median duration of visit of 2-3 days. They pay 80 HRK to the Fishing Union (14.40 USD per day, with 60 HRK diverted to the state, and 20 HRK remaining in the Fishing Union); maximum 5 kg of fish, or 2 mature fish specimens, can be taken home.

The catch and release method is more and more popular, and currently represents approx. 10% of the total angling activity; however, it is limited to special localities (Drnić Lake), and it is not supposed to occur on Drava river.

Illegal fishing does occur, but its quantity is unknown. Ten rangers are hired by the Fishing Union in order to fight this issue. Most of the wooden cottages on Drava river banks are also built illegally (Figure 66).

¹²Revizija ribolovno-gospodarske osnove Zajednica sportsko ribolovnih klubova Koprivnica and Revizija ribolovno-gospodarske osnove Zajednica sportsko ribolovnih klubova Đurđevac 2009-2015.



Figure 66: Fisherman cottage on the Drava River in the PSA.

The average quantity of fish catches is estimated by the Fishing Union at 10 tons per year in total (8.2 t in 2013); this figure includes both the river catch and catch at man-made lakes with no connection to the river.

Methodological approach and results. Members of the Croatian angler community are obliged to record every catch in their personal documents; this catch data is statistically processed (Table 11). While fish species and weights are recorded, the locality of the catch is not transferred to the central database, which is why it is not possible to distinguish among the fish catches in the Drava river watercourse and other standing localities (predominantly sand pits). The Fishing Clubs Association Koprivnica and the Fishing Clubs Association Đurđevac, which manage the PSA, were asked to provide data on fish catches and to estimate the contribution of the Drava River and its oxbows to the total number of catches. However, the obtained data (in Table 11) shows a significant discrepancy compared with the allowed catch limits, and is quite likely underestimated; this data was therefore not used for calculating the value of the service.

In terms of the quantity of catch, the most prominent species in the PSA are common nase (*Chondrostoma nasus*), common bream (*Abramis brama*), ide (*Leuciscus idus*), asp (*Aspius aspius*; Figure 68), Prussian carp (*Carassius gibelio*), common barbel (*Barbus barbus*), with pike, carp and grass carp species also frequently caught.



Figure 67: Common nase (*Aspius aspius*). Photo: Dušan Jelić; SINP archive.

According to the Croatian law¹³, Fishing Clubs Associations are holders of fishing rights, and are therefore responsible for the management of individual fisheries sites, and have to make revisions of their fishing Management Plans every 6 years. These revisions should include the annual fishing quotas, as well as fish increment (Table 12 and Table 13) and the total fish quantity.

For the purposes of calculation of the service, the annual quotas have been used, given the fact that they reflect both the ability of the ecosystem to provide fish production, and the usability of this service by the angling community. According to this method, the average value of the service (using both areas) per ha is **277 USD** per year.

¹³Freshwater Fisheries Act (OG 106/01, 07/03, 174/4, 10/05, 14/14).

Table 11: Fish catch overview of the Koprivnica Fishing Union; area: 515 ha.

Fish species	Number of catches in Drava river 2011	number of catches in Drava river 2012
Carp (<i>Cyprinus carpio</i>)	28	31
Grass carp (<i>Clenopharyngodon idella</i>)	123	132
Bighead carp (<i>Hypophthalmichthys nobilis</i>)	0	0
Silver carp (<i>Hypophthalmichthys molitrix</i>)	0	0
Wels (<i>Silurus glanis</i>)	18	16
Pike-perch (<i>Sander lucioperca</i>)	14	25
Pike (<i>Esox lucius</i>)	112	124
Tench (<i>Tinca tinca</i>)	15	15
Common bream (<i>Abramis brama</i>)	190	176
Idc (<i>Leuciscus idus</i>)	116	113
Asp (<i>Aspius sp.</i>)	104	101
Prussian carp (<i>Carassius gibelio</i>)	324	112
Common nase (<i>Chondrostoma nasus</i>)	960	771
Common barbel (<i>Barbus barbus</i>)	367	165
<i>Rutilus pigus virgo</i>	32	79
Other autochthonous species	456	313
Total	2859	2173

Table 12: Annual fish increment for the most prominent fish species in the Koprivnica Fishing Union area for the planning period 2009-2015.

Locality	Total annual fish increment (kg) in 2009-2015						area (ha)
	carp	pike	pike-perch	wels	other	in total (kg)	
Watercourses							
Rijeka Drava with armbeds	9569	2030	950	2313	24879	39740	900
Standing water body							
Šodrana "Dmić"	275	15	8	30	65	393	1,15
Šodrane "Stare Sekuline"	89	21	7	29	129	275	3,5
Šodrane "Sekuline nove"	161	43	14	21	58	297	4,5
Sabolekove grabe	125	29	11	18	59	241	2,4
Čingi – Lingi	714	93	83	125	94	1109	18
Standing water bodies in total	1364	201	123	223	405	2315	29,55

Table 13: Annual fish increment for the most prominent fish species in the Đurđevac Fishing Union area for the planning period 2009-2015.

Locality	Total annual fish increment (kg/ha) in 2009-2015	Area (ha)
Watercourses and oxbows		
Rijeka Drava s rukavcima	132	369,72
Rijeka Mura s rukavcima	128	74,61
Potok Gliboki	88	22,26
Potok Koprivnica	64	7,76
Potok Segovina	56	14,65
Kanal Bistra	53	3,01
Ješkovo oxbow - big lake	48	19,41
Ješkovo oxbow - small lake	45	6,73
Watercourses + oxbows	76,75	515,14
Oxbows only	46,5	26,14
Sandpits		
Lake Šoderica	67	15172
Lake Gabajeva Greda - large lake	46	5,7
Lake Gabajeva Greda - small lake	39	3

Table 14: Price list of common freshwater fish species for the 2012 season. Grass carp, silver carp and rainbow trout are alien species, and depend on stocking by anglers. Only economically important autochthonous species have been used for the calculation.

Fish species	price kn/kg	price \$/kg
Carp (<i>Cyprinus carpio</i>)	37,3	6,7
Grass carp (<i>Ctenopharyngodon idella</i>)	22,4	4,0
Wels (<i>Silurus glanis</i>)	55,4	10,0
Silver carp (<i>Hypophthalmichthys molitrix</i>)	11,2	2,0
Pike-perch (<i>Sander lucioperca</i>)	69,4	12,5
Rainbow trout (<i>Oncorhynchus mykiss</i>)	41,1	7,4
Pike (<i>Esox lucius</i>)	47,1	8,5
Tench (<i>Tinca tinca</i>)	38,2	6,9
Bream (<i>Abramis brama</i>)	16,0	2,9
Average price	37,6	6,8

Table 15: Annual quotas for freshwater fish species in Koprivnica and Đurđevac fishing areas.

	ha	price per ha \$	limit kg	total value \$	limit kg /ha	\$/ha
Đurđevac						
Drava river and oxbows	900	6,8	23845	162 146	26	177
Standing waters	29	6,8	1487	10 112	51	342
Koprivnica						
Drava river and oxbows	515	6,8	34819	236 769	68	451
Standing waters	160	6,8	6326	43 017	40	264
In total						
Drava river and oxbows	1415	6,8	58664	398 915	41	277
Standing waters	189	6,8	7813	53 128	41	276
In total			66477	452044		

To evaluate the fish provision service in scenario B, we used the analogy with the existing accumulation Varaždin. For the purposes of calculating the fishing quotas in the accumulation of HEPP Varaždin, we used the data from the fishing Management Plan for 2013 of The Fishing Clubs Association Općina Cestica 1995. This club manages the river Drava from the Croatian-Slovenian border (56 ha); the accumulation of HEPP Varaždin (Ormož Lake) with the surface of 145 ha; 3 rkm of the HPP Channel "Formin" (20 ha), and some smaller tributaries.

In terms of catch numbers, the most prominent species in this area are pike, bream, asp, common barbel, white bream, common nase, carp, chub, roach, pigo, tench, *Gymnocephalus* sp. and pike-perch. Bighead carp and grass carp are also frequently caught. The average price of fish meat for these species is 6.8 USD per kg. The annual quotas for freshwater fish species in Općina Cestica were 135 USD per ha in the old river Drava bed, 55 USD in Channel Formin, and 269 USD in HEPP Varaždin (Table 16). This makes the value of the service comparable with the scenario A, if expressed in the price of fish meat per ha. Molve 1 and Molve 2 accumulations have the area of 870 ha and 1,006 ha

respectively, which gives the total value of the service of 505,000 USD for the scenario B. However, the fish community would be less diverse, and popular rheophilic species would be missing. Moreover, the fish stock in accumulations is supported by stocking, on which we do not have sufficiently precise information to be included.

Table 16: Annual quotas for freshwater fish species from The Fishing Clubs Association Općina Cestica 1995.

	ha	price per ha \$	limit kg	total value \$	limit kg/ha	\$/ha
River Drava (old watercourse)	60	6,8	1108	7540	20	135
Chanel "Formin" of HPP	20	6,8	162	1102	8	55
Accumulation reservoir of HPP Varaždin	145	6,8	5742	39046	40	269

5.2.3.3. Game animals provision

Introduction. Game is any animal hunted for food, or not normally domesticated. Game animals are also hunted in sport and leisure activities; hence, this service is connected with tourism and recreation as well. In Croatia, according to the Hunting Act (OG 140/05, 75/09, 153/09, 14/14), game is classified as either "small game" or "large game". Small game includes small animals, such as rabbits, pheasants, geese or ducks. A single small game licence may cover all small game species, and be subject to yearly bag limits. Large game includes animals such as deer, bear, and elk, and the permission for hunting such game is frequently subject to individual licensing, where a separate licence is required for each individual animal taken.

Game provision depends on the structure of landscape. A mosaic structure, where game animals can find both food and shelter, provides good conditions for game in principle. The presence of large preserved forest areas usually also provides a suitable environment for valuable trophy game. Such landscape structures are also present in DSDF and PSA, which means that game provision should be evaluated as well.

In terms of hunting, the Drava section in the PSA is managed by the Hunting Association Koprivnica-Križevci County, which is a member of the Croatian Hunters Association. The hunting grounds of the Repaš forest are managed separately by the Croatian Forests. According to Grubešić and Krapinec (2005), the Repaš forest has been designated as one of the most valuable hunting grounds: in the periods 1991/1992 and 2003/2004, there were 47 animals in medal range out of the total of 84 harvested animals (Figure 68).



Figure 68: Repaš forest hunting centre

Methodological approach. The evaluation of the service is based on the number of harvested animals and market prices for game animals. The data of registered hunters and the number of harvested game animals were collected from the Hunting Association Koprivnica-Križevci County and the Repaš Forestry for hunting seasons 2011/2012 and 2012/2013. The Hunting Association Koprivnica-Križevci County consists of 3 hunting clubs, located in Koprivnica, Đurđevac and Križevci. Due to the fact that the PSA includes only one part of the hunting grounds of Đurđevac and Koprivnica clubs, the estimation of game animal harvest in the PSA took into account only those parts of hunting grounds that are encompassed by the PSA: area VI/104 Koprivnica 1 (38,879 ha), and two grounds in the Đurđevac area: VI/102 Đurđevac 1 (22,977 ha), and VI/103 Đurđevac 2 (3,030 ha). These two hunting clubs had 1,018 Croatian members and 27 visiting foreign hunters in 2012. According to the estimates of hunting club representatives, the number of hunters inside the PSA is much lower, and there were only 27 Croatian members and 16 foreign hunters registered in 2012.

In order to estimate the hunting potential, the annual game harvest for each species in hunting grounds VI/104 Koprivnica 1, VI/102 Đurđevac 1 and VI/103 Đurđevac 2 was multiplied with market prices of game (according to the pricelist of game from the Ministry of Agriculture, Forests and Water Management¹⁴, Table 17). Where individual species were not included in this price list, the pricelist of the Croatian Forests¹⁵ was used.

Two hunting grounds in the PSA are managed by the Croatian Forests - Peski VI/6 and Repaš VI/9, and since the whole Repaš forest is a prominent hunting ground, these harvests were calculated separately. The total size of hunting grounds in the Repaš forest is 20,505 ha. The number of Croatian hunters registered in the territory of these hunting grounds in hunting seasons 2010/2011 and 2011/2012 was 441 and 333 respectively. The number of foreign hunters in hunting seasons 2010/2011 and 2011/2012 was 273 and 285 respectively.

Results

¹⁴ Cjenik divljači, Ministarstvo poljoprivrede, šumarstva i vodnog gospodarstva («Narodne novine» broj 67/06).

¹⁵ Cjenik odstrela divljači i usluga lova s važnošću od 01. travnja 2014. do 31. ožujka 2015., Hrvatske šume.

The total number of harvested animals in Koprivnica and Đurđevac hunting grounds is shown in Table 17, and the data for the Repaš forest is shown in Table 18. Roe deer and wild boar are the most important species for hunting. The total values of harvested animals are provided in Table 19. If we present the total value per area unit, the value of the service is 15 USD per ha in Koprivnica-Đurđevac hunting grounds, and 18 USD per ha in Repaš forest hunting grounds.

Table 17: Harvested game animals in hunting grounds VI/104 Koprivnica 1, VI/102 Đurđevac 1 and VI/103 Đurđevac 2.

Game species	price of game animal (hunting fee and price of game meat)*	number of game harvests in in 2012**	kn/all harvests annually	\$ annually
Large game animals				
Red deer (<i>Cervus elaphus</i>) 125-300kg	8 833	79	697 833	125 510
Roe deer (<i>Capreolus capreolus</i>) 17-25kg	2 100	989	2 076 900	373 543
Wild boar (<i>Sus scrofa</i>) 150-300kg	3 750	399	1 496 250	269 110
Fallow deer (<i>Dama dama</i>) 40-75kg	4 983	5	24 917	4 481
Small game animals	466	1 053	490 698	88 255
European hare (<i>Lepus europaeus</i>)- bonity classes	122	2 996	365 512	65 740
Common Pheasant (<i>Phasianus colchicus</i>)	112	1 147	128 464	23 105
Mallard/wild duck (<i>Anas platyrhynchos</i>)	250	28	7 000	1 259
European badger (<i>Meles meles</i>)	233	4	932	168
Wildcat (<i>Felis silvestris</i>)	466	71	33 086	5 951
Marten (<i>Martes sp.</i>)	196	25	4 900	881
Greylag Goose (<i>Anser anser</i>)	196	10	1 960	353
Eurasian Coot (<i>Fulica atra</i>)	93	185	17 205	3 094
Hooded Crow (<i>Corvus cornix</i>)	20	177	3 540	637
<i>Corvus monedula</i>	20	266	5 320	957
Red fox (<i>Vulpes vulpes</i>)	250	4	1 000	180
European polecat (<i>Mustela putorius</i>)	250	1 684	421 000	75 719
<i>Coturnix coturnix</i>	28	345	9 660	1 737
<i>Columba palumbus</i>	100	70	7 000	1 259
<i>Pica pica</i>	20	191	3 820	687
<i>Garrulus glandarius</i>	196	3	588	106
Eurasian Woodcock (<i>Scolopax rusticola</i>)	159	98	15 582	2 803
<i>Anser fabalis</i>	159	124	19 716	3 546
Total value of game animals			5 832 883	1 049 080

Table 18: List of game animal harvests in hunting grounds Peski VI/6 and Repaš VI/9 in Repaš forest, the quantity of harvest in 2012, and value according to the price list.

Hunting season	Game species	number of game catches	price of game animal (shooting and game meat)	kn annually	\$ annually
2010/2011	Red deer (<i>Cervus elaphus</i>)	42	8 833	371 000	66 727
	Fallow deer (<i>Dama dama</i>)	0	4 983	0	0
	Roe deer (<i>Capreolus capreolus</i>)	135	2 100	283 500	50 989
	Wild boar (<i>Sus scrofa</i>)	228	3 750	855 000	153 777
	European hare (<i>Lepus europaeus</i>)	64	466	29 824	5 364
	Common Pheasant (<i>Phasianus colchicus</i>)	2 524	122	307 928	55 383
	Grey Partridge (<i>Perdix perdix</i>)	87	159	13 833	2 488
	Mallard duck (<i>Anas platyrhynchos</i>)	162	112	18 144	3 263
	In total 2011			1 879 229	337 991
2011/2012	Red deer (<i>Cervus elaphus</i>)	55	8 833	485 833	87 380
	Fallow deer (<i>Dama dama</i>)	2	4 983	9 967	1 793
	Roe deer (<i>Capreolus capreolus</i>)	147	2 100	308 700	55 522
	Wild boar (<i>Sus scrofa</i>)	286	3 750	1 072 500	192 896
	European hare (<i>Lepus europaeus</i>)	136	466	63 376	11 399
	Common Pheasant (<i>Phasianus colchicus</i>)	2 335	122	284 870	51 236
	Grey Partridge (<i>Perdix perdix</i>)	41	159	6 519	1 172
	Mallard duck (<i>Anas platyrhynchos</i>)	169	112	18 928	3 404
	In total 2012			2 250 693	404 801

Table 19: Total and proportional (per ha) game animal harvests in studied hunting grounds.

Hunting ground	Area	Game harvest \$	Harvest per ha \$
Koprivnica and Đurđevac VI/104 Koprivnica 1, VI/102 Đurđevac 1 and	64886	993 691	15
Repaš forest hunting grounds Peski No. VI/6 and Repaš No. VI/9 2011	20505	337 991	16
Repaš forest hunting grounds Peski No. VI/6 and Repaš No. VI/9 2012	20505	404 801	20
Repaš 2011 and 2012 average	20505	371 396	18

5.2.3.4. Drinking water provision

Introduction. Floodplain and river ecosystems provide drinking water supply, which is mostly used by abstraction from aquifers (Figure 69). Aquifers are in dynamic balance with the hydrological regime of the entire watershed, being recharged by precipitation, stream water through permeable river bottom, and flood pulses with overbank flows. Depending on the environmental legislation at the national level, controls may be placed on water abstraction in order to limit the amount of water that

can be removed. Over-abstraction can result in rivers drying up, or the level of groundwater aquifers reducing unacceptably.

According to the European Water Framework Directive (2006), good quantitative status is assigned to groundwater bodies, where, despite long term water abstraction in an area, there is no lowering trend of groundwater levels. For this reason, each EU country should define the limits of sustainable groundwater management, or sustainable groundwater yield.

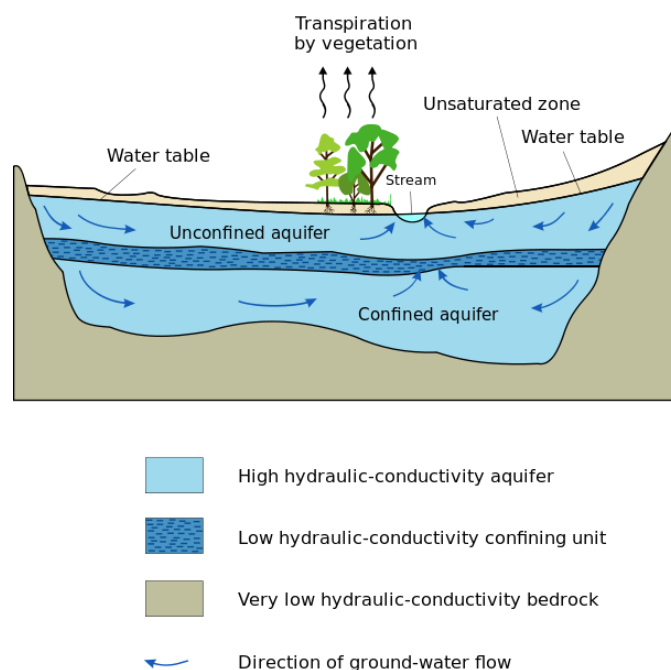


Figure 69: Scheme of an aquifer and its dynamics (Source: Wikipedia).

Situation in DSDF and PSA. A vast majority of drinking water in northern Croatia is abstracted from underground aquifers situated under the Drava, Sava and Danube floodplain areas (Figure 70). The number of inhabitants who are using public water infrastructure supplied from the Danube basin aquifers is 2.35 million. This constitutes 77% of the total number of inhabitants in the area (3.045 million); the remaining 23 % use private wells, sourced from underground waters as well. (Source: Croatian Waters).

The quantitative status of groundwater in alluvial aquifers in northern Croatia has been assessed by Brkić et al. in 2010. The main focus of this study was on analysing the long-term trends in aquifer water levels, based on long-term monitoring provided by piezometers throughout the rivers Drava, Sava and Danube. The results of this study point to a generally negative groundwater level trend in almost the entire area of the Drava and Sava alluvial aquifer. A more detailed statistical analysis points to two principal reasons behind this trend: the deepening of the Drava and Sava river bed, and a decreasing trend of total annual precipitation. The impact of these factors has been assessed by proper statistical analysis, based on separate analysis of particular time periods with different precipitation patterns, which proved the independent effect of these factors. The deepening of river beds is a direct consequence of the shortening of river traces and a misbalance in transport of river bed load trapped in accumulations, which results in the consequential strengthening of the erosion potential of river water. The decrease of flood extent, which is the long-term trend in water management, may also result in adverse effects on groundwater recharge.

A vast majority of piezometers (Figure 72) point to negative trends, with the exception of those in the close vicinity of accumulations in Varaždin County, where the presence of aboveground water bodies results in increasing underground water levels; this trend, however, is not apparent in a wider area of these reservoirs (Figure 72).

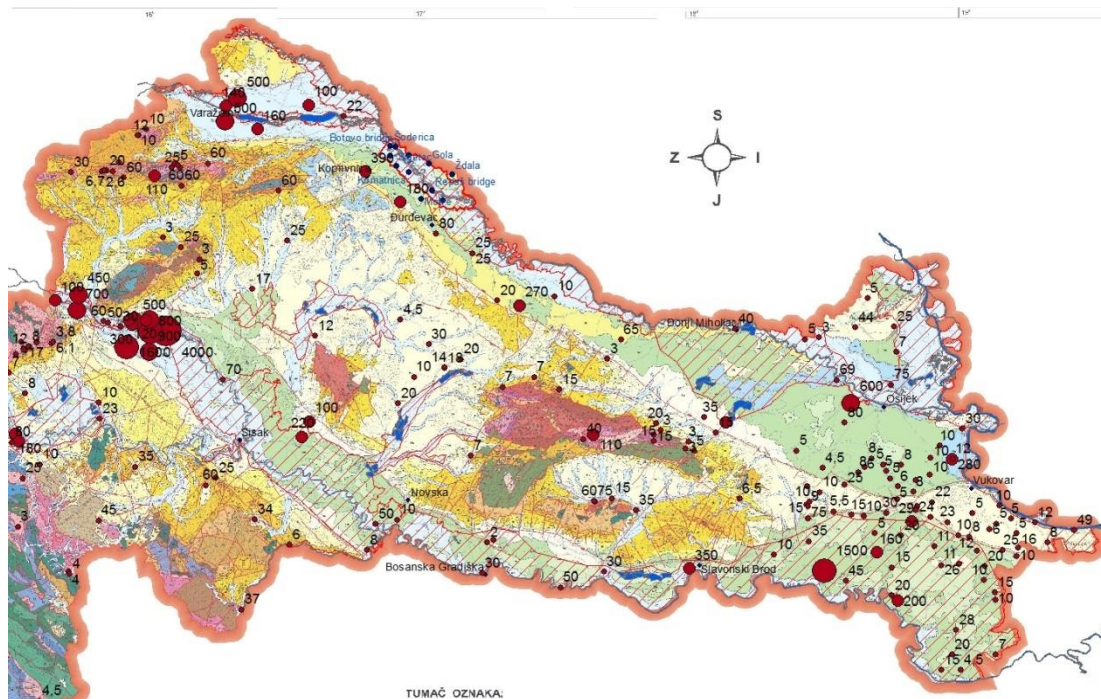


Figure 70: Abstraction sites with the maximum potential of abstraction in m^3/s . For Geological Map legend, see Figure 7 on page 18 (Croatian Geological Survey, 2009).

The PSA is situated on quaternary deposits with aquifers of very good transmissivity, which are covered by impermeable deposits.

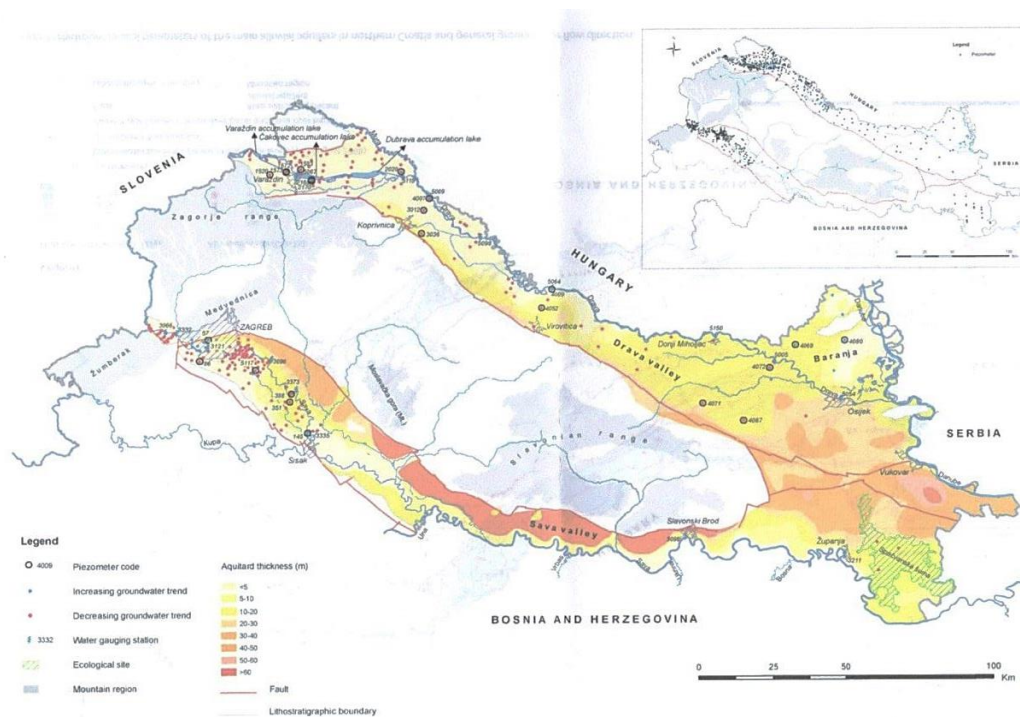


Figure 3: Monitoring network for groundwater and surface water levels and thickness of aquitard in northern Croatia.

Figure 71: Monitoring network for groundwater and surface water levels with the thickness of aquifers in northern Croatia (Brkić et al., 2005).

In terms of aquifers, the PSA is located on quaternary sediments with aquifer of good permeability covered by low-permeability strata with virtually no aquifer (on the right bank of the Drava River), or on sediments with very good permeability (on the left bank, Figure 72). The general status of water quality and the relative amount of water can be characterized as good. There are two underground water bodies under the PSA area – Novo Virje and Legrad-Slatina (Figure 74). The potential storage of underground waters Q_{inf} for Novo Virje is $18 \cdot 10^6 \text{ m}^3 \cdot \text{year}^{-1}$, with no abstraction sites. Legrad-Slatina has Q_{inf} of $362 \cdot 10^6 \text{ m}^3 \cdot \text{year}^{-1}$, with abstraction of $19 \cdot 10^6 \text{ m}^3 \cdot \text{year}^{-1}$.

Value of service for the PSA. We estimated the value on the basis of the abstracted amount of drinking water for Legrad-Slatina, by multiplying its price per m^3 , which amounts to 19.4 mil USD per year. The value per hectare (for the area of Legrad-Slatina water body) is $396 \text{ USD} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ (Table 20). This value is underestimated, however, because it does not include abstraction from private water wells. The overall value for DSDF can be estimated on the basis of the number of inhabitants using the aquifers in DSDF floodplains – which is 3.045 million inhabitants. This value is 189 million USD, and it does not include water consumption of the business sector, which therefore means that it is underestimated as well (Table 20).

The impact of scenarios A-C cannot be evaluated properly due to the complexity of hydrological processes and lack of data. However, it can be assumed that scenarios A and C would result in better groundwater recharge and that they would stabilise the aquifer water storage, while scenario B, due to the absence of inundation, and due to less permeable bottom of accumulation (compared to the active river bottom), would result in a reduction of groundwater recharge. Babbist et al. (1999) estimate that the speed of groundwater recharge is 1 mm per day in the Lonjsko polje flood detention area.

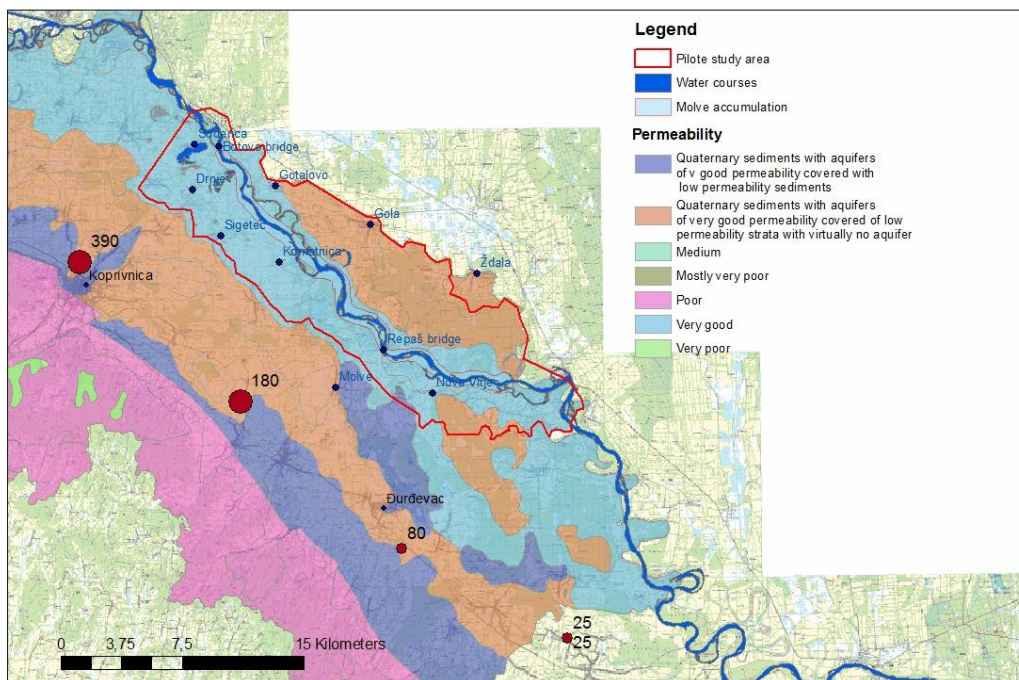


Figure 72: Character of aquifer in the wider PSA area and abstraction sites with maximum capacity Q max.

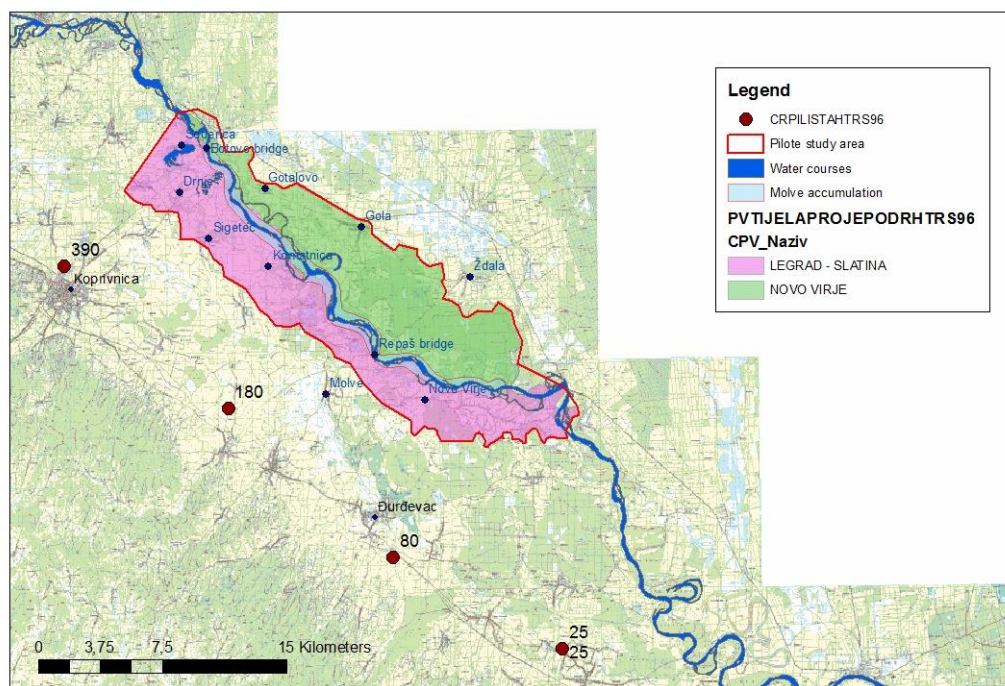


Figure 73: Defined underground water bodies Legrad-Slatina and Novo Virje and location of the PSA.

Table 20: Value of the drinking water provision service for DSDF and PSA (based on underground water body Legrad-Slatina).

		Value of the service \$ per year	Value of the service \$ /ha.yr	Area km2
Price of drinking water in Croatia \$ (kn)	1,025 (5,7)			
Annual average water consumption per person (m3)	60,80			
Number of inhabitants using the water from aquifers in north Croatia floodplains	3 045 826,00	189 849 183	146	13000 (Geol.floodplain)
Number of inhabitants using the water from aquifers in Koprivnička Križevci county:	115 584,00	7 204 459	41	1746
Abstraction in undreground water body Legrad-Slatina (m3.yr-1)	19 000 000,00	19 478 417	396	492 (floodplain part of Legrad Slatina)

5.2.3.5. Gold provision (Gold prospecting, placer mining)

Gold deposits are layers of sediment in the alluvial deposit enriched by particulate gold, and the thickness of such layers is between 3 cm and 100 cm. In Croatia, gold deposits can often be found in alluvial deposits of rivers and streams. They have been identified in quaternary deposits of the rivers Drava and Mura, as well on the corridor Trnovec-Legrad-Podturen. On the river Drava, gold deposits can be found from the Slovenian border to Terezino Polje, and on the river Mura from the river mouth to Podturen.

In the recent Drava sediment, there are no gold deposits. Gold could be found on places such as sand and gravel bars, before HEPP stopped the accumulation of alluvial deposits containing gold. In such places, natural erosion processes would flood the gold deposits during the high water period, when gold deposits could be found on the inner side of river meanders. This gold is usually 0.1-0.8 mm in size (0.3 mm on average), and .930 fine gold.

Small-scale gold mining used to be common in Podravina for centuries. The first data on gold prospecting on the Drava River stems from 1553 (the Zrinski noble family), but it can be assumed that the practice originates from the Roman period. At the beginning of the 20th century, 400-500 people from Donji Vidovec, Donja Dubrava, Sv. Marija na Muri, Legrad, Hlebine and other villages along the Drava River were active in gold prospecting. In 1939, there remained only 200 gold miners, and 20 years ago only few of them were still active. Two men per day were usually required for gold prospecting, and they could extract 0.5-2.0 g of gold from 1 m³ to 3 m³ of deposits per day.

In the 1820s, the annual collection of gold was 6 kg, and in the 1980s it was 12 kg per year. In this process, 5,000 m³ of sediment would be separated. In 1955, a geological research on gold deposits was performed near Trnovac, Donji Vidovac, Mali and Veliki Bukovac and Legrad, with 10 boreholes. The results showed that these deposits are not profitable. The annual gold yield was 2.5-24.4 mg of gold per 1 m³ of sediment, and there were only few layers discovered with a significant 100-150 mg yield of gold per 1 m³ of sediment. The only fully successful gold prospecting was performed in 1986, when 1,142 mg of gold was obtained from one tone of sediment (Marković, 2002).

At present, gold prospecting on the river Drava is vanishing due to the small economic value of gold deposits and the fact that HEPPs have stopped accumulation of alluvial deposits containing gold. The prospectors can still be found on the Drava banks, however (Figure 74). The day yield in the summer of 2014 (Figure 74 on the right) was worth 500 HRK (90 USD) per day. However, gold prospecting can be a suitable activity for tourists, attracting them to the region (see Section 5.2.4.).



Figure 74: Contemporary gold prospecting on the Drava River in Molve area (in the summer of 2014): equipment (left) and daily yield (right).

5.2.3.6. Sand and gravel provision

Sand and gravel provision is an important ecosystem service of floodplains (Haslam, 2008). Excavation from sand and gravel pits (Figure 75) should be regulated, and the limitations should be followed. The newly created sand and gravel pits can become valuable habitats, due to littoral zones and open sand areas attractive for nesting of some bird species attracted to gravel and sand bars in the active river. Taxes paid by excavation companies are also an important source of funds for municipalities around the river. In addition, gravel and sand pits are destinations of swimmers, tourists and anglers, and they can increase the attractiveness of the entire area.

Excavation of gravel directly from rivers (Figure 76) accelerates the deepening of river beds, which is why it was banned on the Drava River several years ago.



Figure 75: One of the largest gravel pits, Šoderica Lake near the Botovo bridge, Drava.



Figure 76: Abandoned ships used for gravel extraction from the Drava River near Križnica.

5.2.4. Cultural services

5.2.4.1. Recreation/tourism

Introduction

The ability of ecosystems to provide recreation for people is being increasingly recognized in recent decades (Haslam, 2008; TEEB, 2010). This ecosystem service depends on the ecological status of the ecosystem, its accessibility and tourist infrastructure. Nature-oriented tourism, or ecotourism, is a responsible approach exposing visitors to a nature-based experience, while simultaneously sustaining or improving the ecological status of an area, as well as enhancing the quality of life for local (and often peripheral) communities. Ecotourism facilities are expected to operate in harmony with the ecosystem, and to remain consistent with the culture and social expectations of the people living within the affected communities.

The 11th Meeting of the Conference of Ramsar Convention Parties, held in Bucharest in July 2012, enacted the Resolution XI.7 on Tourism, Recreation and Wetlands, which confirms that sustainable tourism and recreation can contribute to the achievement of public policy objectives and can bring economic opportunities for securing wetland conservation, their wise use and the maintenance of key socio-economic wetland values and functions, both in Ramsar Sites and in other wetlands. It confirms that sustainable tourism and recreation can both benefit wetlands and contribute to the conservation of ecosystem services, global biodiversity and sustainable development goals and targets, and recognizes that sustainable tourism should optimally use the environmental resources, respecting the socio-cultural authenticity of host.¹⁶

¹⁶Transboundary Ecotourism Guidelines for the Sava River Basin - One River, Four Countries, Unlimited Possibilities (International Sava River Basin Commission, 2013).

The importance of nature protection for tourism development is growing. According to the Institute for Tourism (2007), nature-dependant tourism constitutes 7% of all tourist activities in the world, growing at an annual rate of 10%-30%. Ecotourism constitutes between 7% and 10% of the entire tourism sector, with an annual growth of 2% to 4%; adventure tourism grows at an annual rate of 8%.¹⁷

Situation in DSDF and PSA

Although there are some remarkable tourist activities and attractors in DSDF, tourism in this area can be characterized as mostly undeveloped, since it is not fully using the potential of natural and cultural heritage present in the area. The protected areas of Kopački rit and Lonjsko polje (Figure 76) are among the most successful areas; however, if we compare the number of visitors to these localities with similar types of ecosystems abroad (Table 22), it is obvious that there is a remarkable potential yet to be developed.



Figure 77: Village Čigoč in Lonjsko polje Nature park. Main tourist attractors are the traditional architecture and stork nests that can be found on almost every roof. Stork feeding habitats are grazed wetland areas, followed by meadows. The breeding success of storks in the area is the best ever recorded for this species worldwide. Size of surrounding pastures and regular flooding correlates with the breeding success of these populations (Schneider-Jacoby, 2004).

¹⁷Prirodna resursna osnova i razvoj turizma u Regionalnom parku Mura - Drava u Koprivničko- Križevačkoj županiji (Institute for tourism, Croatia, 2010).

Table 21: Number of tourist visitors in different wetland destinations of a similar landscape character (2012).

Area	Tourists/year	ha	tourists/ha.year
Duna Drava National park, Hungary	116250	49000	2,37
Lonjsko Polje nature park	20000	50650	0,39
Kopački rit nature Park	30000	17000	1,76
Koprivnička Križevci county	7651	174800	0,04

Rivers Mura and Drava represent a specific river area of Koprivnica-Križevci County, with significant natural and cultural heritage. The Regional Park has a high touristic potential thanks to its preserved natural river corridor and related landscape. As a result, this area is much more attractive than the neighbouring western and eastern Drava watercourse in Varaždin County, where hydropower plants are present, or Virovitica, where the river mostly lost its floodplain habitat. The most recognized natural and cultural identity of the County is the river itself. Habitats such as alluvial wetlands and alluvial forests of pedunculate oak are among the most unique habitats in Europe, combined with rich ichthiofauna and ornitofauna. Climate conditions allow for diverse summer and winter activities.

In the context of cultural attractiveness, the most significant element is the naive art heritage of Podravina, which has its roots in Koprivnica-Križevci County, and constitutes an integrated part of the Regional Park (see the following section). The Institute for Tourism emphasizes the tourist potential of the Drava River as a central attraction of Koprivnica-Križevci County.

Tourism in the Regional Park is poorly developed. According to official statistics, there were only 6,705 tourists and 18,241 overnight stays in the whole of Koprivnica-Križevci County in 2012 (Table 22). Accommodation is offered only in the towns of Koprivnica and Đurđevac, and in the municipalities Gola, Virje and Molve (official data from the Koprivnica-Križevci County Tourist Board). Inside the Regional Park, gastronomy and accommodation offer is poorly developed (Table 23).

Table 22: Numbers of tourists in Koprivnica-Križevci County and the town of Đurđevac (Source: Koprivnica-Križevci County Tourist Board). The number of tourists does not include one-day visitors, because this number is undetectable.

Koprivnica-Križevci County						
2010		2011		2012		
Number of tourists	Number of overnight stays	Number of tourists	Number of overnight stays	Number of tourists	Number of overnight stays	
6712	10859	9535	20018	6705	18241	
Town of Đurđevac						
	2010		2011		2012	
	Number of tourists	Number of overnight stays	Number of tourists	Number of overnight stays	Number of tourists	Number of overnight stays
Domestic tourists	3056	5779	3333	5483	4874	10352
Foreign visitors	1124	1811	995	1600	1425	3372
Total number of tourists	4189	7590	4328	7083	6299	13723

Table 23: Accommodation facilities in Koprivnica-Križevci County (Source: Koprivnica-Križevci County Tourist Board).

Accommodation capacities in Koprivnica-Križevci County			
	Type of accommodation facility	Name of	Number of beds
Koprivnica	Hotel	Podravina	98 + 3A
	Hotel	Bijela kuća	23+1A
	Hotel	Zlatan i Marijela	26
	Apartments to rent or rooms in guest houses	Marbis	3A
	Tourist pensions	Tara	12
	Doss house	Sunčano selo	14
	Agritourist pensions (daisies)	Jastrebov vrh	4
Đurđevac	Hotel	Picok	200
	Hunting lodge	Peski	20
Gola	Hunting lodge	Čambina	14
Virje	Hotel	Crna Mica	8
	Apartments to rent or rooms in guest houses	Vršić	6
	Agritourist pensions (daisies)	Ana Vincek	8
Total	18	18	433 + 7A

The main touristic attractions and activities in Koprivnica-Križevci County include the following:

1. Regional Park Mura-Drava – angling, hunting, boating;
2. Đurđevac (old town, gallery with the collection of the Croatian naive painter Ivan Lacković Croata, Đurđevački pijesci, ethnological collection Slavko Čamba);
3. Hlebine, gallery Hlebine, Ivan Generalić's old house with the gallery and Josip Generalić's atelier, ethno house "Janičina hiža", and a number of small private galleries of naive art;
4. Swimming and angling: Lake Šoderica (Legrad), Lake Čingi Lingi near Molve;
5. Legrad – river bend Mura-Drava, zoological reserve Veliki Pažut;
6. Molve – pilgrim church "Podravska katedrala";
7. Podravske Sesvete – ethnological collection Cugovčan, ecological peace garden;
8. Repaš forest, Čambina – hunting;
9. Cycling: the cycling routes along the Drava River have recently been established (Figure 78), although they lack direct access to river banks.

Main events with the potential to attract tourists:

1. Koprivnica – "Motif of Podravina" (Podravski motivi) – fair of naive art, old crafts, gastronomy and folklore;
2. Koprivnica – "The Renaissance festival" (Renesansni festival);
3. Đurđevac – Picokijada – "Legend of Picok's";
4. Molve – Assumption of the Virgin Mary on August 15th (Velika Gospa) – a religious manifestation.

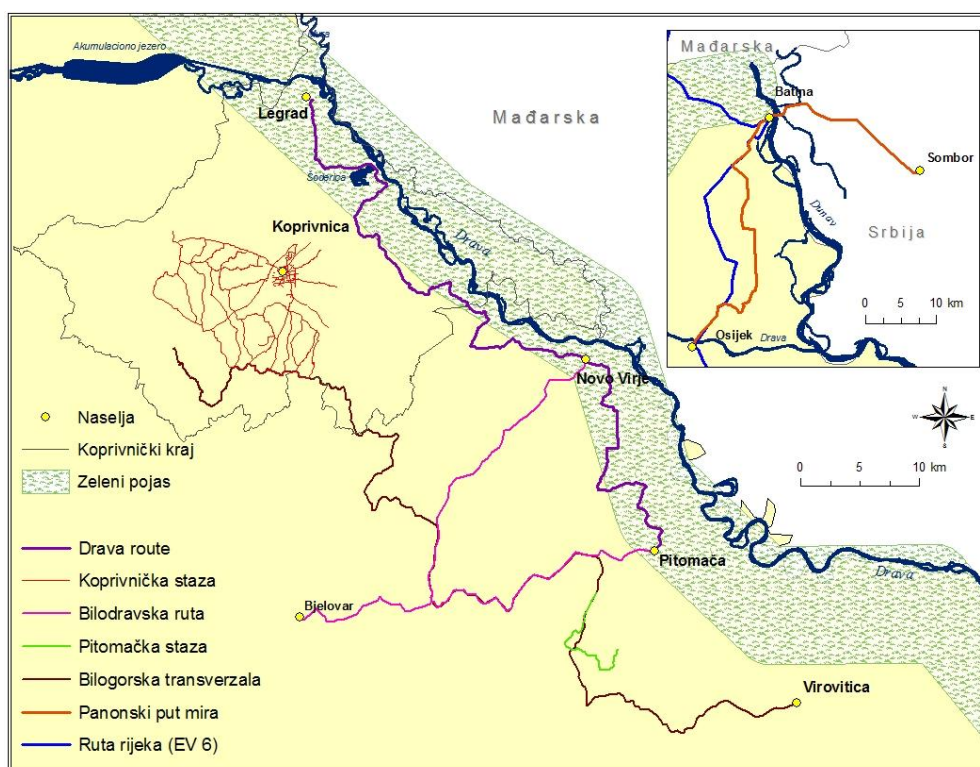


Figure 78: Selected Cycling routes of Koprivnica-Križevci County In the PSA and its vicinity (Turinski, 2012).

Ecotourism



Figure 79: Komatnica Horse Riding Club – the first ecotourism enterprise in the PSA

The first ecotourism enterprise in the PSA was the horse riding club in Komatnica (Mr. Zvonko Mišir, Športsko konjički klub Komatnica), approximately 10 km from Molve. Nowadays, Komatnica has about 25 permanent settlers, but it used to be much bigger in the past (250 inhabitants). Due to the extensive flood in the seventies and lack of jobs, the village is mostly abandoned today. Mr. Mišir established a civil society association to bring new life to the village. They claimed the former school building for their purposes. Three new rooms for guests were prepared, together with stables for several horses, a kitchen, a grill fireplace, and other usual facilities. Two ponies and one horse are offered for riding. In addition, the guests with their own horses can also be accommodated. Given the fact that the area is not popular with tourists, a prerequisite for success of this enterprise would be the promotion of the entire area, in order to attract visitors.

Evaluation of ecosystem service: recreation

Evaluation of this ecosystem service is based on a variety of methods; however, most of these methods depend on sociological approaches, such as the filling out of forms (questionnaires) focusing on economic indicators, for instance on how much is the respondent willing to pay in order to travel to a particular ecosystem (protected area) – in other words, the travel cost method is used (Turner et al., 2008). In addition, the economic impact of tourism can be assessed by analysing daily spending. Given the fact that such research would not fit into this study in terms of time limitations and available financial sources, one should at the very least estimate the potential for scenarios A-C in the PSA.

In scenario B – which includes Molve 1 and Molve 2 accumulations – it would be difficult to expect an increase in the number of visitors. As opposed to that, support for and development of sustainable tourism constitutes an integral part of scenario C in the PSA. Based on comparable wetland areas (Table 21) and potential attractors (with the Drava River as primary attractor), we estimate that **the number of visitors might increase five to ten times**, assuming that proper policies are adopted.

When it comes to the policies, measures and ideas relevant for improving the recreation/tourism ecosystem services, we can mention the following:

- The Regional Park Mura-Drava should be developed as an attractive destination, and the tourist board team should develop tourism planning in terms of nature conservation, with a focus on the ecological component, in order to contribute to the sustainable development of the area.
- Infrastructure and attractors adjacent to the river should be developed, specifically:
 - Visitor centres and access points with information about the river and floodplain ecosystem, history of the area, etc. (Figure 80).
 - Camping sites for canoers and boaters.
 - Restaurants and accommodation facilities.
 - Cycling and walking trails leading the visitor to the river banks as well.
 - Bird watching towers and centres. Bird watching is becoming an increasingly popular hobby, and its importance and value as a niche market in tourism is recognized (Biggs, D. et al., 2011). It is the most common form of ecotourism in the world. The Mura-Drava Regional Park could use this touristic niche, given its unique natural beauty, alluvial wetlands and the richness of flora and fauna species.¹⁸
 - Organized canoe trips and rentals.
 - Floating mill replicas. Floating mills (Figure 81) are very characteristic and unique examples of old craftsmanship in the Podravina region. There is a plan of Molve municipality to build one such mill in Molve. In 1865 (according to the map survey of the Austro-Hungarian Empire), there were 58 floating mills in the PSA (16 if which were in Molve).
 - Good practice from other similar nature parks, such as the Duna-Drava National Park, should be studied and adopted. This Hungarian national park has 1,167 canoers per year and many touristic services, such as the Walking Tour, Photography Tour, Cycling Tour, Canoeing on Danube, Canoeing on Drava, Guaranteed Trip, Illustrious Day, Open Day, education programs, open-air school (outdoor education), cultural programs (concerts).
 - It would also be possible to reflect good practice from the Croatian protected wetland areas, such as the Lonjsko polje Nature Park (50,650 ha), where the annual number of tourists exceeds 20,000¹⁹, or the Kopački rit Nature Park (17,000 ha), where the annual number of tourists reaches 30,000.
 - Rules of access for visitors to protected Natura 2000 sites should be developed, in order to minimize potential harm to protected species (by limiting access to gravel bars during the breeding period, for instance).

¹⁸The value of avitourism for conservation and job creation - An analysis from South Africa (Biggs D et al., 2011).

¹⁹ MARKETING PLAN Područja Parka prirode Lonjsko polje za razdoblje od 2013. do 2020. godine.

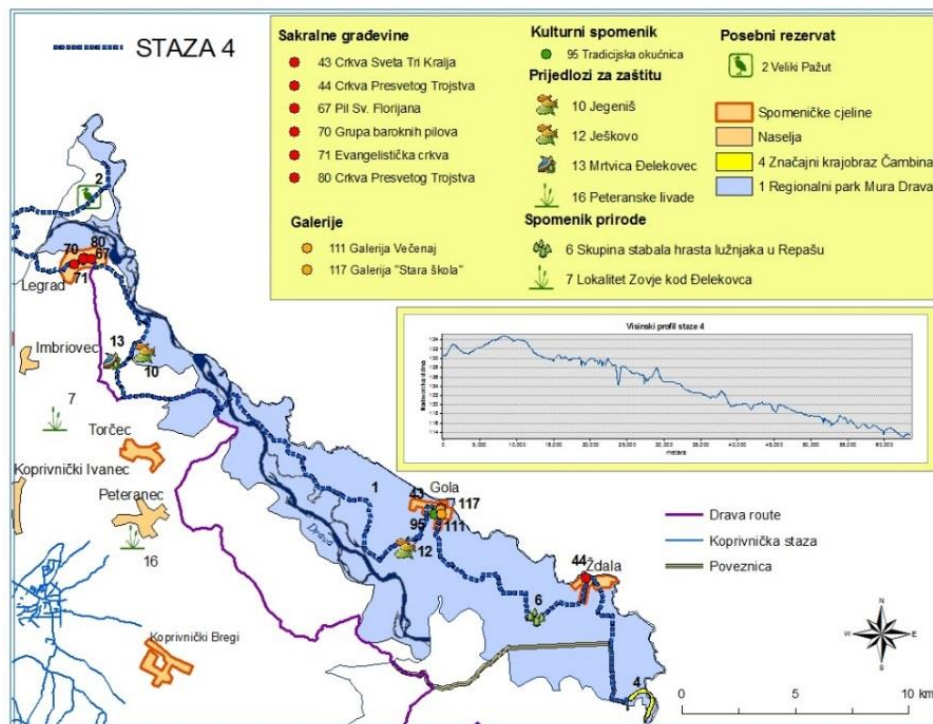


Figure 80: Proposal of potential cycling routes in Prekodravlje within the Regional park Mura-Drava (Turinski, 2012).

5.2.4.2. Art inspiration

The ecosystem service of art inspiration is usually listed near the bottom of the list of ecosystem services, as a less important and/or recognised type of service. Haslam (2008), together with other authors, points out the intangible character of that service. According to the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage, the intangible cultural heritage (ICH) – or living heritage – is the mainspring of humanity's cultural diversity, and its maintenance is a guarantee for continuing creativity. Intangible Cultural Heritage means the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity.

Naturally, an intangible character of a value does not prevent it from having economic importance. Haslam (2008), for instance, notices the fact that some areas possess attractiveness for tourists because of famous artists who lived and created there (Lake District in England, for instance). The visitors coming to such places create demand for services that is important for the local economy.

Cultural heritage of the Podravina region, and especially of the PSA, is closely connected with naive art, a unique artistic school quite well known not only in Croatia, but also abroad. The most prominent locality is the village of Hlebine, with its gallery of naive art and the Generalić Collection. Hlebine is the core of local naive art, but we should also mention the settlements Gola, Molve, Gornja žuma and Đelekovac, as well as the municipalities Novo Virje, Peteranec and Podravske Sesvete. The establishment of the Mura-Drava-Danube Biosphere Reserve provides an opportunity

for revitalization of local art, especially through international cooperation and international initiatives.

Special technique of the Hlebine school is based on reverse painting on glass (canvas being too expensive in previous times). The naive art started developing in the Hlebine area in the 1930s, when the academic artist Krsto Hegedušić spotted the talent of two local boys for drawing pictures – Ivan Generalić and Franjo Mraz. These amateurs had their first exhibition in Zagreb in 1931 (when they were 17). The second generation came in the 1950s. Again, they were amateurs without an academic background. At present, there are about 100 naive artists in the area from Koprivnica to Đurđevac, on both sides of the river (also in Gola). The dominant themes of this art school include the life of countrymen and nature, or life in nature (Figures 81-84). Many paintings show ecosystem services and activities connected with sustainable use of natural resources: fishing, harvesting, grazing, cutting of firewood, transport, floating mills, etc. They usually illustrate a kind of harmony between the nature and man, a close relationship between human activities and natural phenomena (Figure 64), such as, for instance, natural flooding or floodplain forests.

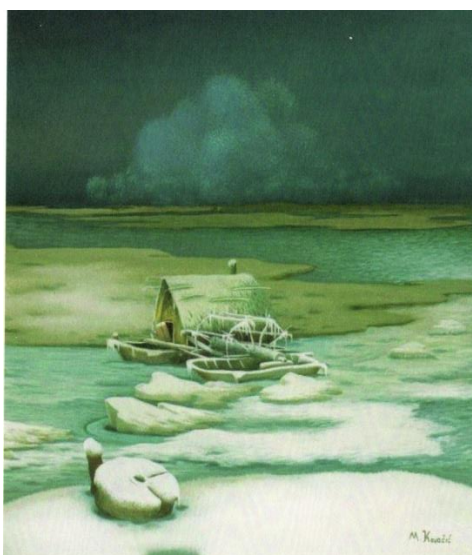


Figure 81: Mill. Mijo Kovačić



Figure 82: Fisherman. Mijo Kovačić

Economic relevance. The price of paintings starts at 70 USD, but usually ranges from 250 USD to 400 USD, if the painter is not widely known. Famous artists sell their paintings for more than 1,400 USD. For most people, this is simply a contribution to their main income, rather than their main job. Mijo Kovačić, the most famous painter, usually makes one painting per month, and sometimes works on paintings longer. In general, it takes from 14 days to 6 months for a painting, with 10 paintings per year. Their price ranges from 6,000 USD to 70,000 USD. There is no central register of paintings, which is why we cannot calculate the exact overall economic turnover. Many authors (there are approximately 300 of them) have their Internet pages and local private galleries.

Mijo Kovačić has the Gallery Mijo Kovačić in Zagreb, sponsored by private sponsors, and also by the Kovačić family. Admission is free. On average, there are 15 visitors a day – or 5,475 visitors per year. In the vicinity, there is also the State Museum of Naive Art. The Local Museum of Naive Art is located in Hlebine.

For scenarios A and C, we can estimate the economic benefit from this ecosystem service in the range of 100,000 to 300,000 USD per year. Scenario B would practically destroy the principal source of artistic inspiration (floodplain forests and natural flooding, for instance), and therefore should be taken as having zero value.

More proper evidence and price and turnover estimation should be ensured in order to properly evaluate this service. Apart from the intangible and economic value, it also has a value for the Croatian prestige abroad, given the fact that it is a valued and unique artistic product.



Figure 83: Flood in Podravina and sustainable use of natural resources, naive artist, Šumarija Repaš.



Figure 84: Hunter's dream. Mijo Kovačić

Support for indigenous breeds as cultural heritage

Indigenous breeds are important as cultural heritage, and also in terms of maintaining specific and irreplaceable landscapes, character of the area, and genetic diversity. Among other ecosystems, floodplains also provide habitats for indigenous species (Figure 85).

During the development of the European civilization in the previous millennia, indigenous livestock has become a constituent part of traditional landscapes. Local vegetation was controlled by grazing and foraging of autochthonous animal breeds. Indigenous animal species became adapted to local climate and habitat conditions, and semi-resistant to local pests and diseases.²⁰ Domestic animal breeds provide key agro-ecosystem functions, such as nutrient cycling, seed dispersion and habitat maintenance. Animal genetic resources and animal management systems are an integral part of ecosystems and productive landscapes throughout the world. By moving their herds seasonally, pastoralists connect different ecosystems. Land-based production systems that have both plant and animal components need co-management of various components of biological diversity, including soils, crops, rangelands and pastures, fodder crops and wildlife.²¹ Numerous rare and endemic species are associated with the habitats in which these indigenous breeds are raised, and the disappearance of these habitats thus also endangers biodiversity.

Due to recent changes in agriculture practices, an increasing number of autochthonous breeds is facing the threat of extinction. With the decline or even disappearance of some of the dominant indigenous animal species, the traditional semi-natural habitat may change. Undergrowth can develop, invasive plant species can spread, and landscape can change from a high-biodiversity grass and low bush habitat into a low-biodiversity habitat.

Indigenous breeds are an important incentive for the revival of rural areas, as they bring extra income to the local community – for instance, through sales of characteristic local food products. As indigenous breeds have become an integrated part of the traditional landscape, they are suitable for managing the biodiversity of habitats, especially in protected areas. A prudent way of managing biodiversity is by including indigenous breeds in the husbandry system in protected areas. This system is already showing results in the Nature Park Lonjsko polje (Slavonian-Syrmian podolian cattle, Croatian Posavina horse).

In the area of the Mura-Drava-Danube Biosphere Reserve, several autochthonous species of domesticated animals have been preserved: the Slavonian-Syrmian podolian cattle, Međimurje horse, Hrvatica hen, small Međimurje dog Međi, and various old plant breeds. In Podravina, one can also find breeds such as the Turopolje pig, black Slavonian pig, and less known indigenous breeds: Drava goose, Croatian hen, Podravina hen, Križevci kukmica hen, Međimurje hen, and Međimuje turkey.

It is necessary to find new opportunities in order to bring indigenous breeds back into rural areas in which they can efficiently revive and maintain landscapes and habitats, while preventing the erosion of biodiversity and specific regional and landscape character, which is also important for tourist development. The evaluation of this service would require specific approaches and methodology, which is outside of the scope of this study.

²⁰Green Book of indigenous breeds of Croatia, State Institute for nature protection, Ministry of Environment and Nature Protection, Croatian Agricultural Agency, 2011.

²¹Global plan of action for animal genetic resources and the Interlaken declaration, Commission on Genetic Resources for Food and Agriculture Food and Agriculture Organization of the United Nations, Rome, 2007.



Figure 85: Indigenous breeds in Posavina (Oprisavci, Poljanci): Slavonian-Syrmian podolian cattle, Cigaja sheep, black Slavonian pig, Croatian Posavina horse. Photo: Brod Ecological Society – BED.

5.3. Ecosystem services compared in variable scenarios in PSA

Evaluated ecosystem services. Comparison of evaluated ecosystem services (Table 25) points to the economic importance of supporting services (habitat provision) and regulating services (flood mitigation). When it comes to provisioning services, the drinking water provision has the relatively highest level.

When it comes to the services which have been evaluated in all the three scenarios for the PSA, scenario C includes the highest values for all three services: wood production, habitat provision and flood mitigation. This is a consequence of land use changes within various scenarios (replacement of natural habitats by accumulation in scenario B, and their enlargement in scenario C; see Section 3.3), and of the structure and enlargement of the active inundation zone, which provides larger flood storage volume. Wood production in the PSA can be impacted by the conversion of floodplain forests. A negative impact is also possible in hardwood floodplain forest areas more distant from the accumulation, and, even more substantially, in the areas located downstream of the accumulation, which are not positioned in the PSA. This impact, however, has not been evaluated due to the lack of data sources. Nutrient retention would be higher in scenario C than in scenario A, but additional analysis is needed to evaluate scenario B.

Services evaluated only for scenario A – game animal production, fish production and drinking water provision – can also be estimated for other scenarios. Unlike fish production, where the situation is unclear because we do not know fish production for the proposed accumulation, the impact on game animal production will definitely be negative in scenario B, and positive in C. Drinking water production depends on how the groundwater recharge will be influenced by the accumulation.

Table 25: Comparison of values for evaluated ecosystem services in scenarios A, B and C in the PSA.

List of Ecosystem services relevant for Drava Sava Danube Floodplains					
Ecosystem service			Estimate for scenario		
	\$		A	B	C
			mil. \$. for pilote study area 201 km ² .year ⁻¹		
Wood production	284	\$.ha of forest ⁻¹ .year ⁻¹	60	55	67
Fish production	277	\$.ha of water body ⁻¹ .year ⁻¹	0,45	0,5	> A
Flood mitigation	5020	\$.ha of floodplain ⁻¹ .year ⁻¹	26,4	-7,4	31,5
Habitat provision	17800	\$.ha of floodplain ⁻¹ .year ⁻¹	139	107	179
Game animals production	18	\$.ha of floodplain ⁻¹ .year ⁻¹	1,45	< A	> A
Drinking water provision	396	\$.ha of floodplain ⁻¹ .year ⁻¹	19,5	?	> A
Nutrient retention	250	\$.ha of floodplain ⁻¹ .year ⁻¹	0,95	?	1,28

Non-evaluated ecosystem services. Table 26 shows the estimation for other identified ecosystem services which were not evaluated. The size of red circles indicates the estimation of relative values in the comparison of scenarios A, B, and C.

Table 26: Estimation of relative values for non-evaluated ecosystem services for scenarios A, B, and C in the PSA.

List of Ecosystem services relevant for Drava Sava Danube Floodplair			
Ecosystem service	estimate for scenario		
	A	B	C
Biomass energy	•	•	•
Irrigation water supply	•	•	•
Agriculture production	•	•	•
Balance of erosion and acumulation	•	0	•
Carbon sequestration	•	•	•
Local climate regulation	•	•	•
Air purification	•	0	•
Draught mitigation, water storage	•	•	•
Biocorridor provision	•	•	•
Estetic value of landscape	•	0	•
Raw material for local crafts	•	•	•
Habitats for indigenous breeds	•	•	•

6. Incentives important for support and strengthening of ecosystem services in DSDF

Nature protection

The EU nature protection instruments are implemented in the Croatian law (entered into force in July 2013). Hence, NATURA 2000 sites are established on the Drava River. Moreover, the Drava River and its floodplain area are part of the core zone of the Mura-Drava-Danube Biosphere Reserve in Croatia and Hungary (Figure 87). For this reason, nature protection of the rivers Drava and Danube has an international character, and cannot be limited only to the Croatian national perspective. Comprehensive issues of nature protection in DSDF and PSA are described in Section 1, and a complete list of protected areas in DSDF is provided in Annex 1.

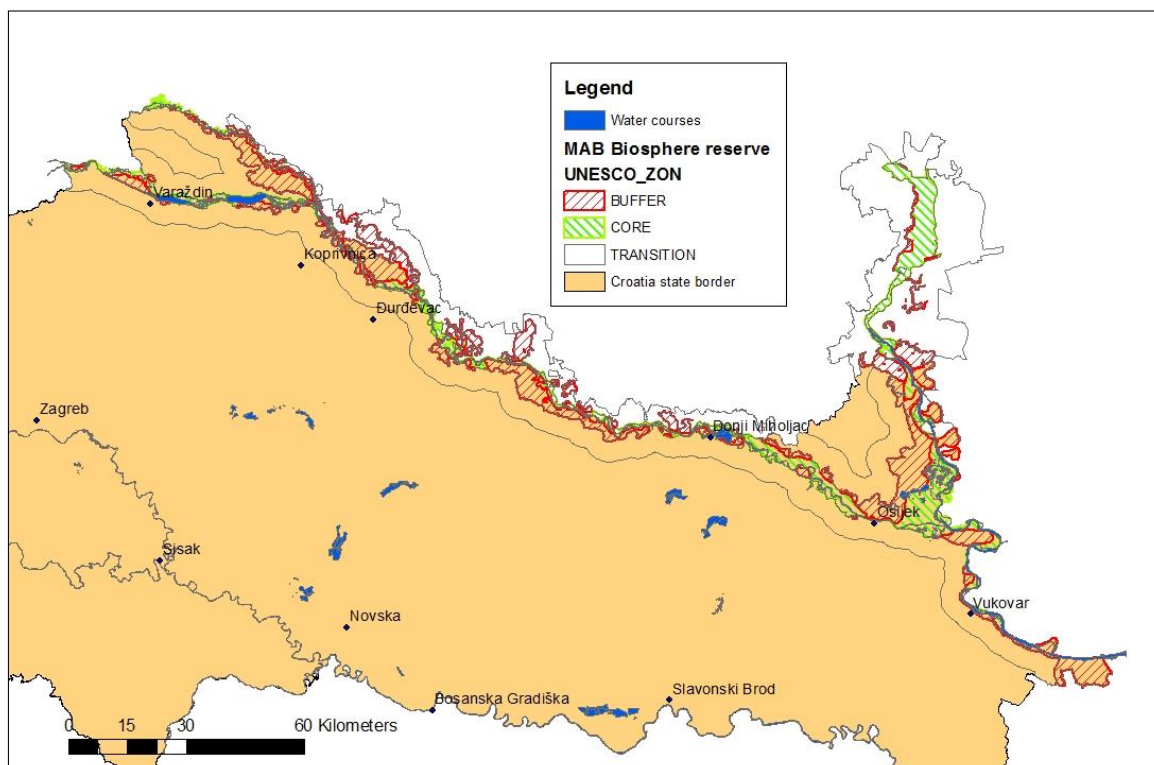


Figure 86: Biosphere Reserve Mura-Drava-Danube: core, buffer, and transition zone.

European directives

The European union Council stressed the need to integrate biodiversity concerns into all EU and national sectoral policies, in order to reverse the continuing trends of biodiversity loss and ecosystem degradation.²² When it comes to the legal framework for the preservation of wetland conditions in the territory of the Drava River, what follows are some directly applicable regulations.

Considering the EU Directives such as the Water Framework Directive and the Floods Directive, Member States shall implement the necessary measures to prevent deterioration of the status of all bodies of surface water and to enhance and restore all bodies of surface water, with the aim of achieving good surface water status at the latest 15 years after the date of entry into force of the Directive.²³ The WFD's objectives of achieving good groundwater quantitative status (Annex V.2.1.2) and good groundwater chemical status (Annex V.2.3.2) require that, among other things, the groundwater needs of terrestrial ecosystems that depend directly on bodies of groundwater be protected, and where necessary restored to the extent needed to avoid or remedy significant damage to such ecosystems.

When it comes to the Directive on the assessment and management of flood risks (2007/60/EC), flood risk management plans should focus on prevention, protection and preparedness. With a view to giving rivers more space, they should consider, where possible, the maintenance and/or

²²<http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm>

²³ Water Framework Directive (2000/60/EC), Article 4.

restoration of floodplains, as well as measures to prevent and reduce damage to human health, the environment, cultural heritage and economic activity.

Croatia has already started fulfilling its commitments in regard to the Flood Directive, specifically within the framework of the EU IPA 2010 twinning project “Development of Flood Hazard Maps and Flood Risk Maps” (2013 – 2014). The purpose of this project is to implement the requirements of the EU Floods Directive, which includes the preparation of flood hazard maps and flood risk maps for the Republic of Croatia. The results of this twinning project will be used in the preparation of flood risk management plans. Croatian institutions (Ministry of Agriculture, Croatian Waters) are collaborating with three EU Member States, the Netherlands, Austria and France, in the implementation of this twinning project (<http://twinning.voda.hr/>).

In the context of main EU instruments on nature protection, having in mind the planned hydropower dams on the Drava river, the following Water Framework Directive requirements should be taken into account: the requirement for a flow regime in accordance with the ecological criteria²⁴; the requirement for undisturbed migration (the ability of fish to bypass migration hindrances). One other WFD-related criterion highly relevant for the construction of hydropower facilities is connected with the morphological changes on rivers caused by the use of the water body, since morphology plays a decisive role with respect to the evaluation of water bodies.²⁵ Another issue that may represent a burden for hydropower plans is the aspect of cost-covering prices for water services.²⁶ This involves the recharging of external costs to the users of water bodies.

National and regional strategic plans

Protected river area of the Drava River is the key area in the spatial development of Koprivnica-Križevci County. Having in mind the fact that environmental protection is an integral part of strategic planning across all sectors, it is important to consider this area in the context of the Croatian National Strategy for Physical Planning and the Croatian Tourism Development Strategy until 2020.

Although the Croatian National Strategy for Physical Planning allows for new hydropower dam construction on the Drava River, hydropower plant construction invokes an extensive set of spatial and ecological issues, as well as transboundary agreements, and is hardly feasible.

On the other hand, the Croatian Tourism Development Strategy until 2020 promotes environmental protection and sustainable management of ecosystems. In addition, the EU Sustainable Development Strategy has three key objectives: economic prosperity, social equity and cohesion, and environmental protection. The environmental and cultural protection segment is focused on minimising pollution and degradation of the global and local environment, and on adequate use of scarce resources in tourist activities; the aim is to maintain and strengthen cultural richness and biodiversity, and to contribute to their appreciation and conservation.

Important projects relevant for nature protection, sustainable development and ecosystem services in the PSA:

- **LIFE Drava Croatia (2013)**

²⁴Water Framework Directive (2000/60/EC), Article 1/34.

²⁵ Water Framework Directive (2000/60/EC), Article 11.

²⁶ Water Framework Directive (2000/60/EC), Article 9.

The aim of the project (in proposal stage) is to ensure renaturation of the river and alluvial forest ecosystem of the lower Drava between Koprivnica and Virovitica, as the first stretch of a free-flowing river after a long chain of hydro power plants. Despite major interference of the river regulation and the construction of water power stations, this stretch of the river has remained comparatively close to its natural form, and it presents an extraordinary area of international importance from the point of view of nature conservation. The river restoration concept includes an analysis of the current situation and the threats posed by human activities. The study aims to highlight concrete measures for the restoration of the Drava River in the project region (which is significantly overlapping with the PSA of this study), which will represent the basis for future activities in the area of both river engineering and ecology.

- **NATREG** - Prirodna resursna osnova i razvoj turizma u Regionalnom parku Mura-Drava u Koprivničko-križevačkoj županiji (2009-2011)

This project was oriented on the determination and valorisation of natural and anthropogenic potential of tourism development in the Regional Park Mura-Drava in Koprivnica-Križevci County. The study results could be implemented in the Spatial Plan of the Regional Park (Prostorni plan posebnih obilježja Regionalnog parka). The study area encompassed the Regional Park Mura-Drava in Koprivnica-Križevci County and 10 municipalities: Drnje, Đelekovec, Ferdinandovac, Gola, Hlebine, Legrad, Novo Virje, Molve, Peteranec and Podravske Sesvete. The concept of sustainable tourism development in the context of a high nature protection status of the area was elaborated in detail.

- **SEE River project** - Sustainable Integrated Management of International River Corridors in SEE Countries (2012-2014)

This project focuses on the preparation of a common agreement in river corridor management between 12 countries along six river corridors: **Drava**, Bodrog, Neretva, Prut, Soča and Vjosa. In order to harmonise stakeholders interests at different levels, and in order to achieve future sustainable use of the river corridor, the SEE River Toolkit would be prepared. The majority of activities will be developed and implemented on pre-selected pilot sites of the Drava river corridor in all five riparian countries: Italy, Austria, Slovenia, Croatia and Hungary. The countries included in the project are Italy, Austria, Slovenia, Croatia, Ukraine, Slovakia, Bosnia and Herzegovina, Albania, Greece, Hungary, Romania and Moldova.

Subsidies

The Action Plan for Ecological Agriculture Development in the Republic of Croatia for the period 2011-2016²⁷ estimates that the number of ecological agriculture producers and the land surface will

²⁷Akcijski plan razvoja ekološke poljoprivrede u Republici Hrvatskoj za razdoblje 2011.-2016. godine.

be increasing by 30% per year. According to forecasts, Croatia might have 5,000 registered ecological producers by the end of 2016, who would manage 90,000 ha. Ecological production would reach 8% of the total agriculture production in 2016.

In 2011, the national subsidies for regular plant/crop production were 369.20 USD/ha (2,055.00 HRK/ha) for arable land, and 126.12 USD/ha (702.00 HRK/ha) for meadows and pastures. Special additional financial support was 520 USD/ha (2,894.00 HRK/ha) for ecological production of vegetables and perennial plantations, 430 USD/ha (2,394.00 HRK/ha) for arable land, and 278 USD/ha (1,548.00 HRK/ha) for meadows and pastures.

A higher level of subsidies (278 USD/ha) for ecological production on meadows and pastures, compared with intensive land use, should also stimulate extensive management in floodplain areas. Considering the fact that 33% of Natura sites in Croatia encompass agricultural land, extensive management should play a significant role in nature protection in the Regional Park Mura-Drava.

7. Summary and conclusions

Floodplains in northern Croatia along the Drava, Danube and Sava rivers (DSDF) represent a unique, large, interconnected and relatively preserved floodplain ecosystem which is recognised on both the national and international level, and which is subject to nature protection measures at a variety of levels (Natura 2000, Regional Parks, MAB UNESCO Biosphere Reserve, Ramsar sites).

Apart from providing valuable habitats that support biodiversity, the floodplain ecosystem provides a number of ecosystem services with economic relevance. These services include provisioning ecosystem services – drinking water, wood, fish, game animals and other resources; regulating ecosystem services – flood protection, drought protection, nutrient and carbon cycle stabilisation, sediment retention; cultural services – recreation, art inspiration and others.

Due to the prevailing threats to the integrity, functioning and existence of floodplain ecosystems, there is an increasing need in recent times to evaluate these services, in order to better understand the benefits of floodplain ecosystems, and in order to evaluate possible losses in case that these systems would lose their near-nature state, or be totally destroyed.

The **most prominent threats** to DSDF include the plans to build a system of hydroelectric power plants by using water accumulations on the river Drava. These accumulations may have a variety of negative impacts on the existing services provided by DSDF. In addition to direct destruction of natural ecosystems, another highly adverse effect would be the prevailing misbalance in the transport of bed load material – gravel and sand, characterised by trapping of the material in the accumulation, with increased erosion downstream of the dam. One consequence of this misbalance would be the acceleration of the river flow, due to the cutting off of meanders and the narrowing of river beds, which would cause higher erosion that results in the deepening of river beds (which is at the level of 1.7 cm per year on the Drava River at Botovo), and the accompanying draining of underground waters and decrease of aquifer water tables, which are important for growth of floodplain forests and drinking water abstraction.

The system of planned hydropower accumulations on the Drava River – HEPP Molve 1 and Molve 2 and VHS Osijek – would turn 64 rkm of the river into a reservoir, and destroy 56 km² of core zones of the Drava river floodplain habitats. With the installed power of 114 MW and an annual production of

720 GWh, this system would reach 50% of the electricity production achieved by the existing HEPP North at Varaždin, but it would require an area twice as large as that of HEPP North. This is a consequence of the lower river slope (0.34‰), which is less convenient for using hydroenergy.

Nine ecosystem services have been evaluated in the pilot study area (PSA, 201 km², 38 rkm) delineated for the purposes of this study, and two of them have been evaluated for the entire range of DSDF. Three ecosystem services – wood production, flood mitigation and habitat provision – have been evaluated for all three alternative scenarios in the PSA: the as-is state (scenario A); construction of accumulations Molve 1 and Molve 2 (scenario B); sustainable development characterised by the extended active floodplain zone (scenario C).

The regulating service of **flood mitigation** has been evaluated on the basis of flood storage volume provided by the floodplain inundation zone or by the accumulation. Monetary evaluation was performed on the basis of the shadow project method, using the cost of provision of retention volume in the technical structure of polder or accumulation type. The total area of designed inundation zones in DSDF is 1,588 km², which represents a remarkable volume, considering the fact that depth can reach 4-6 m. The largest flood storage capacities are located in the Sava river floodplain, where they are estimated at 2.12 billion m³. In the PSA, the inundation volume was calculated at 166 million m³ for scenario A, 198 million m³ for scenario C, and 47 million m³ for scenario B, with the retention volume estimated at 50% of the total storage volume of the proposed reservoir. Monetary evaluation gave the value of 5,020 USD.ha⁻¹.year⁻¹ for scenario A, where the service is currently provided without any cost, as opposed to scenario B, where investments would be needed.

The value of **nutrient retention** as ecosystem service has been evaluated on the basis of the existing studies within the Danube river basin pollution reduction programme, where the value is estimated at 250 USD per ha of active floodplain.

The evaluation of **habitat provision** is based on Croatian habitat mapping, where ecologically valuable habitats relevant for floodplains have been analysed for their area located in DSDF and PSA. For monetary evaluation, the average cost of habitat restoration was used (on the basis of revitalisation experiences for the Danube and Drava rivers in Austria or Slovenia, and on the basis of wetland revitalisations in the Czech Republic). The most valuable habitats include floodplain forests, namely hardwood alluvial forest of pedunculate oak (code E22, area 106,000 ha, value 2.2 billion USD); mixed oak-hornbeam (E31, area 83,000 ha, value 1.6 billion USD); alluvial willow and poplar forest (E11/E12, area 38,000 ha, value 763 million USD); and alluvial forest of black alder and narrow-leaved ash (E21, area 28,000 ha, value 366 million USD). Humid grasslands also belong to the most valuable habitats, with the area of 57,000 ha and value 1.2 billion USD, together with permanent watercourses and standing waters (area approx. 35,000 ha, value 540 million USD). In the PSA, the value of floodplain habitats is estimated at 139 (A), 107 (B) and 179 (C) million USD.

Wood production has been evaluated both as productive value – for monetary evaluation, we used the usual market price of wood products – and as total value, which also includes non-productive value according to the methodology used by the Croatian Forests Ltd., resulting in 5.7 times higher value compared with the productive value of floodplain forest. The productive value of forests in DSDF is 2.5 billion USD, whereas the total value peaks at 17.2 billion USD. In the PSA, the productive value is 60 (A), 55 (B) and 67 (C) million USD, with yearly increment per ha at 284 USD. The impact of scenario B was assessed only as an effect of the decrease of forest due to the destruction by accumulation. The adverse effect on underground water table and forest growth has not been

evaluated in this study, although it is supposed to be large and affecting remarkable areas of forests downstream of the PSA.

Fish production has been quantified only for the PSA in scenario A, based on fish management plans for the relevant fishing grounds (Croatian Fishery Association). The allowed catch limits have been used for running waters (river Drava) and standing waters. When it comes to monetary evaluation, we used the average prices of freshwater fish meat. Fish production in the PSA is estimated at 450,000 USD; in terms of the value per hectare of natural river and oxbow habitats (unstocked waters), it stands at 277 USD.

Game animals production in the PSA has been estimated for scenario A solely on the basis of annual animal harvests in the relevant hunting grounds (Koprivnica, Đurđevac, Repaš forest), and on the basis of price for particular game species. The total value of the service is 1.45 million USD, or 18 USD per hectare.

Drinking water provision pertains to the whole extent of geological floodplains in northern Croatia, where over 3 million inhabitants depend on this service. For the entirety of the PSA area, we estimated the service according to the annual abstraction from the Legrad-Slatina underground water body and the average price of drinking water in Koprivnica - Križevci County. The value of the service is 396 USD per hectare.

Provision of recreation has been estimated on the basis of the number of tourist visiting Koprivnica-Križevci County. On the basis of comparisons with other tourist destinations of a similar character (such as the Duna-Drava National Park in Hungary), we estimated that the potential number of visitors might be 5-10 times higher than the present number of tourists, which is low as a result of undeveloped infrastructure, difficult access to river ecosystems, and lack of information for visitors. Scenario B would not provide better recreation possibilities compared to scenarios A and C.

Art inspiration has been assessed for the naive art painting school, originating in the PSA and being inspired by the river and its ecosystems. For scenarios A and C, we can estimate that the economic benefit would be in the range of 100,000 USD to 300,000 USD per year; scenario B would practically destroy the principal source of this inspiration, and should therefore be taken as having zero value.

Comparison of scenarios for evaluated ecosystem services: When it comes to the services evaluated for all three scenarios for the PSA, scenario C provided the highest values for three key services: wood production, habitat provision and flood mitigation. This is a consequence of land use changes in these scenarios (replacement of natural habitats by accumulation in scenario B, and their enlargement in scenario C), as well as a consequence of the structure and enlargement of the active inundation zone, which provides larger flood storage volume.

Impact of the proposed HEPPs Molve 1 and Molve 2 on ecosystem services, including both evaluated and non-evaluated services, is mostly negative.

When it comes to the **incentives important for the protection and strengthening of ecosystem services**, we have emphasized the importance of: 1) nature protection, which seems to be satisfactory at present; 2) consistent implementation of the relevant European directives, specifically the Directive on the assessment and management of flood risks (2007/60/EC), where the requirement of ensuring space for rivers is strongly formulated, as well as the Water Framework Directive (2000/60/EC), which bounds EU countries to improve the ecological status of rivers; 3) wise use of subsidies for support to extensive management in floodplains; and 4) realisation of development and restoration projects, in particular those of international character.

Messages to decision makers

Floodplains in northern Croatia along the rivers Drava, Sava and Danube provide a number of benefits – ecosystem services – in their current state, with a remarkable economic impact.

Aquifers sourced and maintained by these rivers provide drinking water storage for over 3 million inhabitants of northern Croatia, and for a number of enterprises.

Floodplain forests (oak, ash, hornbeam, alder, willow and poplar), with the estimated value of 2.5 billion USD (as value of wood storage), provide a remarkable annual wood harvest worth 73 million USD. Hardwood products are particularly valued and highly priced, coupled with growth trends.

The surface of 1,600 km² of floodplains provides major flood storage capacities, which mitigates the floods by both reducing the peak discharges and slowing down the flood waves due to rough surfaces (forest vegetation). It would be very expensive to provide such flood protection artificially via engineering structures such as polders or reservoirs.

The restoration of wetlands and active floodplains within the Danube basin rivers has been recognised as a principal tool to mitigate the adverse nutrient load flowing into the Black Sea. The ability of these ecosystems to uptake and store phosphorus and nitrogen has been recognised as an economically relevant tool to tackle this international problem.

Valuable habitats provide shelter and support for endangered biodiversity. In a situation in which most floodplain habitats have been destroyed in Europe, which is why they are currently subject to revitalisation in a number of expensive projects, floodplains of the abovementioned rivers remain relatively preserved.

In addition to wood production, flood protection and habitats, floodplains and rivers also provide fish, game animals, sand and gravel; they also clean the water by re-cycling nutrients, store carbon, stabilise climate by supporting the water cycle, provide opportunities for recreation, inspire artists (in naive art and songs), and provide land for agriculture, including the traditional indigenous breeds and local food products.

For the purposes of maintenance and protection of these ecosystem services, it is necessary to keep the floodplains active. In other words, it is important to enable overbank flows and regular flooding of floodplains, in order to source underground waters important for aquifer levels and ensure the growth of trees, flood mitigation and connectivity within the ecosystem.

When it comes to considering the development projects, such as hydropower accumulation systems, these benefits should be taken into account and included in cost-benefit studies, as well as in the calculation of possible losses.

The proposed benefits of multipurpose projects should be considered cautiously and thoroughly as they are introduced. In case of the existing reservoirs, promises regarding water for irrigation, tourist development and improvements in natural habitats have not been fulfilled. Quite to the contrary: the deepening of river beds endangered the aquifer levels, led to a drastic decrease of wood increment, negatively impacted upon hunting, aesthetic value of the landscape and water self-purification; it blocked migration routes for fish and damaged or destroyed natural habitats. Flood

protection remained limited because of the constant need to produce energy, which makes it impossible to empty the reservoirs in order to mitigate the floods effectively. The proposed accumulations on the Drava river would produce half the energy produced by the HEPP North at Varaždin, but it would require twice bigger area than the previously built accumulations.

When it comes to the future perspectives for northern Croatian floodplains, the preservation or enlargement of active floodplains should be a priority, together with wise use of floodplain sources, such as extensive management in the core zones with the aim of protecting rivers from pollution. The development of sustainable tourism has a great potential, as well as alternative energy sources (*no-dam* solutions, biomass). In the context of incentives important for maintenance and/or enhancing of ecosystem services, one should support the mechanisms of subsidies that motivate land users for extensive management, projects focused on revitalisations of floodplain ecosystems, and motivation for local communities to wisely connect the use of natural resources and economic activities.

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Annex I - Protected Areas in DSDF

EU ecological network Natura 2000 – SPA

HR1000013 Dravske akumulacije	Drava
HR1000014 Gornji tok Drave (od Donje Dubrave do Terezinog polja)	Drava
HR1000015 Srednji tok Drave	Drava
HR1000016 Podunavlje i donje Podravlje	Danube
HR1000004 Donja Posavina	Sava
HR1000005 Jelas polje	Sava
HR1000010 Poilovlje s ribnjacima	Sava
HR1000001 Pokupski bazen	Sava
HR1000011 Ribnjaci Grudnjak i Našice	Sava
HR1000009 Ribnjaci uz Česmu	Sava
HR1000002 Sava kod Hrušćice	Sava
HR1000006 Spačvanski bazen	Sava
HR1000003 Turopolje	Sava

EU ecological network Natura 2000 – pSCI

HR2000728 Biljsko groblje	Drava
HR2000730 Bistrinci	Drava
HR2001416 Brezovica-Jelik	Drava
HR2000570 Crni jarki	Drava
HR2001347 Donje Medjimurje	Drava
HR2001308 Donji tok Drave	Drava
HR2001307 Drava - akumulacije	Drava

HR5000014 Gornji tok Drave (od Donje Dubrave do Terezinog polja)	Drava
HR2000572 Kloštarski (Kalinovački) peski	Drava
HR2000364 Mura	Drava
HR2000573 Petrijevci	Drava
HR2001085 Ribnjak Grudnjak s okolnim šumskim kompleksom	Drava
HR5000015 Srednji tok Drave (od Terezinog polja do Donjeg Miholjca)	Drava
HR2001004 Stari Gradac - Lendava	Drava
HR2001005 Starogradački Marof	Drava
HR2001006 Županijski kanal (Gornje Bazje - Zidina)	Drava
HR2000372 Dunav - Vukovar	Danube
HR2001309 Dunav S od Kopačkog rita	Danube
HR2001088 Mala Dubrava - Vučedol	Danube
HR2001500 Stepska staništa kod Bapske	Danube
HR2001502 Stepska staništa kod Šarengrada	Danube
HR2000394 Kopački rit	Danube;Drava
HR2001403 Bijela	Sava
HR2001086 Breznički ribnjak (Ribnjak Našice)	Sava
HR2001323 Česma - šume	Sava
HR2001289 Davor - livade	Sava
HR2000463 Dolina Une	Sava
HR2000234 Draganićka šuma - Ješevica 1	Sava
HR2000426 Dvorina	Sava
HR2000427 Gajna	Sava
HR2001216 Ilova	Sava
HR2001335 Jastrebarski lugovi	Sava
HR2001326 Jelas polje s ribnjacima	Sava
HR2000642 Kupa	Sava

HR2001293 Livade kod Grubišnog Polja	Sava
HR2000416 Lonjsko polje	Sava
HR2000593 Mrežnica - Tounjčica	Sava
HR2001031 Odra kod Jagodna	Sava
HR2000415 Odransko polje	Sava
HR2001370 Područje oko Hrvatske Kostajnice	Sava
HR2001503 Potok Bregana	Sava
HR2001288 Pričac - Lužani	Sava
HR2000449 Ribnjaci Crna Mlaka	Sava
HR2000450 Ribnjaci Draganići	Sava
HR2000437 Ribnjaci Končanica	Sava
HR2000441 Ribnjaci Narta	Sava
HR2000451 Ribnjaci Pisarovina	Sava
HR2000438 Ribnjaci Poljana	Sava
HR2000440 Ribnjaci Siščani i Blatnica	Sava
HR2001327 Ribnjak Dubrava	Sava
HR2001243 Rijeka Česma	Sava
HR2001311 Sava nizvodno od Hrušćice	Sava
HR2001415 Spačva JZ	Sava
HR2001414 Spačvanski bazen	Sava
HR2000420 Sunjsko polje	Sava
HR2001070 Sutla	Sava
HR2000623 Šume na Dilj gori	Sava
HR2000444 Varoški Lug	Sava
HR2001379 Vlakanc-Radinje	Sava
HR2001356 Zrinska gora	Sava
HR2001006 Županijski kanal (Gornje Bazje - Zidina)	Sava

HR2000465 Žutica

Sava

Ramsar sites

Crna Mlaka

Nature Park Lonjsko polje and Mokro polje

Nature Park Kopački rit

Croatian National Category of Protection according to Croatian Nature Protection Act (OG 80/13).

Nature Park

Kopački rit

Lonjsko polje

Regional Park

Mura - Drava

Significant Landscape

Čambina

Erdut

Gajna

Jelas polje

Jelkuš

Križnica

Križnica

Mura

Odransko polje

Pašnjak Iva

Savica

Spačva

Sunjsko polje

Širinski otok

Turopoljski lug

Vir

Virovi

Special Reserve

Bara Dvorina

Crna mlaka

Crni jarki

Česma

Đol Dražiblato

Jastrebarski lugovi

Jelas ribnjaci - dio

Krapje Đol

ornithological

ornithological

forest

forest

ornithological

ornithological

ornithological

ornithological

Lože
Podpanj
Prašnik
Radiševo
Rakita
Sava - Strmec
Sava - Zaprešić
Varoški lug
Varoški lug - šuma
Veliki Pažut
Vukovarske dunavske ade

forest
ornithological
forest
forest
ornithological
ornithological
ornithological
zoological
forest
ornithological
forest

Natural Monument

Biljsko groblje - travnjak
Gorjanovićev praporni profil u Vukovaru
Topole u Dravskoj šumi
Hrastovi u Drenovcima
Brijestovi u Drenovcima
Hrast u Županji
Hrastovi u Starim Mikanovcima
Hrast Iulius
Hrastovi kod šumarije Repaš

ornithological
geological
botanical
protected trees
protected trees
protected trees
protected trees
protected trees
protected trees

Horticultural Monument

Bilje - park oko dvorca
Dalj - park pokraj patrijaršije
Donji Miholjac - park uz dvorac
Ilok - park oko starog grada
Karlovac - Marmontova aleja
Karlovac - Vrbanićev perivoj
Križovljangrad - park uz dvorac
Križovljangrad - park uz dvorac
Noskovačka Dubrava - skupina stabala
Osijek - Perivoj kralja Tomislava
Valpovo - park oko dvorca
Park forest
Brdo Djed
Dravska šuma
Kanovci
Kunjevci
Zvirinac

park
park
park
park
protected trees
park
park
park
protected trees
park
park