Programme co-funded by European Union funds (ERDF, IPA)

Output 6.1.
Holistic guideline for resilient riparian forests

April 2021
Novi Sad, Serbia

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Holistic guideline for resilient riparian forests

Prepared in line with REFOCuS project activity plan

for WP6 - The Policy Interface

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1. INTRODUCTION

Riparian areas represent a small but critical component of the landscape (Sibley and Gordon, 2010). The term "riparian", deriving from the Latin *riparius* ("*of/on a river bank*", Oxford Dictionary of Current English 1996), refers to "land adjacent to a body of water" (Ilhardt et al. 2000). It is generally accepted that these proportionally small areas of transition between terrestrial and aquatic environments have disproportionate high importance due to their strong influence over landscape-level processes (Sibley and Gordon, 2010). The REFOCuS project (http://www.interreg-danube.eu/refocus), running under the "Environment and culture responsible Danube region" of the Interreg Danube Transnational Programme, has riparian forests in the transboundary Biosphere Reserve (BR) along the rivers Mura, Drava and Danube (MDD) in focus (Box 1). It aims to contribute increasing resilience of riparian forests in the Mura-Drava-Danube Biosphere Reserve (MDD BR) through the joint research efforts of forest research centers from five countries (Austria, Hungary, Slovenia, Croatia and Serbia) and practitioners.

BOX 1: The future transboundary **Mura-Drava-Danube Biosphere Reserve (MDD BR)** covers an area of approximately 8300 km^2 in the countries of Austria, Slovenia, Hungary, Croatia and Serbia and consists of four spatially connected approved Biosphere Reserves. New parts of the MDD BR were recently nominated and together they are the largest protected river area in Europe to be approved as a single transboundary biosphere reserve by the UNESCO in 2021. The entire core zone of this important ecological corridor - a belt of riparian forests along the three rivers - has been designated as part of the Natura 2000 and contains protected areas of various categories.

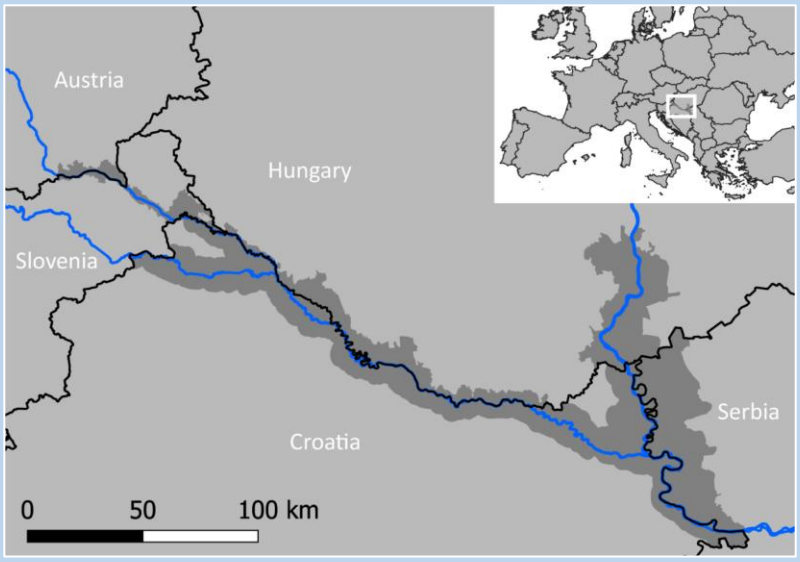

Figure 1. The study area across Austria, Slovenia, Hungary, Croatia, and Serbia is the transboundary MDD BR. It is displayed in dark gray, country borders in black, and the three major rivers in blue (after Sallmannshofer et al. 2021).

Work of the REFOCuS project is portioned into packages and the Work Package 6 (WP6) "The policy interface" is about bringing societal aspects into the research shaped by natural-sciences. These societal aspects include foremost interests of actors having stake in the MDD BR riparian forests, but refer also to the policy landscape that is framing management and protection of these forests, as well as transfer of research results into practice.

This WP6 report aims to establish a bridge between the REFOCuS project outputs and their potential users. Users may differ from forest owners having their property within the riparian zone, non-governmental organisations having stake in the habitat protection of wetlands, to the resource managers or MDD BR-related communities. But generally, they include all actors having stake in the MDD BR. If you belong to these groups of stakeholders and you got attracted by the REFOCuS project you may want to check how its results may fit with your interests and activities. In front of you is a Holistic guideline. The word *holistic* indicates that this document gives a comprehensive overview about the research results that the REFOCuS team either produced or systematized (Chapter 2). The word *guideline* indicates that you will be shown how to use REFOCuS research evidence for your particular project or activity related to riparian forests (Chapter 3). Before that, some basic insides into the current state (Chapter 1.1) and the policy and planning framework (Chapter 1.2) will be given.

1.1. The current state

The forest coverage area within the MDD BR varies greatly between countries, from 90483 ha in Croatia, to only 4017 ha in Austria (Table 1). The area covered by forests in Hungary, Serbia and Slovenia has is 56108 ha, 22570 ha and 8843 ha, respectively. The highest share of private forests is in Austria and Slovenia (80% and 76.6%, respectively), whereas in Serbia and, to major extend, in Croatia all the forests are public. Mixed forests are dominant in Austria (80%), Croatia (80%) and Slovenia (89.6%), whereas the share of mixed and pure forests in Serbia is similar (44.4% vs. 55.6%).

Table 1. General information about MDD BR forests across project partner countries: inventory data and expert estimations given during the Stakeholder Workshop in Novi Sad (April 16-17, 2019).

Country	**MDD BR forest area** (ha)	**Ownership** (%)		**Composition of pure and mixed forest** (% of growing stock)		**Regeneration** (% area)	
		Private	**Public**	**Pure**	**Mixed**	**Artificial**	**Natural**
Austria	4017	80	20	20	80	60	40
Croatia	90483	10	90	20	80	20.2	79.8
Hungary	56107	21	79	n.a.	n.a.	80	20
Slovenia	8843	76.6	23.4	10.4	89.6	75	25
Serbia	22570	0	100	55.6	44.4	36.5	63.5

Source: *Interreg Danube REFOCuS D6.1.1 (adapted).*

The natural regeneration is dominant in Serbia (63.5% of total area) and Croatia (79.8%), while artificial regeneration is more used in Austria, Hungary and Slovenia (Table 1).

The most dominant tree species in the total growing stock of the MDD BR across the partner countries (except Slovenia) is *Quercus robur*, whose share ranges between 10.2% in Slovenia to 46% in Croatia. Two *Fraxinus* species - *Fraxinus angustifolia* and *Fraxinus excelsior* are present in Hungary and Slovenia, although in the later the forestry service does not distinguish between the two in the databases. *F. angustifolia* occurs also in Croatia and Serbia where it is the second most abundant tree species in the growing stock. *F. excelsior* is present in Austria, and similarly to the previously mentioned *F. angustifolia*, it is the second most common tree species there. The share of *Populus nigra* in the total growing stock of project partner countries is less than 10%, and ranges between 9% in Croatia to only 1% in Austria. *Alnus glutinosa* has the highest share of growing stock in Slovenia (22.4%), whereas in Serbia this species is barely present (0.01%). Lastly, *Ulmus* sp. is present in a percentage of less than 1% in Serbia, Croatia and Slovenia, 1.6% in Hungary and 5% in Austria (Table 2).

Table 2. Tree species composition in Mura-Drava-Danube Biosphere Reserve across partner countries (only tree species of project interest are presented).

Country	**Tree species** (% of total growing stock)					
	Quercus robur	*Fraxinus*		*Populus nigra*	*Alnus glutinosa*	*Ulmus* sp.
		angustifolia	*excelsior*			
Austria	20	0	10	1	5	5
Croatia	46	9	0	9	3	0
Hungary	36.5	15.0	1.3	6.7	7.8	1.6
Slovenia	10.2	13.0		7.8	22.4	0.8
Serbia	16.6	3.4	0	1.6	0.01	0.3

Source: *Interreg Danube REFOCuS D6.1.1. (adapted).*

1.2. Policy framework and planning

Riparian forests in the MDD BR are under the influence of a complex policy framework containing legal acts and strategic programs in the first place. Both, legal acts and strategic programs are sectoral (forestry), as well as cross-sectoral (biodiversity, nature protection and other like water, agriculture or spatial planning). Summary of countries´ detailed legal and strategic documents can be found in the REFOCuS Deliverable D6.1.1, chapter 4. As expected, conservation and management of riparian forests across all partner countries is regulated by the set of previously mentioned (regulatory) acts with national scope and strategic programmes. It shows the mosaic of often overlaping and typically vaguely formulated policy documents that as such leave space for interpretations or create confusion and so contribute to already existing conflicts between various stakeholders (Chapter 2.2.2).

The use of forest reproductive material (FRM) of non-native trees species (NNTS) is differently regulated across partner countries. In general, there is no special rule/law/act that regulates use of NNTS reproductive material, but this issue is rather regulated indirectly throughout different acts and strategy documents (see D6.1.1., chapter 4.3.).

Table 4. The use of forest reproductive material (FRM) of non-native tree species and presence of provenance recommendations for the use of FRM.

Country	Use forest reproductive material (FRM) of non-native trees species (NNTS)	Existence of provenance recommendations for the use of FRM
Austria	Allowed to use FRM of any tree species in forests; the decision is up to the forest owner	Provenance recommendations are recommendations only and not mandatory
Croatia	Allowed in accordance with Regulation on provenance of tree species, Law on short rotation wood plantations, Law on Nature Protection	Provenance recommendations are obligatory for collecting and use of FRM
Hungary	Allowed in accordance with forestry management plans	Provenance recommendations are recommendations only and not mandatory
Slovenia	Introduction of NNTS into forests is allowed in accordance with rules listed in Nature conservation act; allowed according to the Forest Act. But is not allowed in the MDD BR, a Natura 2000 site, according to Decree on special protection areas (Natura 2000 areas)	Provenance recommendations on altitude are obligatory for collecting and use of FRM, but not on provenance regions. These are just recommendations.
Serbia	Allowed to use FRM of NNTS in case when it is produced in official nurseries from reproductive material of known origin	Provenance recommendations are obligatory for collecting and use of FRM

In contrast to Austria and Hungary, where the provenance reccommendation for collecting and use of FRM are on the voluntary basis (e.g. not mandatory), thay are obligatory in Croatia, Serbia and partially obligatory in Slovenia. In Slovenia, following the collection and use of FRM in a given altitude belt is obligatory, while use of provenance regions is only recommended. Regarding Serbia, subsidies are connected to this prescription, as the State subsidizes only the use of FRM from known regions of provenance. In contrast, the subsidy system in Hungary favours native tree species, but there is no special funding for the use of the recommended FRM sources (provenances) within the species.

References:

- Ilhardt, B.L., Verry, E.S., Palik, BJ. (2000). Defining riparian areas. In: Verry, E.S., Hornbeck, J.W., Dolloff, C.A. (eds.). Riparian management in forests of the continental eastern united States. Lewis Publishers, New York, p. 23-42.
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- Sibley, P., Gordon, A. (2010). Managing riparian forests: a decision support system. Sustainable Forest Management Network, Edmonton, Alberta, 42 pp.

2. MAIN ISSUES IN MDD BR AND KNOWLEDGE GENERATED TO ADRESS THESE ISSUES

This chapter deals with the main issues in the MDD BR (as identified in the dialog between stakeholders and researchers within WP6) and presents scientific and expert knowledge (that was either generated or systematised by the REFOCuS project to adress these issues).

2.1. Main issues in MDD BR

WP6 organized two stakeholder workshops. One of the aims was to gain insides into the "hot issues" regarding riparian forest management and conservation in the MDD BR though an open discussion between researchers and stakeholders. These issues can be divided into ecological and social (Table 5). Within both categories, subcategories presented here were deemed "strongly present", or "partly present" during the workshop in Novi Sad (April 2019) (the third category was "absent"). The later online workshop (October 2020) was used to refine estimations given for the main ecological issues: decline of underground water, pests and diseases, natural regeneration and availability of forest reproductive material (native species). In parallel to that, the (social) issue of conflicting interests was addressed through the questionnaire distributed among diverse stakeholders in each country (the results of the analysis are expected in May 2021).

Table 5. Main issues in Mura-Drava-Danube Biosphere Reserve (MDD BR) as estimated during Stakeholder Workshop held in Novi Sad on 16-17th April 2019 and Online stakeholders workshop held on 15th October 2020 (Stojnić et al. 2021). For details look D6.1.1. and the report from the Online stakeholders workshop.

Country	Main issues				
	Ecological				Social
	Decline of underground water	Pests and diseases	Natural regeneration problems	Forest reproductive material availability -Native species-	Conflicting interests of stakeholders
Austria	++	++	+	++	++
Croatia	+	++	+	++	++
Hungary	++	++	++	+	++
Slovenia	++	++	++	++	++
Serbia	++	++	++	+	++

Legend: (++) strongly present, (+) partly present.

- Decline of underground water is a widespread problem especially in for pedunculate oak. The dieback of oak trees is widely present, not only in mature stands, but also at regeneration sites, causing reforestation failures. Climate change is identified as an additional trigger.
- Biotic and abiotic harmful factors commonly present in MDD BR, including wind throws and wind breaks, and pests and diseases, such as ash dieback caused by *Hymenoscyphus fraxineus*, *Phytophthora* spp., oak lace bug (*Corythucha arcuata*), as well as die-back of *Populus* spp. in poplar

plantations caused by gram negative bacterium *Lonsdalea populi* and fungi belonging to several genera of the phylum Ascomycota.

- Natural regeneration: in Slovenia it is considered extremely difficult due to dense ground vegetation composed mainly of invasive non-native plant species (most limiting), ownership structure, movement of ground material and biotic factors, and therefore human intervention is required (ground preparation, adjustment of species composition). In Austria there is a concern whether native tree species would be able to cope with rapid climatic changes. Therefore, several non-riparian and non-native tree species are being considered for future reforestation, including sessile oak, black walnut and black locust, despite concern of their use in the BR. In Hungary and Serbia, the lack of natural regeneration is widespread, although it has been documented that certain species successfully regenerate spontaneously even at marginal lands (such as pedunculate oak growing on sandy dunes, salted soils, etc.). Despite these problems, use of natural regeneration should not be neglected. Large areas under extensive plantations of hybrid poplar and willows in aforementioned countries also present an obstacle to natural regeneration in MDD BR. High pressure of game was identified across partner countries as an obstacle to forest regeneration.
- Forest reproductive material (FRM): Availability of native FRM is generally not a problem, but most countries (except Austria) stress that irregular mast years of pedunculate oak may sometimes be problematic. For Austria, the establishment of trade connections with Eastern Europe would be beneficial, since the seed imported from Western Europe seems not to be well adapted to Austrian conditions.
- Conflicting interests of stakeholders: The forests in the MDD BR are at the intersection of different Laws and Directives from the forest and nature protection sectors, which often overlap and lead to different interpretations of forest management in the field. Also, various stakeholders (e.g. the state and private forest owners, nature conservation governmental and non-government organizations, civil society, etc.) have different attitudes towards priority forest management goals (e.g. market-orientation vs. nature conservation), which often leads to conflicts.

References:

- Interreg Danube REFOCuS D6.1.1. Report on the overview of the national legislations of the five countries constituting Mura-Drava-Danube Biosphere Reserve and EU regulations and directives relevant for health, conservation and management of riparian forests.
- Interreg Danube REFOCuS. WP6 Policy Interface. Report from the Stakeholders workshop: A6.1. Overcoming conflicts between conservation and forest management stakeholders within existing policies. 16-17th April 2019, Novi Sad, Serbia.
- Interreg Danube REFOCuS. WP6 Policy Interface. The report from the Online stakeholders workshop: How to harmonize forest management planning and nature conservation in riparian forests of Mura-Drava-Danube Biosphere Reserve? 15th October 2020, Online meeting.
- Stojnić, S., Krajter-Ostoić, S., Zavođa (Stevanov), M. (2021). Case study: Stakeholder perspectives on riparian forest management and conservation in the Mura-Drava-Danube Biosphere Reserve. In: Sallmannshofer, M., Schüler, S., Westergren, M. (Eds). Perspectives for forest and conservation management in riparian forests. Studia Forestalia Slovenica, 168. ISBN: 978-961-6993-62-3 [also available in Serbian]

2.2. Scientific and expert knowledge that was produced or systematised within the REFOCuS project to adress main ecological and social issues

Within the REFOCuS project researchers either produced specific information pool or systematised already existing research results. They can be found in the project web base, as well as in peer-review journals. This chapter offers their highlights, structured according to the main MDD BR issues (as ecological and social) and their scientific base (natural and social sciences).

2.2.1. Ecological issues (natural sciences)

Main ecological issues include underground water, pests and diseases, natural regeneration problems and the availability of forest reproductive material.

Underground water

Adaptive management of pedunculate oak (Quercus robur L.) forests in Serbia in the light of climate change

A number of biotic and abiotic factors have been identified that contribute to *Q. robur* decline. Although the causes of oak decline are complex and probably involve diverse direct and indirect factors, drought stress has been frequently reported as the main driver of oak dieback across Europe.

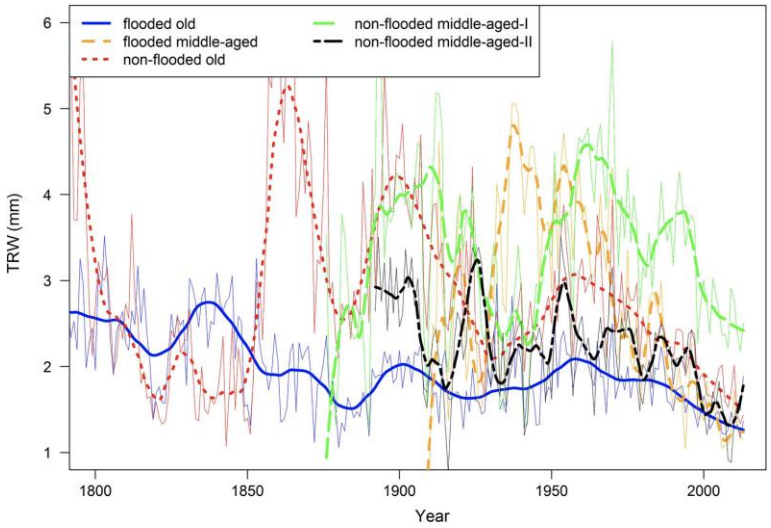

Figure 2. Tree-ring widths of five *Quercus robur* L. tree groups situated along Sava River, for the 1800-2012 period with splines (bold lines) (source: Stojanović et al. 2015a).

The phenomena of droughts and temperature extremes, as well as decline of the Danube and the Sava rivers' water levels have been identified as the most important factors affecting future adaptive management of pedunculate oak forests situated along Sava and Danube Rivers in Serbia (Stojanović et al. 2014, 2015a, b).

Integrated solutions for the management of pedunculate oak forests:

1. improvement of regeneration practice (see “Regeneration of pedunculate oak (*Quercus robur* L.) forests in the light of climate change“),
2. promotion of mixed forests and structural diversity (e.g. mixed oak forests have been reported to suffer less damage from biotic and abiotic stress agents),
3. increase of groundwater level during prolonged drought periods (e.g. new water management strategies, including abstention from creating new artificial drainage systems and deep channels besides forest roads, as well as restoration of natural floodplain fens should be considered to provide higher levels of groundwater for particular stands (Stojanović et al. 2015a).

References:

- Stojanović, D., Levanič, T., Matović, B., Galić, Z., Bačkalić, T. (2014). Vodostaj Dunava kao faktor smanjenja prirasta i vitalnosti stabala mešovite sastojine lužnjaka i cera. Šumarstvo 3-4, 153-160.
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Pests and diseases

Management guidelines for bacterial canker caused by Lonsdalea populi in hybrid poplar plantations

Bacterial canker caused by *Lonsdalea populi* is the most serious disease affecting *Populus* x *euramericana* in Europe. The bacterium infects poplars in nurseries and plantations.

Figure 3. Disease symptoms caused by *Lonsdalea populi* on *Populus x euramericana* clone "I-214" in Serbia (source: M. Zlatković).

Typical disease symptoms appear in summer and autumn when the climate is warm and humid, and these include branch and stem cankers with sticky and often foamy exudates with a rotten smell that ooze from the cracks. Once exposed to the air exudates darken and stain the tree bark. Sometimes, the infected bark peels away from the sunken canker area exposing a rotten wood with a fermentation odor and a creamy mass of white exudates. In an advanced stage of the disease, cankers may cause crown die-back and the diseased trees die within a few weeks.

Because the use of antibiotics for plant diseases control possesses a significant risk to human health and the environment, and because of the growing threat of antimicrobial resistance, most countries in Europe do not approve antibiotics as active ingredients in pesticides, whereas some countries permit their use only for certain crops or in emergency situations. Therefore, management options for bacterial disease problems in poplar plantations are limited. Genetic improvement programs that continuously screen new clones for disease resistance or at least tolerance while assuring highest possible volume production would be the most promising strategy for *Lonsdalea* disease control. Moreover, a good management approach for disease prevention is to promote the general health and vigor of the trees through various cultural practices including fertilization, watering, avoidance of mechanical injuries, weed control and maintenance of an optimal plant density. Plants should be properly protected against insect pests which are known to spread bacterial diseases of trees. Good cultural practices also assume planting of poplar clones resistant or tolerant to fungal diseases as well as planting of clones which are best suited for the environment in which they are grown. Nurseries and plantations must be established on soils suitable for poplars to reduce weakening of the plants. Cuttings should be collected only from disease-free, vigorously growing plants and planted during periods of favorable moisture and temperature to minimize stress. If only branches are symptomatic with cankers and ooze, they should be pruned, and wounds should be sealed using grafting wax. Severely infected trees with bacterial ooze on stems should be removed from the plantation as soon as possible to slow the spread of the disease. Bacterial ooze must not come in contact with the soil during either pruning or removal of trees. Soil from areas known to be infected with the bacterial canker must not be moved, either on plant material or equipment.

References:

- Zlatković, M., Tenorio-Baigorria, I., Lakatos, T., Tóth, T., Koltay, A., Pap, P., Marković, M., Orlović, S. (2020). Bacterial canker disease on *Populus* x *euramericana* caused by *Lonsdalea populi* in Serbia. Forests 11: 1080; doi:10.3390/f11101080
- Zlatković, M., Pap, P., Tenorio-Baigorria, I., Koltay, A., Ogris, N., Cech, T. (2021). Diseases of poplars and their hybrids with an emphasis on disease management recommendations. In: Sallmannshofer, M., Schüler, S., Westergren, M. (Eds). Perspectives for forest and conservation management in riparian forests. Studia Forestalia Slovenica, 168. ISBN: 978-961-6993-62-3 [also available in Serbian]

Forest reproductive material

Lack of seedlings of native riparian tree species for restoration and artificial regeneration of native habitats

In Slovenia, there is a shortage of seedlings for the restoration of Natura 2000 habitat types for many of the most important riparian tree species. There is a permanent shortage of seedlings for *Populus alba*, *Ulmus laevis* and all willows except for *Salix alba*.

Figure 4. Seedlings of European black poplar two years after planting along the Mura River in Slovenia (source: G. Božič).

The floodplains along the Mura, Drava and Danube host many forest habitat types. In order to preserve them, many of them have been officially designated and included in the Natura 2000 network. However, their natural regeneration is often impaired where river dynamics have changed too much, ground vegetation, often consisting of alien plant species, is very dense and may prevent suitable light and moisture conditions, where pests and diseases have severely damaged tree species and where browsing is widespread. In such cases, artificial regeneration is used.

Artificial regeneration requires access to high quality seed and seedlings with increased tolerance to biotic and abiotic stressors and with high genetic diversity. Production of such material requires appropriate selection of seed sources, seed collection and processing, promotion of genetic diversity and good nursery conditions.

Because riparian forests often constitute only a small proportion of a country's forests, it may be difficult to obtain high-quality forest reproductive material that is well adapted to riparian forests, especially if national regulations restrict the use of reproductive material from neighboring countries. Reasons for this may be the lack of regular mast years for the target tree species, the decline of their range due to land-use changes, or poor health and thus reduced genetic diversity. Another problem when considering

genetic diversity is the use of clonally propagated material, especially when the same clones are used over and over again. There is also a lack of modern nurseries that would produce seedlings of riparian tree species in larger quantities. A crucial point is also that the production of seedlings requires several years and hard manual labor.

Several measures could be taken to ensure a constant flow of quality seedlings of all riparian tree species:

- Designating a greater number of seed stands and establishing seed orchards for riparian tree species,
- Facilitate the transfer, import and export of seed from riparian forests connected to the same rivers in neighboring countries,
- Improve conditions for long-term seed storage,
- Long-term planning of seedling quantity requirements for different tree species,
- Maintaining equal proportions of male and female trees in forests for dioecious tree species, i.e. black poplar and white poplar.

Natural regeneration

Regeneration of pedunculate oak (Quercus robur L.) forests in Serbia in the light of climate change

Pedunculate oak forests are endangered in multiple ways, in all stages of the development, with the most challenging stage of regeneration, that needs special attention. Regeneration of pedunculate oak forests is possible only with human assistance. However, the taken measures must not be radical, they should be as close as to the natural processes.

Figure 5. Early stage of the juvenile common oak plants (left), and mature common oak stand in regeneration stage (right) (source: Rađević et al. 2020).

Nowadays, the regeneration of pedunculate oak (*Quercus robur* L.) in Serbia is based on the shelterwood cutting system on large areas, where the understory layer and trees of the previous stand are removed in several phases in short regeneration periods (2-3 years), through the preparatory, regeneration and final cuts. Although present management models give good results, changes and improvements are

needed, considering the presence of multiple biotic and abiotic factors that have negative influence on the survival and development of pedunculate oak forests.

For the successful oak rejuvenation and forest management, in general, following measures are considered as optimal by the largest manager of state-owned common oak forests in Serbia (Rađević, 2020) and should be applied in the future: (1) regeneration should be done in the shorter period of time (1-3 years); (2) use of chemicals should be reduced, while taking into account that present undergrowth should not worsen the oak regeneration efforts; (3) by promoting and managing native plants, the presence and development of invasive plants that negatively influence oak development in early stages, is reduced; (4) shelterwood system of regeneration should be conducted in two cutting periods: preparatory-regenerative and final; (5) final cut should be conducted immediately after regeneration has been done. In addition to aforementioned measures, recent research suggested that regeneration plots of 5 ha are optimal for regeneration of pedunculate oak in similar historical and ecological circumstances as those in Serbia (Čavlović et al. 2014).

With the application of above measures the regeneration might be considered as mixed (i.e. a cross between natural and artificial regeneration), since the conditions are close to natural, and would have multiple positive effects: (a) the regeneration of the stand is not dependent on fruiting; (b) the regeneration does not depend on the coverage of the surface by the projection of the oak canopy; (c) possibility to use genetically high-quality seeds from seed plantations, seed stands, as well as plus trees (possibility of designing the arrangement of trees of the future); (d) the success of the regeneration is assured with great certainty (except for extremely unfavorable climatic conditions); (e) the progeny is freed from the shade of the mature trees, so the height growth is more intense, while the plagiotropic and forked growth are reduced; (f) the absence of mature trees reduces the occurrence of oak powdery mildew (due to the full influx of the light on the young trees and faster ontogenetic development of leaves); (g) in most cases it is the only possible way of regeneration (pedunculate oak is practically impossible to regenerate without human assistance); (h) no damage to plants during the export of wood assortments after final cut and soil damage from mechanization; (i) rationalization of the application of chemical agents on rejuvenated surfaces; (j) possibility of spatial optimization of works at the regenerated areas in a short period of time (1-3 years); i.e. works related to area preparation for reforestation and forest utilization of previous stand.

Herbicides might be needed to control fast-growing invasive species during oak regeneration. In disturbed habitats invasive species use open space more efficiently. Forest regeneration without assistance in such circumstances leads to floristic impoverishment, with the dominance of invasive and fast-growing species (Mišić and Broz, 1962; Bobinac, 2000). Compared to year-round use of herbicides in agriculture, their use forests is limited with the rotation period, i.e. a few times every 120-160 years (rotation period). Regeneration is based on the existing seed bank in the soil and on the arrival of seeds from forest habitats in the vicinity, which after removal of invasive species have favorable conditions for propagation.

Following the concept, improvements in the existing management practices should go towards forest regeneration on smaller areas, having approximately the same hydrographic position, and with gradual changes in the structure of the forest landscape (Ostrogović et al. 2010; Bobinac, 2011; Čavlović et al. 2014; Stojanović et al. 2015; Kiš et al. 2016). By adapting the size and spatial distribution of regeneration

plots, the exposure of oak seedlings to extreme summer heat and drought would be mitigated, while wildlife would benefit from better forest connectivity, and landscape and amenity values would be supported.

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2.2.2. Social issues (social sciences)

Fragmented ownership of forests with parcel forest management

Small-scale and fragmented ownership of forest parcels adversely affects riparian forests and makes their sustainable management difficult. One possible solution is to move from parcel (also compartment) management to ecosystem management of forest habitat types.

Slovenia's riparian forests are very fragmented in terms of ownership. Sixty seven percent of forest owners in and around the MDD BR, i.e. in the management area of Murska Sobota, own less than 1 ha of forest land. This fragmented small-scale ownership structure affects the forest structure, especially management types, the distribution of development phases and tree species compositions. However, to achieve better management and economic outcomes, a considerable amount of small forest lots have been planted with fast growing tree species. Such a mixture of forest parcels makes sustainable forest management difficult. One possible solution is to move from the parcel (also compartment) management to the ecosystem management of forest habitat types.

Figure 6. Small-scale ownership structure of riparian forests in Slovenia (source: Pregledovalnik podatkov o gozdovih. https://prostor.zgs.gov.si/pregledovalnik/).

Ecosystem management deals with the management of forest complexes (forest habitat types) at the landscape level. Within these complexes, different management systems, such as expanding gap, irregular shelterwood and free-style silviculture may be used. Additionally, ecosystem management creates pathways to gradually convert irregularly admixed alien species plantations (e.g. red oak and hornbeam, black walnut, poplar, etc.) into forest stands with tree species compositions appropriate for native forest habitat types.

Ecosystem management with forest habitat types brings long-term benefits, such as stability through larger complexes, less pressure from adjacent areas with non-native tree species, and improvement of habitats for fauna (birds, beetles), as deadwood can be more easily incorporated into the management of larger forest complexes. Ecosystem-based management is not strictly opposed to plantation management; it promotes natural structures to retain the habitat type core areas free of non-native species and shifts plantations to forest habitat edges.

The shift from parcel to ecosystem management must be gradual and takes several decades.

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Restoring autochthonous forests – Example of implementing forest certification policy

Forest certification by Forest Stewardship Council (FSC) has been implemented globally, to promote sustainable forest management and mitigate illegal logging and biodiversity loss.

Figure 7. Programme of plantations conversion into autochthonous forests (left) and Conversion study of Public Enterprise “Vojvodinašume” for the period 2020-2029 (right) (in Serbian).

The FSC is an international organization that provides a system for voluntary accreditation and independent third-party certification. This system allows certificate holders to market their products and services as the result of environmentally appropriate, socially beneficial and economically viable forest management (www.fsc.org). The FSC sets standards for the development and approval of FSC Stewardship Standards which are based on the FSC Principles and Criteria. Recent reviews of different certification schemes considered the FSC much more detailed and prescriptive, particularly when considering environmental impact (Gutierrez Garzon et al. 2020).

Public Enterprise “Vojvodinašume” manages the largest portion of forests, marshes and water habitats within the Biosphere Reserve (BR) “Bačko Podunavlje”. The BR was designated on the total surface area of 176635 ha, extending over the alluvial zones of the central Danube plain (https://en.unesco.org/biosphere/eu-na/backo-podunavlje), encompassing several existing protected areas in Serbia. The largest of the protected areas is Special Nature Reserve “Gornje Podunavlje“ managed by the public enterprise company.

The forest enterprise went through process of the FSC certification in 2006/2007, targeting the certificate of sustainable forest management under *SGS Qualifor Programme* (www.sgs.com). The forest management in the lowland forest was assessed on a set of 10 principles and 56 criteria of sustainability.

The first FSC principle is defined as „Compliance with laws and FSC principles“, which requires that „Forest management shall respect all applicable laws of the country in which they occur and international treaties and agreements to which the country is a signatory, and comply with all FSC Principles and Criteria“.

During assessment, it became clear that the national forest management framework, including the supporting mechanisms for establishing fast-growing poplar plantations, was not harmonised with the national commitments rising from nature protection policy. Namely, conversion of natural softwood or hardwood forests to plantations was considered as breaching the Convention on Biological Diversity (https://www.cbd.int). The majority of the areas with non-compliances (418.35 ha) were detected in the protected area along the Danube, where soil conditions were best for growing poplar plantations.

To solve the issue, the forest enterprise committed itself to compensate the loss of natural forests. A ten year plan of backwards plantation-to-forest conversion (2010-2019) was developed in cooperation with national authorities for nature protection (Institute for Nature Protection of Serbia). The cooperation included bilateral contract of long-term technical cooperation between the contracting parties. The first forest restoration plan recently continued with its second phase (2020-2029).

As a result, selected poplar plantations and stands of invasive tree species (*Fraxinus pennsylvanica, Robinia pseudoacacia*) were dedicated to „habitat reconstruction with tree species substitution“. The stands' selections and dynamics of the implementation were developed in cooperation and expertise of the Institute of Lowland Forestry and Environment in Novi Sad (ILFE). The FSC certificate was issued (SGS-FM/COC-005064) and twice successfully renewed (2013 and 2018).

The habitat restorations involved substitutions of non-native species and cultivars (*Fraxinus pennsylvanica, Robinia pseudoacia, Populus* x *euramericana*) with local species forming natural forest communities (*Salix alba, Populus alba, Fraxinus angustifolia, Quercus robur, Q. cerris*).

During the first ten-year period in total 252.22 ha have been converted to autochthonous species in the Biosphere Reserve and adjacent forest corridors. In the next ten-year period, additional 243.49 ha of habitats will be restored with native tree species.

The effects of tree species substitution for habitat restoration:

- Tree nurseries in the Public Enterprise “Vojvodinašume” increased production of native tree species;
- Connectivity of autochthonous forests along the Danube ecological corridor is strengthening;
- Habitat functioning in the restored forests is improving;
- Food web for forest wildlife is enhancing, improving the game management;
- The forest management policy is better balanced considering ecological-economical causalities.

Conversion of plantations has multiple benefits beyond biodiversity increase. For example, bringing back oaks into the landscape provides acorn crops, an important source of food for wildlife and game, with consequences on game management.

Forest restoration contributes in less trade-offs between economic and ecological component in forest management, and delivers of provisioning and supporting ecosystem services (UN, 2005).

Table 6. Implementation of forest conversion to native species forest at Public Enterprise "Vojvodinašume", Forest Estate "Sombor" (the company branch in charge of the majority of forest in the BR)

Period of implementation	Area (ha)
2010 - 2019	252.22 (accomplished)
2020 - 2029	200.02 (planed)
Total	452.24

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Ecosystem services in the protected areas: Sustainable use of nature resources for human health and well-being

In terms of ecosystem services, resilient and healthy ecosystems are the foundation for multiple benefits provided to global and local society.

Figure 8. Forests improve our well-being and quality of life (author: M. Zorić)

Riparian forest ecosystems are among the most diverse and most productive forests in Europe. Numerous endangered species are present in these ecosystems, and these areas still serve them as shelters and safe-

zones in the human-oriented world. One of these nature oases is the MDD BR. Forests like those in the MDD BR provide numerous ecosystem services to humans, including CO_2 sequestration, climate regulation, water cycle regulation, and erosion control. In addition, they also provide a wide range of other, socio-economic services which impact the everyday life of Europe's citizens and local communities: improved human health and well-being, space for social interaction, education and recreation, wood production, improved air quality etc. Last, but not the least, multiple plant and animal species found in this area have a high cultural and spiritual value for certain European ethnic groups.

Although the research on positive impact of forests on human health and well-being started decades ago, the ongoing pandemic intensified the investigation of these benefits provided by forests and their potential for the use in the novel coronavirus treatment. The results of multiple published medical studies on forest therapy showed positive impact on the human: 1) immune system functioning - the increase in the number and the activity of Natural killer (NK) cells for cancer prevention, 2) cardiovascular system-lowering blood pressure and heart rate, 3) respiratory system-decreased symptoms of allergies and asthma, diabetes-decreased levels of blood glucose, and 4) decreased symptoms of depression and anxiety. The exact processes and factors that lead to this effect are not yet fully explained, but it is suspected that the biogenic volatile organic compounds (BVOCs) from trees, known as phytoncides play a major role in this human-nature interaction.

For the sustainable use of natural resources in terms of ecosystem services, the main challenge is to use knowledge on climate changes and consequently the changes in the forests and forest management, as well as on the nature - human relationship in a way that the full potential of these relationships is realized, so both, humans, and forests benefit.

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Pending issues and intensity of stakeholder interests in the Mura-Drava-Danube Biosphere Reserve

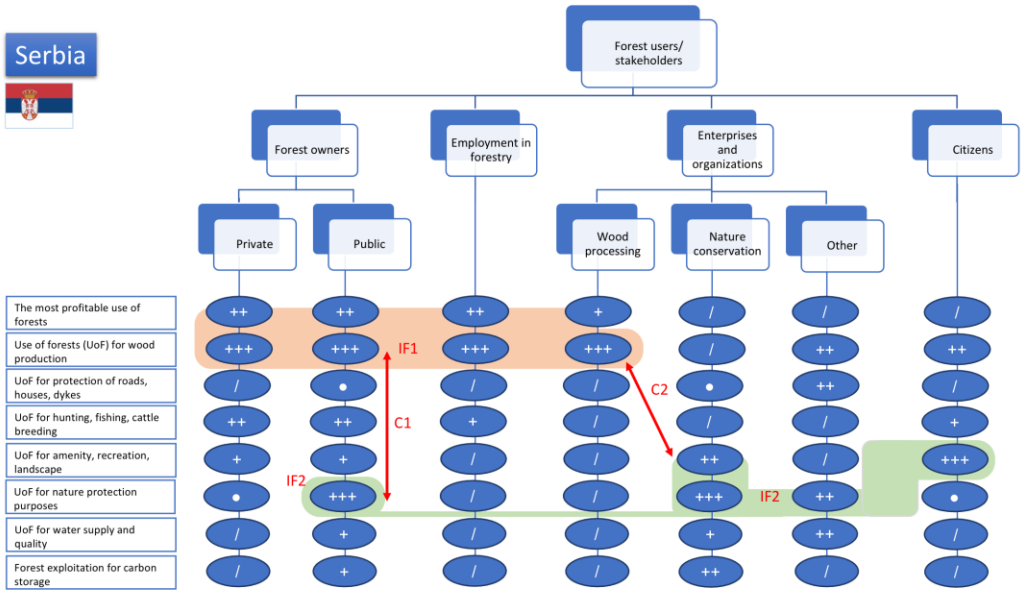
Riparian forests offer unique opportunities for various activities, such as recreation (fishing, hunting, swimming, etc), aesthetic experiences (e.g., picnics), or tourism (e.g., boat driving, cottages), which are all embeded in the aquatic-terrestrial interface (Sibley and Gordon, 2010). Yet, these diverse user interests often face limited spatial capacities of terrestrial-aquatic systems, what may lead to conflicts, e.g. between recreational users and nature protection, where people and wildlife are competing for their use (Dwyer et al. 2000). Therefore it was important for the REFOCuS project to include this social aspect into its research portfolio.

For analytical purpose, users of riparian forest were categorized as: forest owners (private and state), forestry employees, companies (e.g. wood processing) and organizations (e.g. agency for nature protection) and citizens (Figure 9). Also, other categories like tourism were added, when this aspect

exercised particular relevance in the specific area (e.g. in Austria). User interests were grouped into categories of wood production, recreation, nature conservation, protection of houses and infrastructure, water supply, CO_2 sequestration, or the interests in the most profitable use of the forest (e.g. selling the land or clear cutting it and selling the wood, if legally possible and pursued by the owners). The intensity of user interests was estimated for each case study: Austrian, Croatian, Hungarian, Serbian and Slovenian by experts and stakeholders (from case countries) during the workshop in Novi Sad (16-17 April 2019), through case-specific group discussions and one joint session. In the joint session results from each case study were critically discussed and estimations (of the intensity of user interests) backed up while referencing to available sources. Final estimations of the intensities of user interests were included into the analytical schemes for each case, ranging from non-existing (/) to strong (++) and very strong (+++). The focus was on the very strong (and partly also strong) interests of different user groups, which allowed identification of interest fields (IF) and potential conflicting zones (C) between them. Results can be found in the below Figures 10-13.

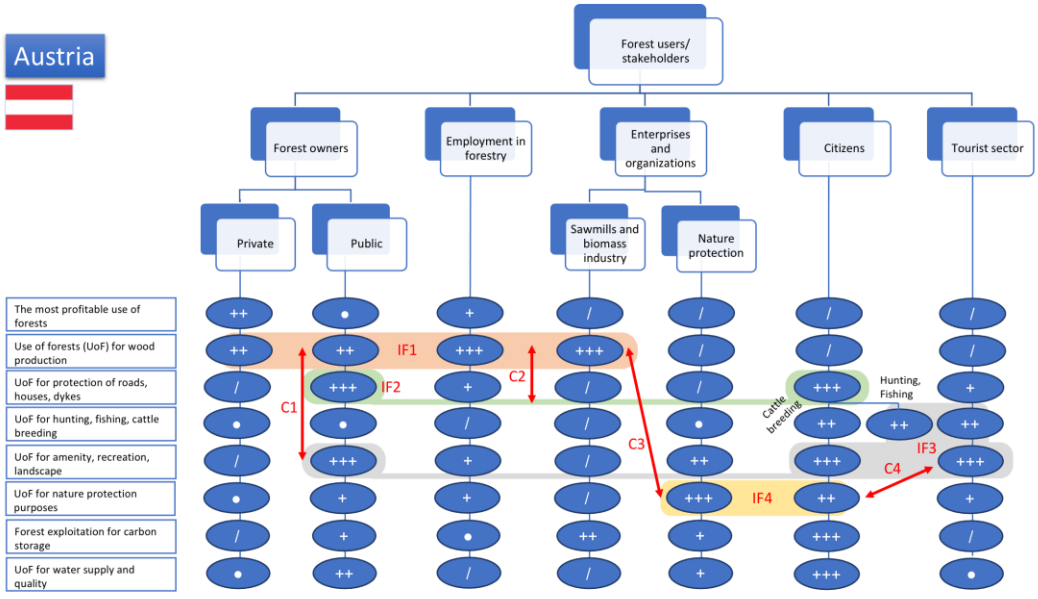
The research team of ILFE (Novi Sad) continued working on the Serbian case of "Koviljsko-Petrovaradinski Rit" also after the workshop. To check estimated intensity of user´s interest, additional interviews were conducted, in combination with (non-participative) observations and qualitative content analysis. Triangulation of sources, critical reasoning, as well as techniques of induction and deduction led to more precise estimations of the intensity of user interests. When estimated user interests were of very strong (and partly also strong) intensity and had the same (or similar) orientation they were marked as a one interest fields (IF). E.g. in "Koviljsko-Petrovaradinski Rit" the state (represented by the province of Vojvodina) and private forest owners, including wood industry, have very strong (and strong) interests in wood production, which is visible in the interest field IF1 (Figure 9). Another user group, made of citizens and nature conservation organizations (Provincial agency for nature conservation) has opposing interests, which may lead to conflicts (Figure 9). Conflicts may emerge between different user groups (C1), but also within one the same group (C2). E.g. the province of Vojvodina (who transferred management rights to the Public Enterprise "Vojvodinašume") has a very strong interest in wood production (for creating market revenues) on the one hand but also in nature conservation on the other (for providing public goods as required by legislation). In order to balance those interests (towards the overall public interest required by policy and planning), the Vojvodina province may still look internally for a solution.

The current internal solution of Vojvodina province is reflected in the zoning of "Koviljsko-Petrovaradinski Rit", meaning strict protection on 6%, active protection on 29% and profitable use of wood on 65% of the area. This also reflects the actual compromise package between actor interests in Vojvodina province. From the Figure 2 one can also estimate if and how potential shifts in the power of actors could intensify conflicts, e.g. conflicts with actors having strong interests in wood production would increase if zoning would change in favour of nature protection (percentage of strict protection would increase) or conflicts with nature protection would intensify if the current share of 65% forests for wood production becomes larger. Information on the interests and potential conflicts of interests is therefore useful to perceive positions of actors more clearly and depending on that to make targeted selection of scientific arguments (offered by the project) that can best support own activities in the particular riparian forest.



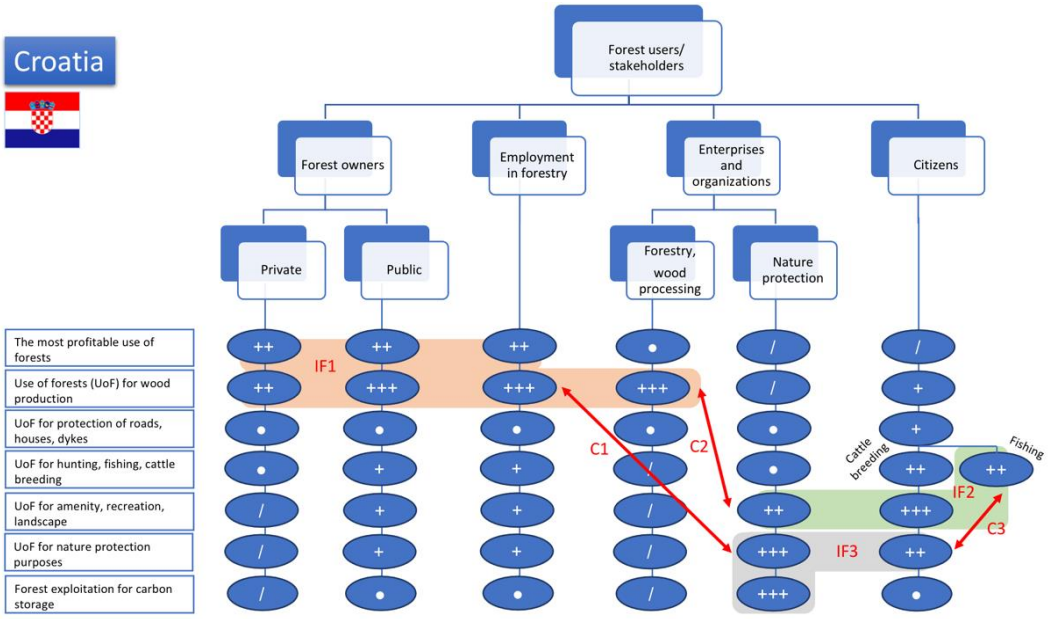
Legend: horizontal - forest users, vertical – user interests, on their intersection (round fields) estimated intensity of user interests: very strong (+++), strong (++), moderate (+), existing (●), non existing (/); C – zone of conflicts; IF – interest field.

Figure 9. Shematic synthesis: forest users, interests, fields of interest and zones of interest conflicts presented on the example of the Nature Reserve "Koviljsko-Petrovaradinski Rit", Serbia (source: Stevanov et al. 2021).



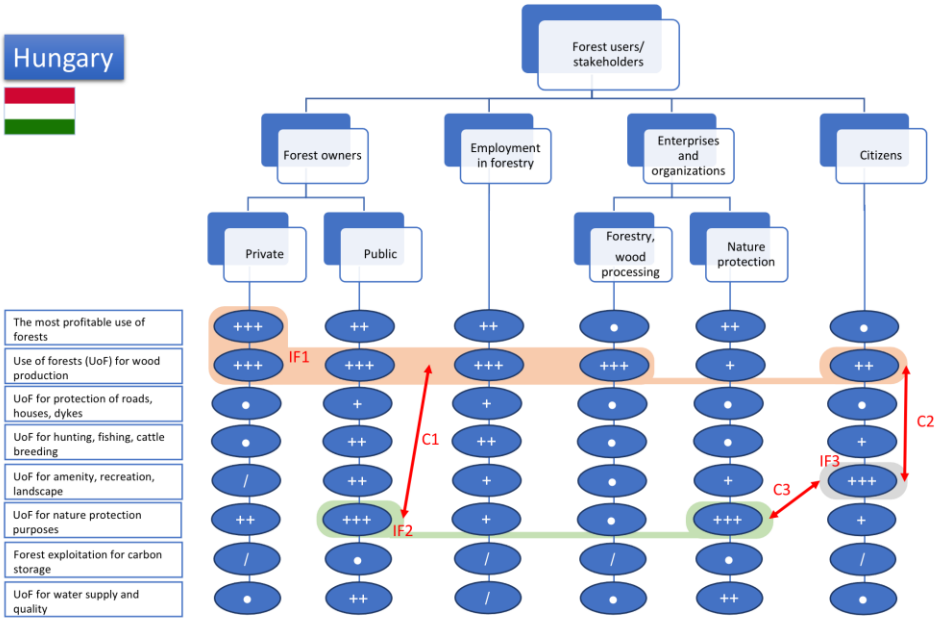
Legend: horizontal - forest users, vertical – user interests, on their intersection (round fields) estimated intensity of user interests: very strong (+++), strong (++), moderate (+), existing (●), non existing (/); C – zone of conflicts; IF – interest field.

Figure 10. Shematic synthesis: forest users, interests, fields of interest and zones of interest conflicts within Mura-Drava-Danube Biosphere Reserve in Austria.



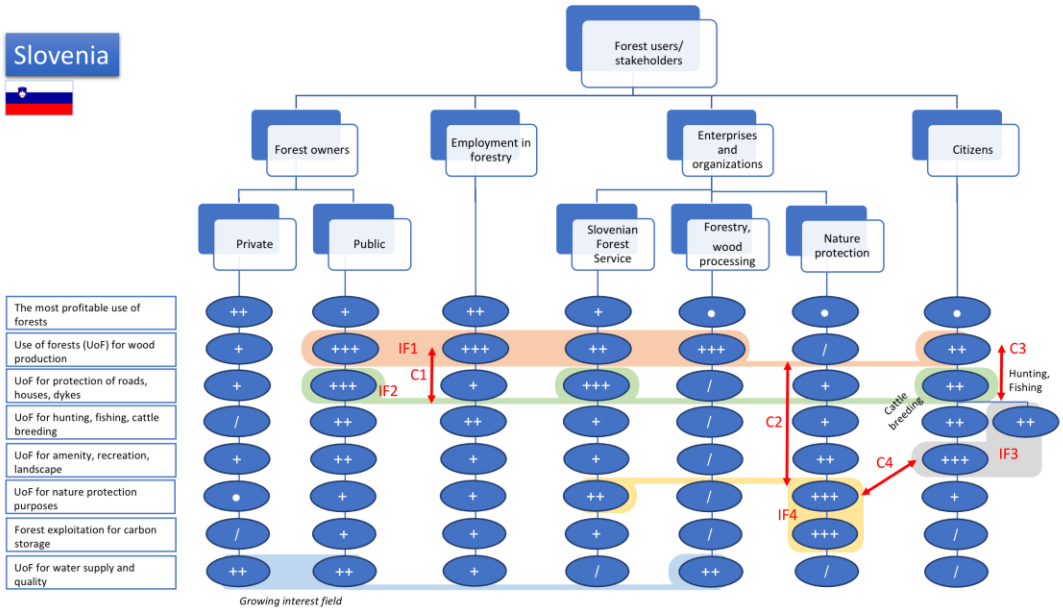
Legend: horizontal - forest users, vertical – user interests, on their intersection (round fields) estimated intensity of user interests: very strong (+++), strong (++), moderate (+), existing (●), non existing (/); C – zone of conflicts; IF – interest field.

Figure 11. Shematic synthesis: forest users, interests, fields of interest and zones of interest conflicts within Mura-Drava-Danube Biosphere Reserve in Croatia.



Legend: horizontal - forest users, vertical – user interests, on their intersection (round fields) estimated intensity of user interests: very strong (+++), strong (++), moderate (+), existing (●), non existing (/); C – zone of conflicts; IF – interest field.

Figure 12. Shematic synthesis: forest users, interests, fields of interest and zones of interest conflicts within Mura-Drava-Danube Biosphere Reserve in Hungar



Legend: horizontal - forest users, vertical – user interests, on their intersection (round fields) estimated intensity of user interests: very strong (+++), strong (++), moderate (+), existing (●), non existing (/); C – zone of conflicts; IF – interest field.

Figure 13. Shematic synthesis: forest users, interests, fields of interest and zones of interest conflicts within Mura-Drava-Danube Biosphere Reserve in Slovenia.

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3. HOW TO MAKE USE OF REFOCUS RESULTS IN PRACTICE?

It is not the science, but practice that implements science-based solutions. And the practice is characterized by the plurality of different interests (Chapter 2.2.2). Ignoring this pluralistic setting may lead to a more limited outreach of scientific knowledge, which often ends up in the universal recommendations and guidelines. To avoid this, the below Guideline rests upon an innovative, theory-based RIU Model (Research-Integration-Utilisation Model, by Böcher and Krott, 2016). The RIU Model assumes existence of pluralistic actors with their own interests and power to implement solutions in practice. When scientists generate research outputs (Research), then actors are free to select information that matches their interests and use it to support own action in the practice (Utilization). Scientists have no influence on what will happen with that information. But they can facilitate the "Integration" of that information into practice-create possibilities for actors to get sensitized for tailor-made scientific information that may support their own solutions in practice. Also actors may want to integrate relevant scientific information into their solutions in practice. For that, they must first judge the relevance of the scientific information for their own solution, then to check soundness of this information and examine factors that may help of hinder their implementation. Below guideline is about these steps. It can support actors in estimating chances of science-based solutions to become implemented in riparian forest while providing step-vise guidance through diverse aspects. Such step-vise guideline proved fruitful in two recent EU projects - the Horizon 2020 "ALTERFOR" (https://alterfor-project.eu/wp4.html) and the Alpine space Interreg project "GreenRisk4Alps" (https://www.alpine-space.eu/projects/greenrisk4alps/en/home), both relying on the knowledge transfer assumptions of the RIU Model.

3.1. Guideline for integrating REFOCuS results into your own activity or project

Management of riparian forests is a complex task, especially in times of climate change and increased pressures on forests for diverse ecosystem services (timber, recreation and amenity, nature protection, etc.). Depending on your tasks, particular riparian forest and your own interest, the results of the REFOCuS project highlighted in the Chapter 2 may have triggered your attention. If you are willing to undertake action or go for a project in a riparian forest of your interest, then the following three steps may lead you to a more realistic picture about the implementation chances.

STEP 1: Make realistic judgment about the relevance of REFOCuS research results for your activity in the riparian forest of your interest

a) Are particular results relevant for your practical problem or ongoing political process	You are related to the riparian forests either through your activities (directly) or interests (indirectly). You may for example be involved in the management of riparian forests, live in a community near it, use riparian area for recreation, picnic or bird watching, be involved in local nature protection. These and similar activities are the key for answering whether REFOCuS research results may be relevant for you or not. If they are relevant, then look if riparian forests and specific ecosystem services of your interest are "hot issues" or not. If they are not (and cannot be pushed by you to become an issue), then the time might not be ripe to go for a project or action to which the REFOCuS project is providing scientific arguments.	YES ☐	NO ☐
b) Are particular results relevant for your potential allies	Especially forestry is known for its "inertia of tradition". Therefore, if you plan to introduce a change in the practice, and so influence management of riparian forests, then alliance will increase your chances for success. You might find allies among enterprises, state agencies or organized interest groups that are connected with forestry, economics, nature conservation, climate change or social agenda. Your ally may (i) closely cooperate and participate directly to implement science-based solution in practice (internal ally) or (ii) be at a distance to your direct implementation activities but provide political/economic support or push others to follow (external allies). There are also potential allies, who will first learn from new scientific results and may join after rethinking their existing practice (learning allies). Independent of that, your potential ally must be on the same line of argument as you. If he/she/it pursues scientific arguments from some other source than it may be difficult to proceed.	YES ☐	NO ☐
c) Can you establish the link between results and the relevant public goals	It is important to think about strong public goal(s) your science-based solution will serve. Try to establish a link between them, e.g. with the public goal of enhancing biodiversity or mitigating climate change. As a source for ideas, but more importantly as a reference, use programmes launched by ministries, international processes but also well acknowledged norms of a civil society. Avoid legitimation of your project by too narrow forest goals like sustainable forestry, because of their limited political outreach.	YES ☐	NO ☐

STEP 2: Make realistic judgment about the scientific basis of REFOCuS research results

a) Do you have channels to science	Think of how you are making use of science in your daily practice - within your organization (e.g. municipality or NGO) or as a single person (e.g. being a citizen undertaking recreation activities in the riparian area near to your home). Are there specific channels to science you already use (e.g. working group in which also researchers are participating and you know them from the meetings; or you have scientifically knowledgeable collaborators within your organization; etc.) or do you have to look for them first? Those channels, with the link to scientific information, can help check and integrate scientific information into your task.	YES ☐	NO ☐
b) Check limitations of scientific results	Scientists are using theory-based models as well as established methods and procedures to arrive at their results, but each model and procedure is bound to specific limitations. For example, only selected variables are included into the models or data sets available to researchers are scarce. Via your channel to science (e.g. regular meeting of a working group; bilateral talk) you can get information about such limitations. This will help you make your own judgment about the suitability of research results for your problem or solution.	YES ☐	NO ☐
c) Check compliance with good scientific practice	If you became interested in using some research results, and information about existing limitations is not restricting you then you still have to check scientific credibility of these results before integrating them into your project/activity. This means searching for some indicators of scientific quality (e.g. results published in scientific journals or connections with other national and international researchers, especially those you already know or even better, you already cooperated with). If this task is beyond your capacities, then think of your existing channels to science or create them. It is not unfair to ask for their independent judgment before deciding to put effort in your project.	YES ☐	NO ☐
d) Selected scientific results can be specified	If your information about existing limitations is sufficient and you checked scientific credibility this will still not show if a specific result fits to your particular problem. It is while science can neither answer the very specific questions of practice nor it can provide comprehensive best solutions. You are therefore free to select only an information that is relevant for you and potentially ask for specifications. This you can do by a phone call to the research team (Chapter 4) for example. In the case you discover larger deficits for use in your particular case, then you may think either to initiate additional research or to step out.	YES ☐	NO ☐

STEP 3: Make realistic judgment about the implementation of your science-based solution in practice

a) Your problem or science-based solution can be embedded into the legal framework	Existing legal framework can either restrict or enable management activities on the ground. Therefore, it is vise to check your legal space of action first. In the five MDD BR countries there is no legislative document that particularly focuses on riparian forests. Instead, the legal framework is very wide and complex. The REFOCuS project reduces this complexity by offering systematized overview of laws and regulations per country and sector (forestry and other). You can then search what is relevant for your particular case, e.g. what legal rights support your forest management ownership type (rights of private ownership), which financial instruments are at your disposal (e.g. rights to apply for public funding), etc. But be also aware of the legal limits. If you detect them, then it might take a very long time to overcome them in a political process.	YES ☐	NO ☐
b) Your problem or science-based solution is supported by sufficient economic resources	Solutions in riparian forest management (silvicultural or other) often require more financial resources than in "regular" forest management. That is why your problem or science-based solution will need a careful and realistic judgment of the costs and the ways of covering them sufficiently, either from the market or from the public funds (budgets, EU projects, etc.). If you act economically-efficient then you may have a broader space of action while saving resources. But remain realistic (also in a long-term) and avoid wishful thinking.	YES ☐	NO ☐
c) Your problem or science-based solution can be embedded into good governance	Riparian forests are a multi-actor and multi-sectoral issue. The REFOCuS focused on different actors and their interests in MDD BR (Chapter 2.2.2) and this information may be a point of departure for considering your own governance strategy. Participation of multiple actors, as one of the principles of good governance, may enlarge your space for action. Additional to rising awareness for example, your strategy of multi-actor participation may trigger different kinds of political and/or economic support for your project. Even if participation processes sound nice they are rather tricky to accomplished in practice (especially by foresters) so it might be better to search for professional support to complement your efforts.	YES ☐	NO ☐
d) Your problem or science-based solution goes along with democracy principles	Independent of the particular aim of your activity or the project you want to undertake in the riparian forest of your interest, have in mind that silvicultural and other management-related aspects are all embedded into a democratic environment. This means that you should not plan activities which are expected to have a larger effect on the forest without informing public and the media about it. The REFOCuS modelling results may, for example, be a highly useful source of arguments for communicating selection of particular tree species in the long-term perspective.	YES ☐	NO ☐

For a final evaluation, you may use the criteria listed in the Steps 1, 2 and 3, as a Checklist. Before you start, look to the highlights provided in this report (Chapter 2), use them to find more detailed information (e.g. project website, etc.), and then provide answers to questions from each step again. The more positive answers you can give (YES ☑), the better are chances for your science-based solution to become implemented in practice.

References:

- Böcher, M., Krott, M. (2016). Science makes the world go round. Successful scientific knowledge transfer for the environment. Springer, Cham, Switzerland, 207 pp. doi: https://doi.org/10.1007/978-3-319-34079-1

* Document has been prepared according to Service contract with title ***Services related to Preparation of the Holistic strategy for resilient riparian forests for the project REFOCuS***, ref. no. ***REFOCUS-1/Holistic strategy***.

4. CONTACTS OF RESEARCH TEAMS THAT CAN PROVIDE DETAILS ABOUT REFOCUS RESEARCH RESULTS

AUSTRIA			
Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)	www.bfw.ac.at	Silvio Schueler	silvio.schueler@bfw.gv.at
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SLOVENIA			
Slovenian Forestry Institute (SFI)	www.gozdis.si	Marjana Westergren	marjana.westergren@gozdis.si
SERBIA			
Institute of Lowland Forestry and Environment (ILFE)	www.ilfe.org	Srđan Stojnić	srdjan.stojnic@uns.ac.rs