Interreg
Danube Transnational Programme
Sava TIES

Study

Land Use in the Sava River Basin

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

Project title:	**Preparation of a Study on land use in the River Sava Basin including Slovenia, Croatia, Bosnia and Herzegovina, and Serbia**
Service type:	**Study**
Client:	Institute for Nature Conservation of Vojvodina Province
Contract number:	ILFE number: 342/3 as of 10.12.2019, Annex 148/2 as of 27.04.2020.
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Note of appreciation: This study was prepared with the support of the managers of protected areas in the Sava River Basin in the designing and distribution of land use questionnaires, of respondents whose participation provided data collection, of forest users who enabled the development of land profiles in Obedska bara and Bosut forests, as well as of our young researchers who were actively involved in the analysis of tree growth.

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Legal basis for the preparation of the Study

The preparation of this study was based on the Contract between the Institute for Nature Conservation of Vojvodina Province, Novi Sad, and the Institute of Lowland Forestry and Environment, Novi Sad, signed on December 10, 2019, for the realization of the Sava TIES DTP2-096-2.3 project.

The project is co-financed by the European Union ("IPA" pre-access fund and European Regional Development Fund "ERDF").

Introduction

The objective of this study was to analyze the changes in land use during the XIX and XXI century in the selected areas and river sections in the Sava River Basin (in Slovenia, Bosnia and Herzegovina, Croatia, and Serbia), and to analyze today's land use practices, impact on productivity (tree growth), and their advantages and disadvantages regarding the introduction and spread, i.e. prevention and control, of invasive plants in the Sava River Basin.

The Study is comprised of three components based on the tasks specified by the Contract and technical specification:

- Land use change maps
- Review of land use practices
- Forest productivity study

The summary in Serbian and English was written based on the performed analysis and figures in the three mentioned parts of the Study and it presents key findings on land use changes since the XIX century, the current practice of land use in protected areas in the Sava River Basin, and the growth of main tree species with respect to land use and the presence of invasive species.

Land Use Study

Executive summary

Statement: This document is produced for Sava TIES DTP2-096-2.3 project.

Introduction

This study analyzes land use changes from late XIX and XXI century land cover maps on protected areas and river sections within Sava River Basin, reveals actual land use practices in protected areas and main forest species dendrochronology, as an expert basis for the further analysis and land management recommendations related to introduction, dispersal or suppression of invasive species.

The study content

The land use study consists of three components, as defined in the Terms of Reference for the service. These are:

- Land use change maps
- Review of land use practices
- Forest productivity study

Each of these three tasks have been developed and accomplished in close cooperation between contracting party, with involvement and contribution of other members of the Sava TIES project consortium. Iterative approach including literature review, field visits, in-door and out-doors consultations on the project sites have been implemented for the accomplishment.

Methods and study area

Component "Land use change maps"

The task, a desk study, included geospatial land cover/land use delineation on 6 protected areas managed by Sava Ties project partners (Obedska bara, Zasavica, Lonjsko polje, Tišina, Una, Odransko polje, Ljubljansko barje) in the Sava River Basin and 6 sections of a river corridor in Sava Basin. For the task historical maps from III Military Surveys of the Habsburg Monarchy covering Sava River with tributaries was pursued and digital processed. The contemporary land use was defined on CORINE Land Cover maps (CLC 2018). In addition, a comparative analysis of land use changes on four protected areas (Odransko polje, Lonjsko polje, Tišina and Obedska bara), where an analysis of changes from the XIX century comparing to the CORINE 2018 maps and to more detailed maps of land use shown in the Sava White Book (Schwarz, 2016).

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Final products of the analyses are digital vector data sets in SHP form with attributes as pre-given in the issued maps, datum WGS 1984, delineating land cover categories (forests, transitional woodland shrub, green urban areas, inland marshes, natural grasslands, shores without vegetation, water courses, water bodies, inhabited areas, industrial or commercial units, arable land, mosaic of small plots, other artificial areas) and linear infrastructure (public roads, forest roads, railways, canals).

Digital land cover – land use maps have been produced (the historical and the contemporary), and the main changes in land use were revealed from the the late XIX to XXI century.

Component "Review of land use practices"

This component reveals land use practices relevant for the plant invasions on Sava River floodplains. The analysis was based on online survey (poll), targeting key sectors and key stakeholders from protected areas in Sava River Basin. Insight into regular activities in land management in forestry, water management, agriculture and other stakeholders was enabled by online survey (questionnaire) for target groups.
The review depicts typical land use categories present in protected areas and threatened by the key invasive species in Sava River Basin. The findings reveal the practices which are in favor and those which prevent the spreading of invasive plant species in forestry, water management and agriculture (e.g. moving and grazing, the use of herbicides, mulching, afforestation and forest utilization)**.**
Sometime the same stakeholders are introducing, spreading and suppressing invasive species (e.g. mowing and IAS-infected hay disposal, introduction of new species and later its selective removal).

Component "Forest productivity study"

This task consists of forest productivity analysis covering two sites along the Sava River with 3 samples in poplar plantation and 6 samples in hardwood forest, of matured age. The samples represent the forest productivity in the forest and plantation, with scarce or no bush vegetation due to long term grazing (cattle, pigs, sheep) and the forest/plantation of the comparable type, age and covered by invasive wooden species in shrub and lower tree layer. History of forest management on the site was analyzed.

The analysis of the dendrochronological analyses indicates a positive correlation between traditional pig breeding and pasturing with a lesser presence of invasive species and the growth of the main tree species on the experimental areas for pedunculate oak and Euro-American poplars.

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Acknowledgements: We would like to express gratitude to the contributors in range of tasks implemented in this study. It was accomplished in support of protected area managers who helped in formulation and distribution of the land-use-questionnaire and its respondents, forest managers who supported soil profile analyses at Obedska Bara and Bosut Forest and our young researchers who effortlessly worked on dendrochronological analyses.

Sažetak

Uvod

Ova studija prikazuje razlike u korišćenju prostora krajem XIX i početkom XXI veku na odabranim zaštićenim područjima i rečnim deonicama u slivu reke Save, otkriva postojeću praksu u korišćenju prostora i resursa u zaštićenim područjima i analizira prirast glavnih vrsta drveća u šumarstvu. Rezultati istraživanja predstavljaju osnovu za dalju analizu i izradu smernica u vezi unosa, širenja i suzbijanja invazivnih biljnih vrsta.

Sadržaj studije

Studija o korišćenju zemljišta sastoji se od tri komponente, kako je definisano u opisnom zadatku za uslugu, a taksativno nabrojane su sledeće:

- Promene u načinu korišćenja zemljišta
- Pregled sadašnje prakse u korišćenju prostora
- Studija produktivnosti šuma

Pregled osnovnih rezultata

Komponenta: Promene u načinu korišćenja zemljišta

Rezultat ovog dela studije je kartiranje načina korišćenja prostora i geoprostorna analiza promena u korišćenju prostora na 6 zaštićenih područja u slivu reke Save, kojim upravljaju partneri na projektu Sava TIES DTP2-096-2.3 (Obedska bara, Lonjsko polje, Tišina, Una, Odransko polje, Ljubljansko barje) i 6 deonica duž toku reke Save sa pritokama. Za kartiranje polaznog stanja u korišćenju prostora kupljene su i digitalno obrađene istorijske karte III Vojnog premera Habsburškog carstva, koje pokrivaju reku Savu sa pritokama. Podaci o savremenom korišćenju zemljišta zasnovani su na kartama CORINE Land Cover (CLC 2018. Dodatno je izvršena uporedna analiza promena u korišćenju prostora za četiri zaštićena područja (Odransko polje, Lonjsko polje, Tišina i Obedska bara), gde je izvršena analiza promena iz XIX veka u odnosu stanje prikazano CORINE 2018 kartama i u odnosu na detaljnije karte korišćenja prostora prikazanim u Beloj knjizi reke Save (Schwartz, 2016).

Konačni proizvodi analize su digitalni skupovi vektorskih podataka u „SHP“ formatu sa prethodno utvrđenim atributima, datum WGS 1984, koji razdvajaju različite načine korišćenja zemljišta (šume, prelazne drvenaste formacije, zelenilo urbanizovanih područja, močvare i bare, prirodne travne površine, sprudovi i obale bez vegetacije, stajaće vode, tekuće vode, naseljene površine, industrijske ili komercijalne površine, njive, mozaik malih parcela, ostale veštačke površine) i linearnu infrastrukutru (putevi, pruge, kanali, šumske proseke).

Komponenta: Analiza postojeće prakse u korišćenju prostora u zaštićenim područjima

Ova komponenta Studije je imala za cilj da otkrije prakse u koršćenju prostora i prirodnh resursa u zaštićenim područjima u slivu reke Save, koje su od značaja za unos, širenje ili sprečavanje rasprostranjivanja invazinvih vrsta biljaka. Uvid u redovne aktivnosti korisnika zaštićenih područja omogućen je puten internet upitnika za korisnike prostora.

Pregled prikazuje tipične načine korišćenja zemljišta u zaštićenim područjima. Analiza prakse korišćenja zemljišta ukazuju na aktivnosti koje idu u korist širenja invazivnih biljaka i one koje sprečavaju širenje invazivnih biljnih vrsta, a dešavaju se u šumarstvu, vodoprivredi, poljoprivredi i drugim delatnostima (npr. košenje i ispaša, upotreba herbicida, tarupiranje, radovi na seči šuma i pošumljavanju).

Ponekad isti korisnici unose, šire i suzbijaju invazivne vrste (npr. košenje i odlaganje sena sa semenom invazivnih vrsta, unošenje novih vrsta i kasnije njihovo selektivno uklanjanje).

Komponenta: Studija produktivnosti šuma

Ovaj zadatak sastoji se od analize produktivnosti šuma koja pokriva dve lokacije uz Savu sa 3 uzorka u plantaži topola i 6 uzoraka u šumama tvrdih lišćara. Uporedni ogledi predstavljaju analizu produktivnost šuma, i to u šumi i plantaži topole, sa proređenom vegetacijom u spratu žbunja usled dugotrajne ispaše (goveda, svinje, ovce) i šume/plantaže sa sličnim stanišnim i sastojinskim uslovima koja nije bila pod ispašom i sa prisustvom invazivnih vrsta u spratu žbunja. Uz navedeno je analizirana i istorija gazdovanja šumama na istraživanim lokalitetima.

Analizom rezultata utvrđena je pozitivna korelacija između tradicionalnog svinjarstva i stočarstva, sa suzbijanjem invazivnih vrsta i prirastom glavnih vrsta drveća na oglednim površinama – hrasta lužnjaka i evroameričkih topola.

Svaka od tri navedene komponente studije je razvijana i ostvarena u uskoj saradnji ugovornih strana, uz učešće i doprinos ostalih članova konzorcijuma Sava TIES. Primijenjen je iterativni pristup koji uključuje pregled literature, konsultacije, terenske radove na oglednim površinama i analizu rezultata.

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Study area

The scope of the study area is the Sava River Basin. According to the spatial analysis of habitats presented in the White Book of the Sava River (Schwarz, 2016), most of the floodplain is covered by forests and forest plantations (51% of the area), meadows and other grasslands (18%), arable land (10%), rivers and other water surfaces (12%). Forestry, agriculture, and water management (land users) are activities typical for this kind of land structure.

As agreed with the Client and for the needs of the future analysis, we selected the protected areas that are managed by the partners in the Sava TIES project, as well as the sections of the watercourse where characteristic changes in land use have been noted. This analysis (the first part of the Study) covers six protected areas and six watercourse sections in all four countries. Five protected areas and four sections out of the previously mentioned are located near the Sava River, one section is along the Sora River near the confluence with the Sava, and one section and a protected area are near the Una River.

Current practices in the use of protected areas, which affect the spread and control of invasive species (the second component of the Study), were determined after surveying the users of protected areas in the Sava River Basin.

The analysis of the productivity of pedunculate oak forests and poplar plantations (the third component of the Study) was performed by setting up experimental areas and taking samples in representative areas of softwood (poplar plantations) and oak forests in the area of "Obedska bara" and ecologically significant area "Bosut forests''.

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Part 1: Land use change maps

The changes in land use were studied by comparing two data sources from two periods: the last quarter of the XIX century and the second decade of the XXI century.

The maps used in the analysis were those of the Third Military Survey of the Habsburg Empire made in the period 1869-1887 with a scale of 1: 25000. The selected maps cover most of the protected areas of the Sava River Basin, showing the former landscape characteristics. Six protected areas were chosen for this study in the project documentation (Ljubljansko barje, Una, Odransko polje, Lonjsko polje and Obedska bara). These areas were first digitalized (in polygons, i.e. vectors in the software package Arc GIS 10.5.1) and then, their visual-cartographic and analytical comparison with modern digital maps (geospatial in GIS and numerical in Excel) was made.

These digital vector maps were compared with the recently published Corine Land Cover digital maps (2018) free to download from the "Copernicus" system for monitoring changes in land use in Europe.

Also, detailed maps of the vegetation cover were developed for three areas for a more detailed analysis.

A comparison of protected areas and other parts of floodplain habitats was made in consultations with the client by selecting 6 sections along the Sava and Una watercourses where there have been significant changes in land conversion (industrialization, settlements, arable land).

The mapped categories of land use have been aligned with the categories from the Corine Land Cover (2018). There are three categories of artificial surfaces. In addition to the settlements that are (regardless of housing density) designated as "Urban fabric", "Industrial or commercial units" and “Mineral extraction sites” have also been singled out. In areas defined as agricultural, there are “Non-irrigated arable land” and “Complex cultivation patterns”, e.g. complex cultivation patterns involving fields with hedges, small orchards, fields and/or meadows.

As the practice of forming artificial meadows and pastures by sowing mixtures of grass seeds is not widespread in the region, the pastures and meadows represent the remains of natural habitats, or they are formed by natural succession, which is why they are marked as “Natural grasslands”. Poplar plantations are classified as highly susceptible to the spread of invasive

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plants in the category of “Agro-forestry”. They are characterized by a single-layer structure of trees, and the land, after intensive agro-technical measures during the initial years (pruning and hoeing of seedlings, taruping, protection from diseases and parasites), has been left to become spontaneously overgrown over the course of many years.

This area is covered in broad-leaved forests, wetlands with inland marshes, and as for the watercourses and water bodies, the most frequent ones are oxbow lakes.

The data was sorted and a statistical analysis was completed in Excel.

Results of the analysis

The floodplains are constantly changing surfaces under the influence of river erosion and accumulation of alluvial material. The diversity of relief and flooding regimes make favorable conditions for the development of various habitats distributed in narrower or wider zones along the coast. The presence of various types of wetland and terrestrial habitat types in a relatively small area ensures high biological diversity, and the spatial distribution of habitats in the form of long, continuous belts along the watercourse makes floodplains the natural ecological corridors. Floodplains are places of seasonal and day-night movements of animals, where numerous species also spread passively when carried over by water, wind, animals, or human activities. Watercourse corridors also enable the spread of invasive species, which is why the study of land use change in the Sava River Basin also includes sections of river corridors that are located outside the protected areas.

The natural vegetation of river valleys is characterized by a complex pattern of forest and wetland habitats, and grassland habitats can also be found in smaller areas. The presence of humans can significantly alter the structure of habitats: deforestation has enabled the spread of grass vegetation which resulted in the formation of meadows and pastures, and areas outside the flood zone have been turned into arable land. The alluvial area has different characteristics in the upper, middle and lower course, which means that the composition and spatial distribution of natural habitats, as well as the possibilities of using natural resources, gradually change from the source of the watercourse to its mouth.

Floodplains in the River Sava Basin at the end of the XIX century

The development of floodplains in the vicinity of mountain watercourses depends on the surrounding relief. A floodplain cannot develop between steep slopes (canyons that cause torrents) but valleys are surfaces where deposited sedimentation from rivers forms plains with a characteristic river relief. In mountainous and hilly regions, these wide valleys are the only areas where arable land can be found, so they have been under human influence since the appearance of first agricultural communities.

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Figure 1. The Una River valley near Pokoj with complex cultivation patterns (shaded in light brown) and wet meadows (shaded in light blue); the settlement consists of several groups of houses (marked with red squares) surrounded by cultivated land. The remains of hygrophilous forests are mostly present in the form of tree lines along the borders. Forest vegetation can be found only on the hills.

An old map from the XIX century shows that the valleys in the watercourses used to be farmland dominated by small plots. Spatial distribution of crops was conditioned by the relief and hydrological conditions: higher parts of the terrain were cultivated, whereas lower, flooded parts were used as meadows and pastures (Figure 3). Meadows and pastures in the coastal zone are marked even in the narrow valleys, such as the **Una valley downstream of Pokoj** (Figure 1), where the settlement occupies most part (62%) of the riverbank zone. Grasslands cover 11% and complex agrarian patterns make 16% of the mapped section. The valley in the area of today's National Park **Una**, upstream from the described river section, shares similar characteristics. The valley is so narrow that the watercourse itself occupies 21% of the mapped area. The riverside belt, as the only area favorable for agriculture, has lost its natural characteristics. The map from the XIX century shows that one-third (34%) of the river valley area consists of cultivated fields without any trees or hedges, and 25% of the land is devided into small plots. Meadows and pastures occupy 16%, and woody vegetation occupies 0.4% of the watercourse valley.

The relief of the valley where the mapped **section of the Sora is, downstream of Škofja Loka** (Appendix – map 1), caused the accumulation of river sediment, but the total width of the river corridor (floodplain and river terraces) is only a few hundred meters. The valley in the XIX century (Figure 2) shows a typical complex pattern of arable land: pastures and meadows cover almost half (47%) of the mapped section, one-third of the area belongs to the eastern part of Škofja Loka, and the terrain at higher altitudes is presented as arable land (16%). The Sora Valley near this section starts widening, and after a few kilometers, it merges with the wide valley of the middle course of the Sava.

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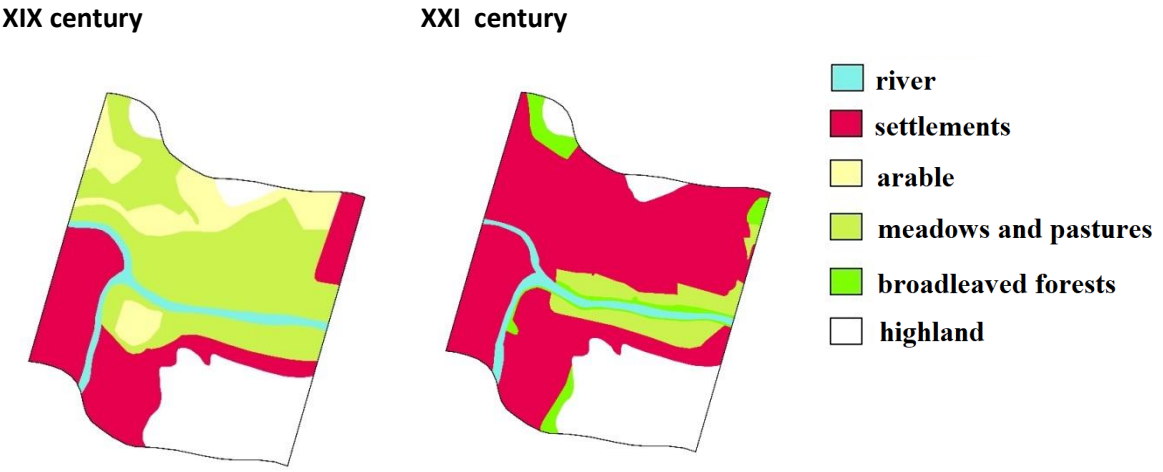

Figure 2. Land use in the Sora valley in Škofja Loka at the end of the XIX century and today

The floodplain of Ljubljanica (today's protected area **"Ljubljansko barje**") stretches across a vast plain that was formed in a valley filled with river sediments. The map of land use shows that, in the XIX century, there used to be a complex cultivation pattern of small plots in this area as well, and the wetter parts of the terrain along the Ljubljanica and its tributaries were overgrown with grass vegetation (Figure 3). Meadows and pastures occupy half of the area (51%), fields cover 26%, and small plots with hedges and scattered trees are present in 20% (Appendix). Intensive use of the locality resulted in less than 1% coverage with forest vegetation.

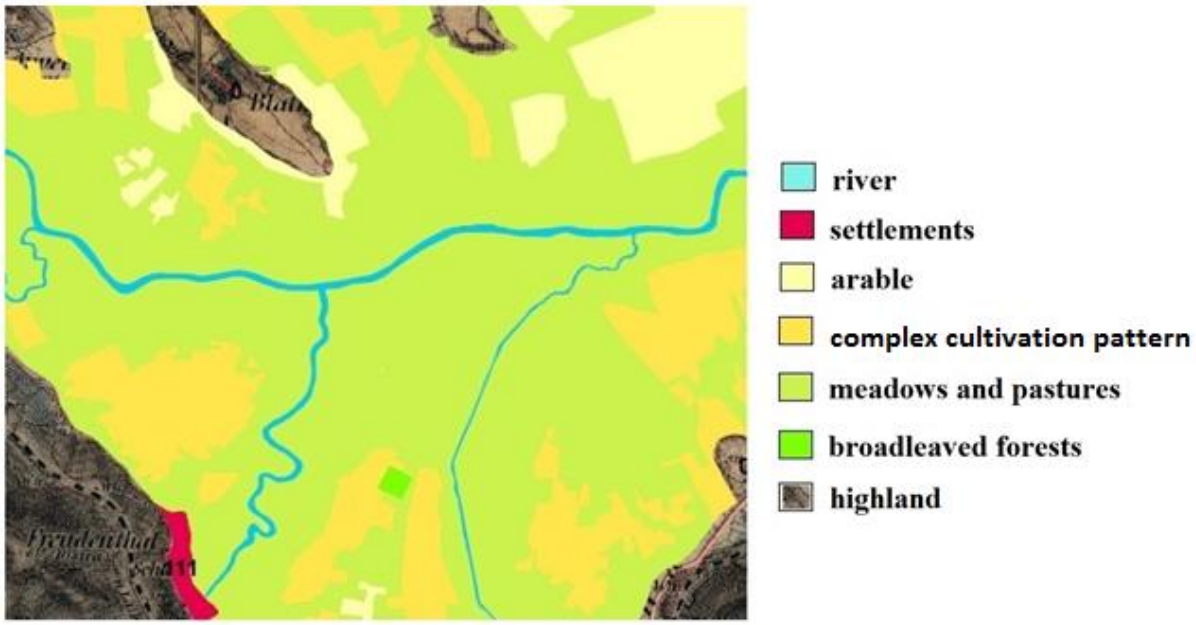

Figure 3. West part of "Ljubljansko barje" is marked with grasslands along the watercourses, and arable land is on higher ground

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The Sava valley, along the middle and lower course of the river, merges with the valleys of its tributaries forming a wide, fertile plain that extends to the mouth. Most of the floodplain of the Sava in the XIX century was marked with the already described complex cultivation patterns (Figure 4), and larger forests survived along the rivers Odra and Lonja. Today, part of the oak forest complex along the Odra River belongs to the protected area **Odransko polje** (Annex – map 3). The share of forests in today's protected area used to be 60% (in the form of a single forest unit), 35% of grassland, and only 2.4% of cultivated land (Appendix). The protected area "**Lonjsko polje**" Annex – map 4). includes part of the lowland forests east of the Sava River and stretches for about 100 km. Old maps show 50% of forest cover, 28% of meadows and pastures, and 11% of complex cultivation patterns in fields and meadows with tree lines and hedges.

The old maps show that river training was already at an advanced level in this period. The maps show meander cutoffs and embankments, the results of local endeavors to regulate the watercourses. The construction of a system of flood defense embankments enabled the expansion of settlements over the floodplain. The mapped parts of the river corridor show that the **section of the Sava River within Sisak** town was already urbanized in this period. Part of Sisak overlooks the almost 30m high floodplain from a hill that was formed of the sediments of the rivers Odra, Kupa and Sava, and the other part of the town is formed on the high bank of the river Kupa. By the end of the XIX century, embankments for flood protection were built along the banks of the rivers Odra and Kupa and, in the following period, they enabled the expansion of the city to the north. Furthermore, Sisak had the infrastructure (railway and port) that initiated the development of the future industrial center (Figure 3). Urban areas occupied 62% of the mapped section, and agricultural areas appeared in the form of complex patterns of fields and meadows with tree lines (16%) or meadows and pastures (11%). Another mapped section of the Sava River, which includes urbanized areas, is located **upstream of Slavonski Brod** (Annex – maps of the river sections). The river corridor contains 30% of urban areas, 23% of fields, 8% of meadows and pastures, and 7% of small plots (fields and meadows with trees and hedges). With its increased width of the riverbed, the Sava River occupies almost a third (32%) of the mapped area.

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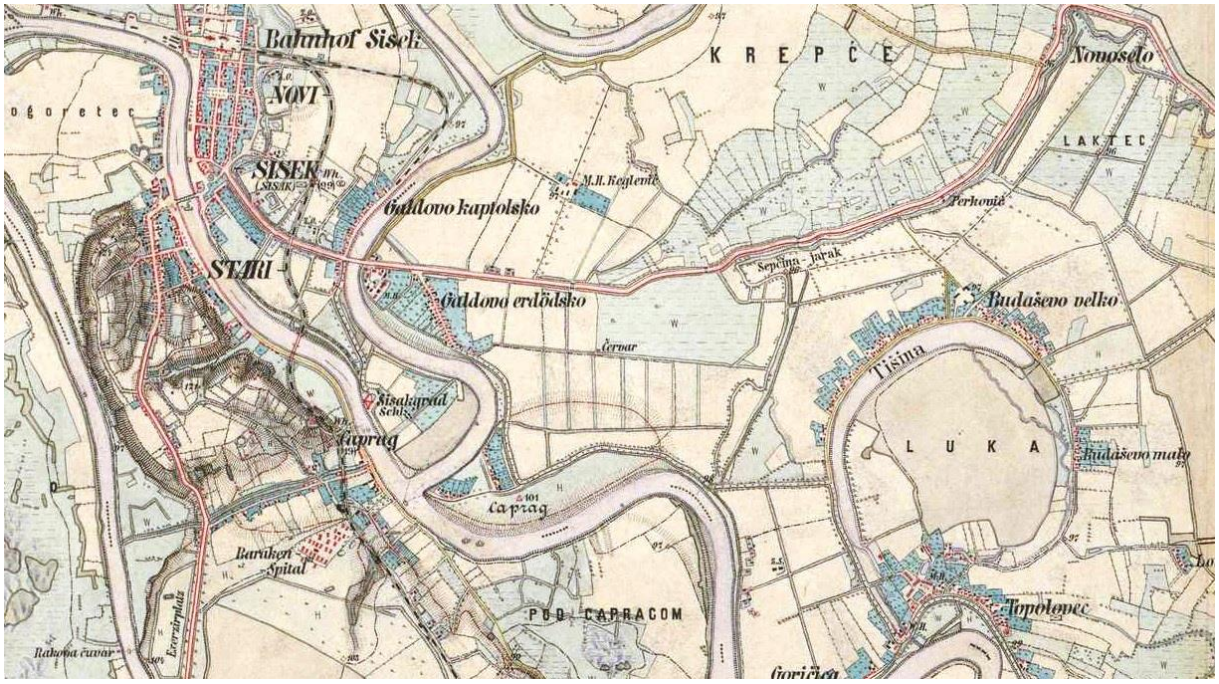

Figure 4. Complex cultivation patterns at the mouth of the Kupa on the defended part of the floodplain with a developed network of reclamation canals. Forests, bordered with thick brown lines, are shown at the mouth of the Kupa and inside the oxbow lake "Tišina"

The cutoff meanders were formed either naturally or by digging a canal which redirected the river course and caused the ends of the cut meander to be filled up. The protected area "**Tišina**" in Bosnia and Herzegovina, entity Republic of Srpska, contains the remains of oxbow lakes (Annex – map 5). In the XIX century, the protected area was predominantly wetland: 15% of the area was covered with open water surfaces, and 33% were marshes. Meadows and pastures covered 22%, a complex of cultivation patterns covered 18%, and forests 10% of the area.

The floodplain of the lower course is characterized by wetland habitats that mainly occur in the form of meanders (oxbow lakes) that often form lines in the floodplain (Appendix – Maps of river sections). In some parts, forest vegetation occurs only in river accumulations, because in the lower parts of the terrain, the duration of flooding did not allow the development of woody vegetation. The oxbow lakes have swamps and ponds with open water surfaces. The map of **Obedska bara** (Appendix – map 6) from the end of the XIX century shows a characteristic picture of a complex pattern of forest and wet habitats distributed along the river relief. Wetlands used to cover 28%, forests 40%, and pastures and meadows 23% of the area. On higher terrains, which were not flooded every year, arable lands were occupying 5% of the area.

Higher terrains of river banks and floodplain, in the lower course of the Sava, show the dominance of agriculture. Half of the mapped section near **Jamena** (Appendix – maps of the river sections) is occupied by fields with hedges and groups of trees (53%), while the forest

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cover is only 7%. Wetlands occupy 8%, and the Sava River 32% of the mapped area. The last mapped section is located 5 km from the mouth of the Sava and includes an island (Ada Ciganlija). The river occupies 50% of the space; the island is covered with forest (35%), and there are meadows near the river banks (13%).

Today's protected areas show two types of landscapes present at the end of the XIX century. Odransko and Lonjsko polje, naturally formed forests, as well as Obedska bara, represent partially changed natural landscapes, while the other three analyzed areas had already changed into agrarian landscapes. These changes continued in the following period as well.

Changes in land use from the end of the XIX century to the second decade of the XXI century

A comparison of the purpose of the protected areas and sections of watercourses outside them (Figure 5) shows a decrease in meadows and pastures in both cases and the presence of forests in approximately the same percentage. The mapped sections show that in the XIX century there was already a significant part of urbanized and other man-made areas whose development was accompanied by the loss of meadows and pastures, as well as other categories typical of agrarian landscape.

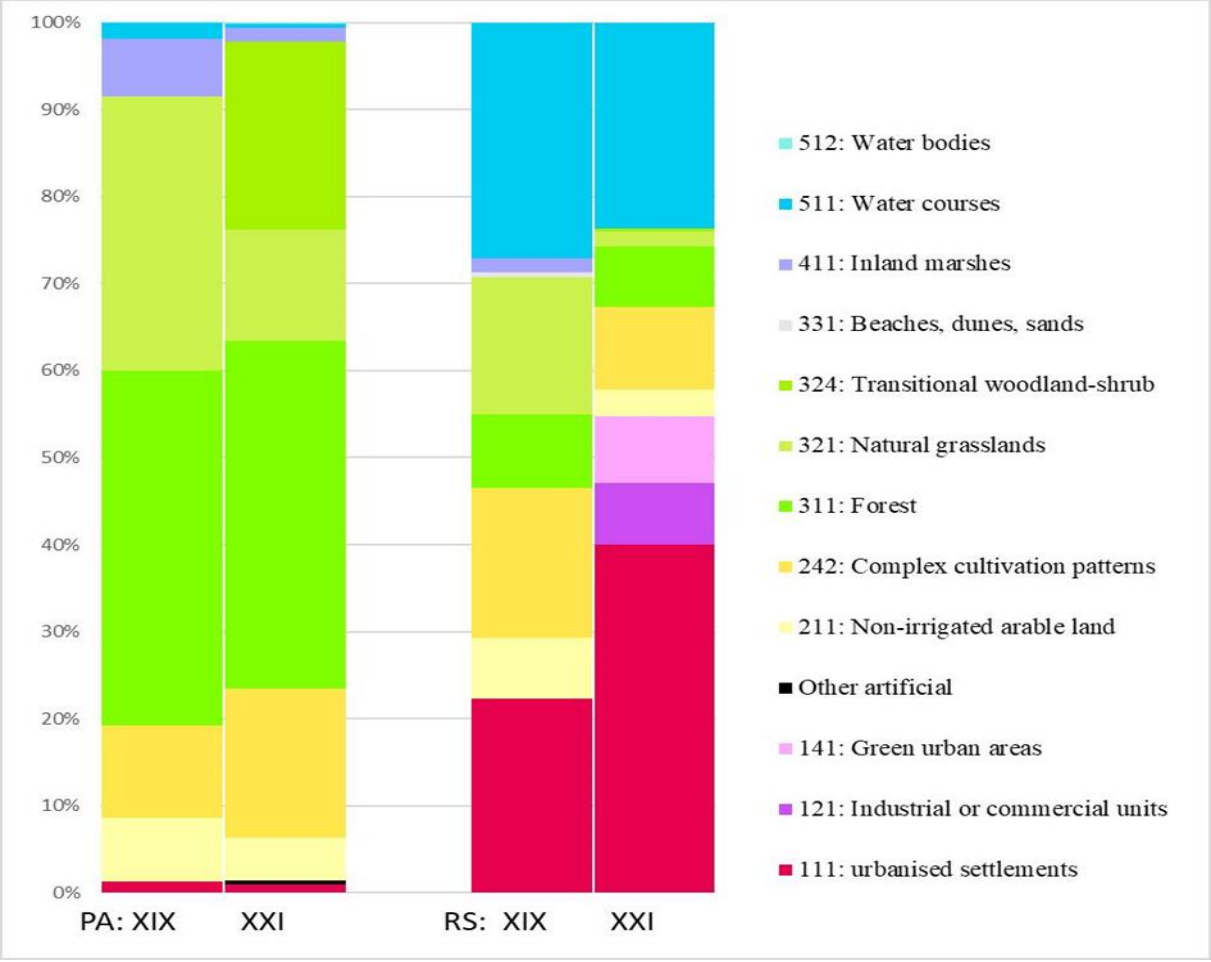

Figure 5: Changes in land use from the end of the XIX century until the second decade of the XXI century

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Cumulatively, the protected areas have undergone some significant changes, such as the reduction of grassland and wetlands, the occurrence of "transitional woody formations" and the increase in the complex cultivation patterns. The "forest" category kept its share, but also the category of plantations appeared.

Changes in protected areas can be observed in the reduction of grassland and the presence of a new category of "transitional woody formations". About half (49%) of these formations occur in areas that were previously marked as forests, and it should be noted that Corine classifies forest clearings and young forests in this category. Almost 30% of these areas were formed by overgrowing of meadows and pastures (natural grass areas), including areas overgrown with invasive woody species. Part of these areas (7%) was created by overgrowing the wetlands, and almost the same percentage occurs on the surfaces of former complex cultivation patterns. As for former fields and water surfaces, it is present but to a lesser extent (3%). Spatial analysis of detailed maps of land cover from the White Book of the Sava River (Schwarz, 2016) shows that this category includes young forests and forest clearings, and in Obedska bara as much as 67% of the area are softwood plantations (mostly Euro -American poplars), which is also true for other protected areas.

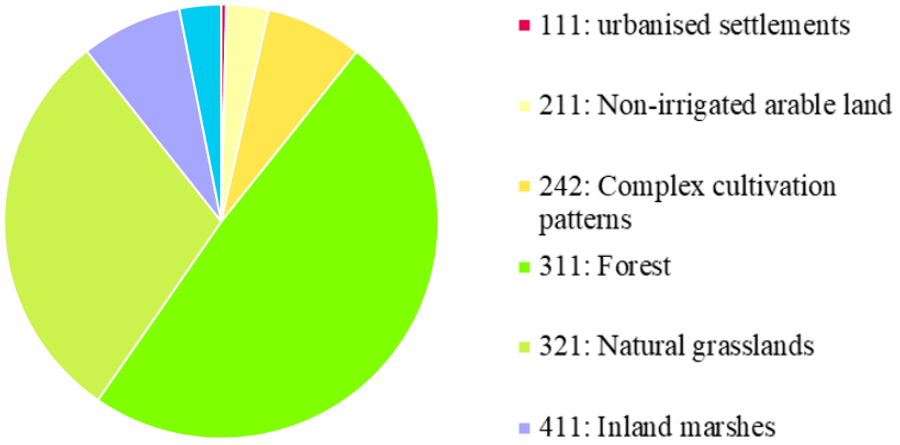

Figure 6. Percentage of categories of land use at the end of the XIX century marked as "transitional woody formations" on today's maps

Significant reduction of grass vegetation can be observed in all studied areas. A detailed analysis of changes from one category to another (Figure 7) showed that meadows and pastures shifted (almost equally) to the categories of forests (30%), transitional woody formations (28%), and complex cultivation patterns (30%). The last category includes mosaics of partially unattended meadows and pastures. Big differences in the surface areas of protected zones, mapped sections outside their borders, as well as a small number of examined sections make this analysis insufficient to provide data on quantitative changes outside the protected zones, although it does indicate the existing trends. The conversion of former meadows and pastures into fields, settlements, industrial and other man-made surfaces occurs outside the boundaries of protected areas, which is presented in Figure 5.

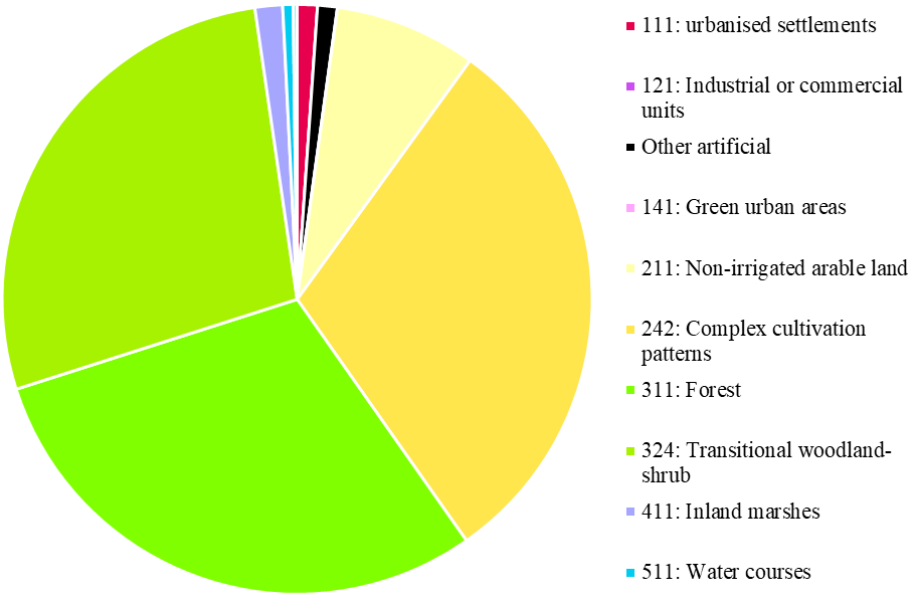

Figure 7. Percentage of different land uses in an area that used to be meadows and pastures at the end of the XIX century according to the Corine Land Cover (CLC 2018)

By reviewing the obtained results and comparing the Corine Land Cover (CLC 2018) maps with field data, it was concluded that this method cannot be used for monitoring and interpretation of changes that take place on small surface areas, or changes within the same type of vegetation. The appearance of complex cultivation patterns at places where unattended grassland used to be stimulated a more detailed historical analysis of these areas. Comparison of locations with maps of land use from the XIX century showed some heterogeneity of this category. More than half (57%) of these areas were previously covered in grass vegetation, and 28% were fields. In both cases, it is a mosaic arrangement of woody vegetation on unattended plots, which may be a consequence of plant invasions (and according to field data it is).

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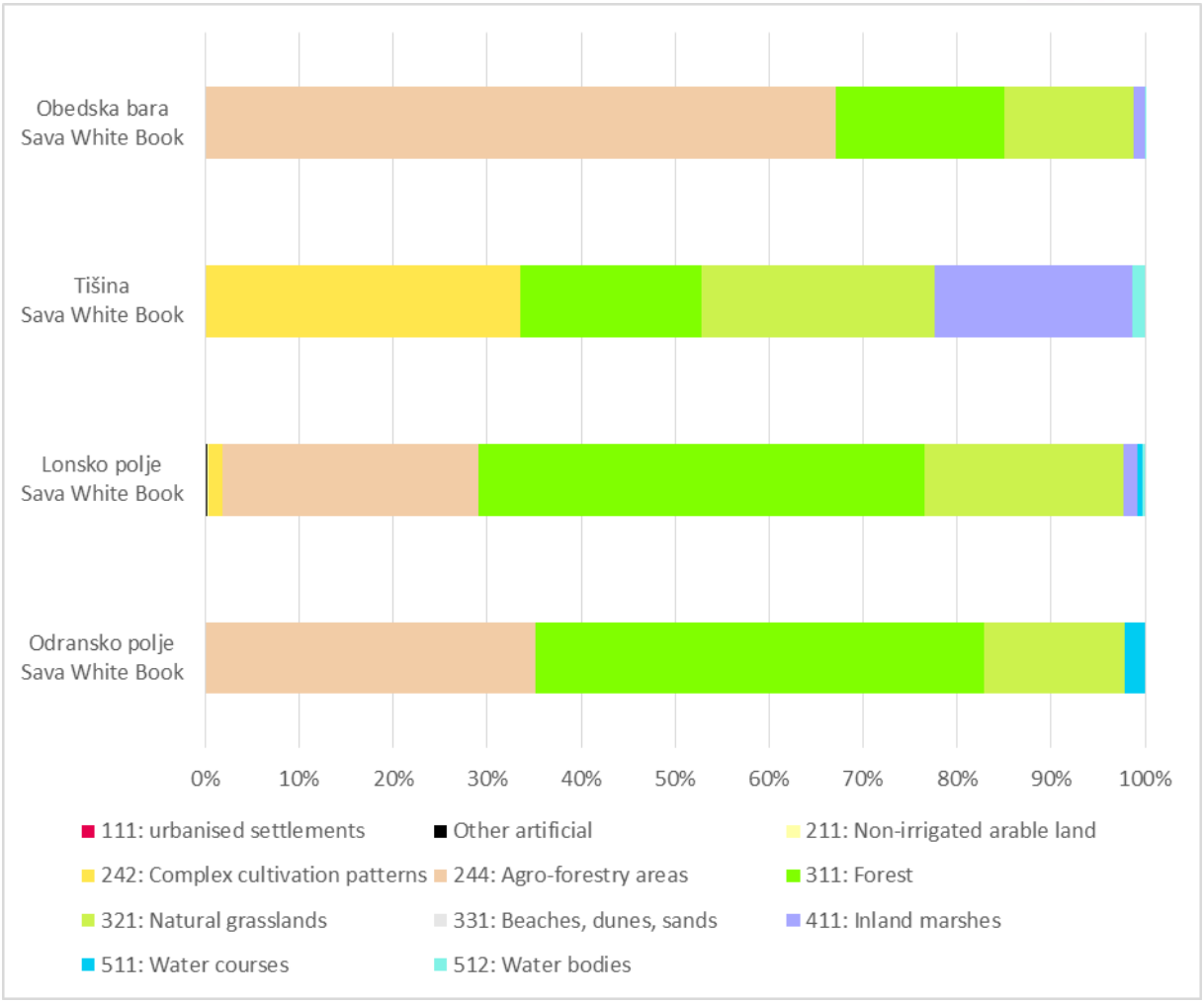

Figure 8. Percentage of different land uses in an area that used to be meadows and pastures at the end of the XIX century according to the maps of land cover of the Sava White Book

The "forest" category kept approximately the same share in its presence, but a new "plantation" category was also introduced. The Corine Land Cover map is not successful in separating the forest from the plantation, which resulted in a distorted presentation of the share of natural forest cover. Only an insight into the changes in spatial position of certain categories shows that the loss of meadows and pastures is associated with an increase in forests.

The line infrastructure includes a network of canals and roads, which were a prerequisite for economic development during the XX century. The analysis of protected areas showed reduced canal and road networks in protected areas.

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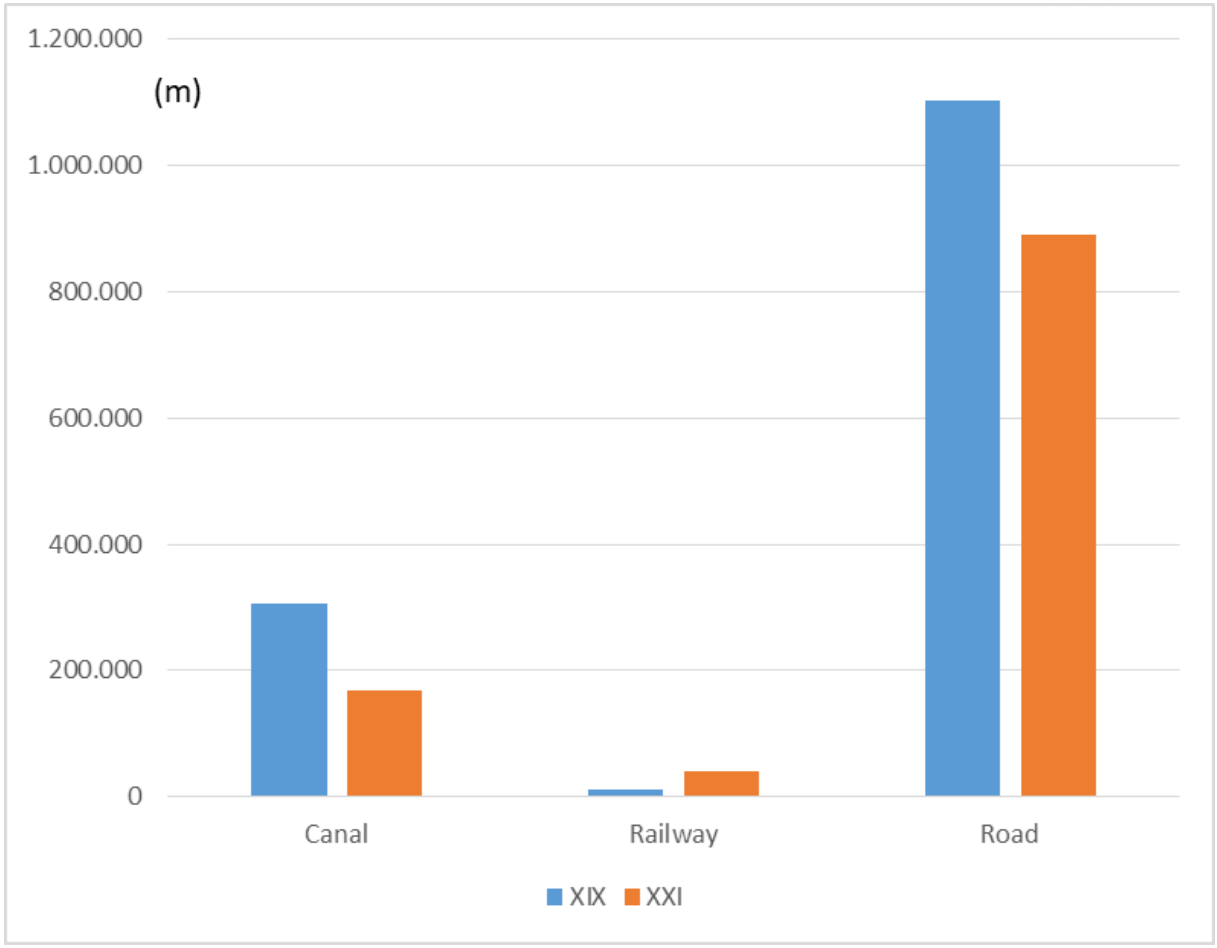

Figure 9 Total length of canals and roads in studied areas

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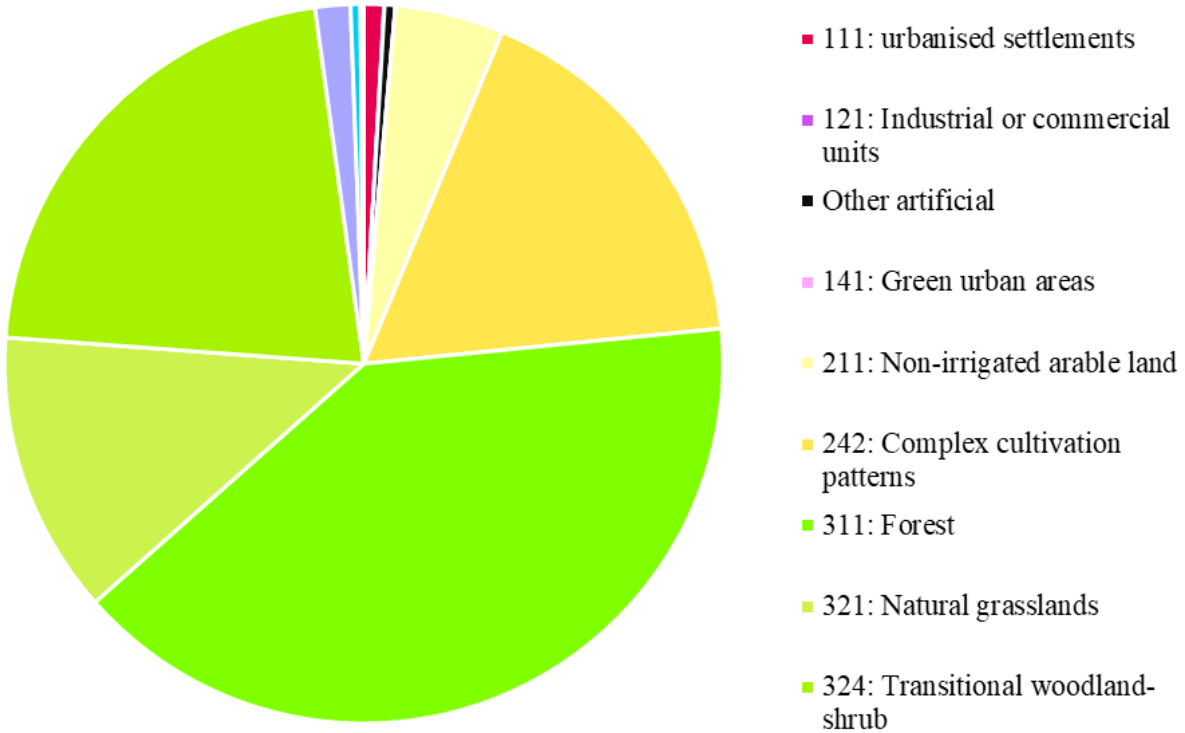
Part 2: Review of land use practices

A review of land use was made based on the land use maps from the previous part of this Study, which show the dominant types of land use in protected areas (Figure 1) and in selected sections of the floodplain.

Based on the presented results of land use, the Contractor's team of experts identified activities that have affected the spread of invasive species in the examined areas, and some questions were prepared for the land users. The collection of data on the most common land use practices (forestry, hunting, agriculture) was conducted using an online questionnaire developed by the Contractor. The poll (Annex 1) was implemented as a multilingual survey available on "Google" consisting of 15 questions with sub-questions and the possibility of multiple selection. The two questions were open-ended type.

Figure 1: Types of land use on mapped protected areas (up) and on selected sections of the floodplains (down)



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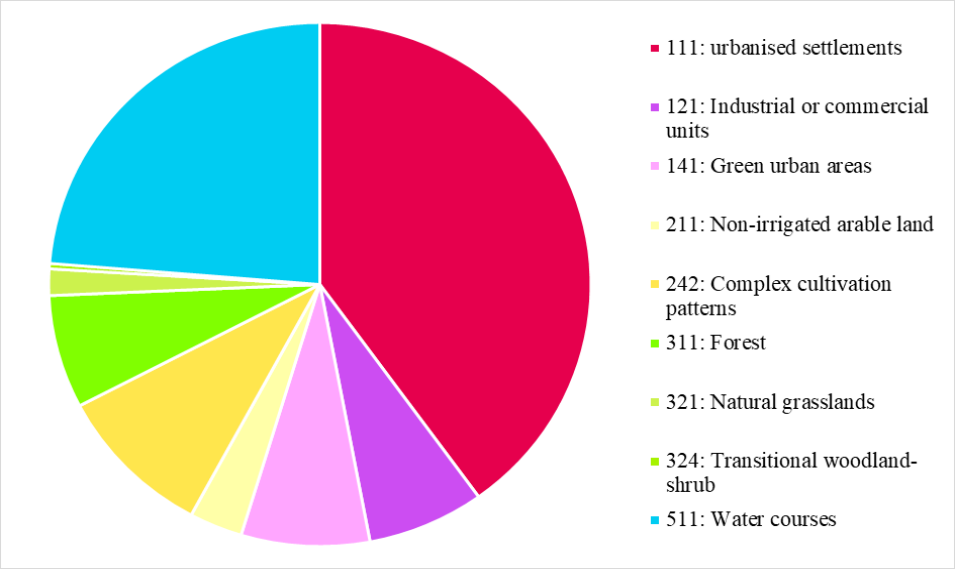
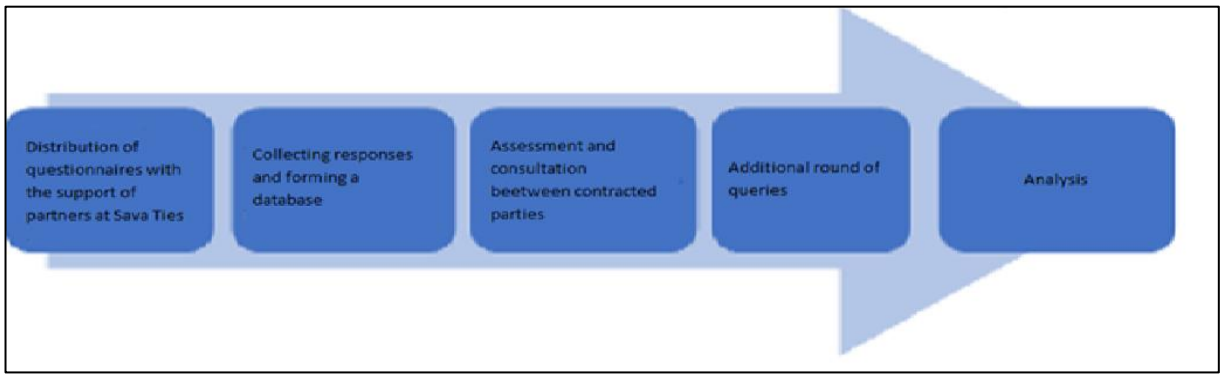


In protected areas, in addition to natural and partially altered habitats (forests, grasslands and wetlands), there are monocultures of hybrid poplars (poplar plantations), as well as smaller plots of cultivated land. Parts of floodplains outside the protected areas show a greater diversity of purposes. The regulation of watercourses enabled the expansion of settlements and other urbanized areas into the floodplain, and the construction of a drainage system enabled the conversion of former wetlands, meadows and pastures into cultivated areas. Land use of selected sections (Figure 1) shows the existing trend of urbanization (cities, villages, holiday homes) in the flood-protected alluvial area.

Scheme 1: Process of land use analysis



A review of the survey results is presented as a list of questions sorted respectively as in the Questionnaire (Annex 1). A percentage of selections for given options is presented.

1. Basic information about the respondents to the questionnaire

In addition to the countries in which the respondents live or work (the Republic of Slovenia, Bosnia and Herzegovina - including the FBIH and RS entities, the Republic of Croatia and the Republic of Serbia), information was also collected on the type of users (direct or indirect user, at local or higher level), by choosing from 5 positions (Government body, Local or

regional self-government/municipality, Public company and other users of natural resources (eg. hunting ground department), private land owner; other). With regard to sectors, users of natural resources that are mostly present in floodplains (agriculture, forestry, water management) were listed and the possibility of adding something else marked “other” was offered (e.g. an organization of citizens interested in the study and conservation of nature).

The total number of received (completed) questionnaires was 54. Most respondents were from Croatia (19) and the least number of them was from Slovenia (5) (Figure: 2).

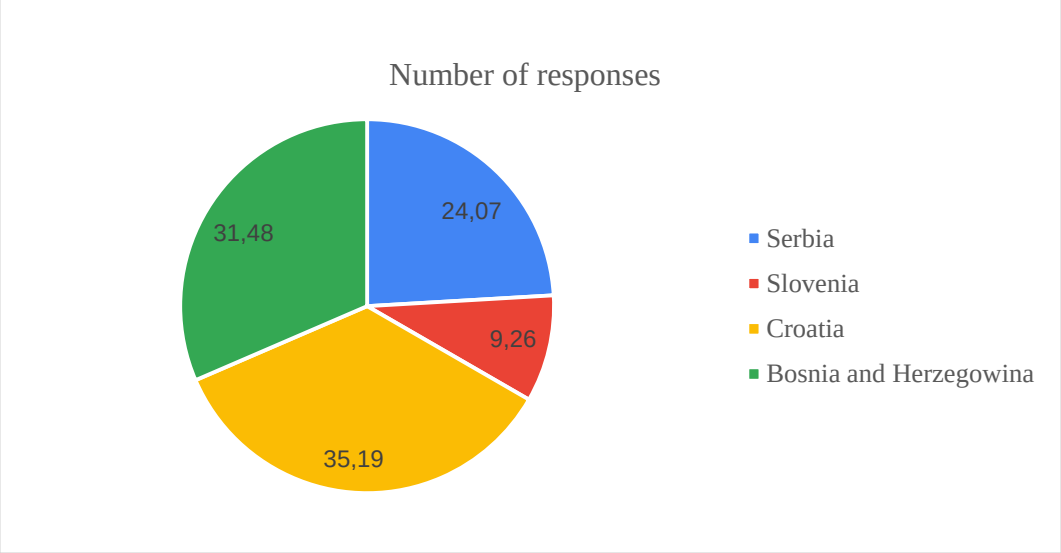


Figure 2: Received answers by country

According to the social position in land use (Figure 3), the largest number of respondents were represented as Public companies and other users of natural resources (around 38%), followed by Private land owners (29%).

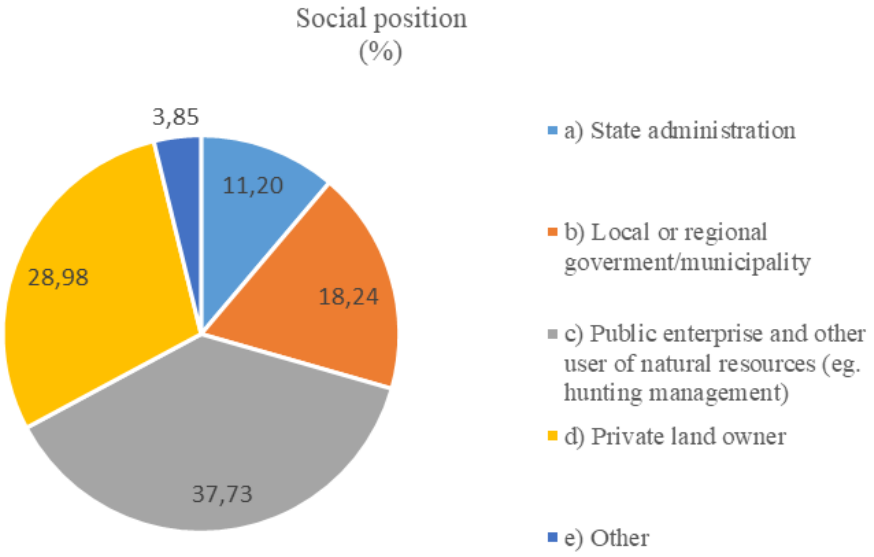


Figure 3: Position in land use

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With regard to the sector they work in (Figure 4), most respondents in the questionnaire answered that they worked in Agriculture (35.79%). Although the Questionnaire is primarily intended for land users, after analyzing the "Other" category from the Questionnaire, it was determined that some land users were also involved in the conservation of nature or environmental protection, which is why a special category "Nature and Environmental Protection" was singled out and almost 16 % of respondents belonged to this category. The remaining respondents in this category were classified in the "Other" category, which included representatives of municipal departments for spatial planning, physical planning and housing and community affairs, other local self-government organizations and educational institutions.

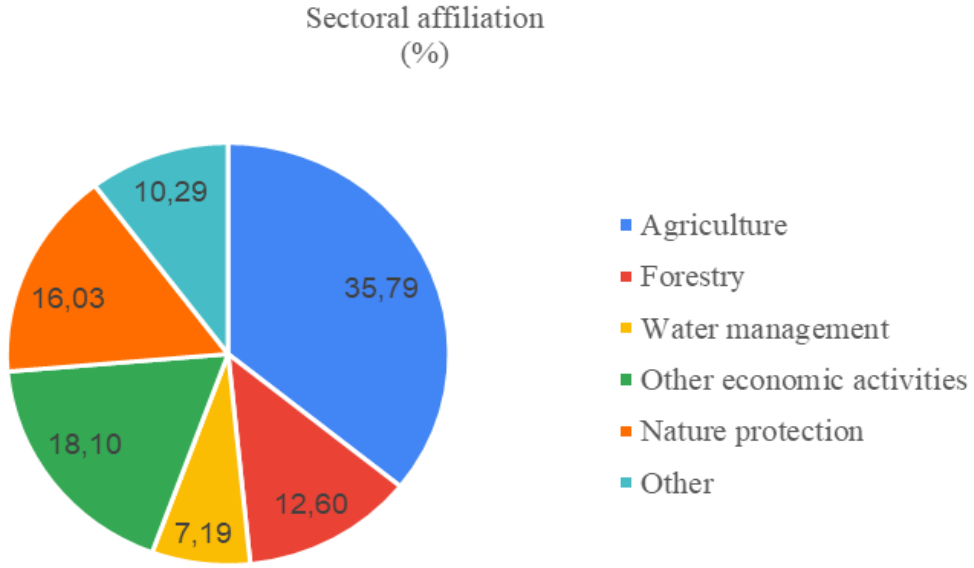

Figure 4: Sectors

The presented structure of respondents is related to the above-mentioned, most common categories of land cover in protected areas, including sectors and activities that have a significant impact on land use in the planning process, which is confirmed by the representative samples.

2.) The following question was: "**Have you heard the term of Invasive Alien Species by now, personally or professionally?"**

The purpose of this question (with a sub-question) was to determine whether the respondents had previously heard the term “invasive species” and where they had heard it (Figure 5).

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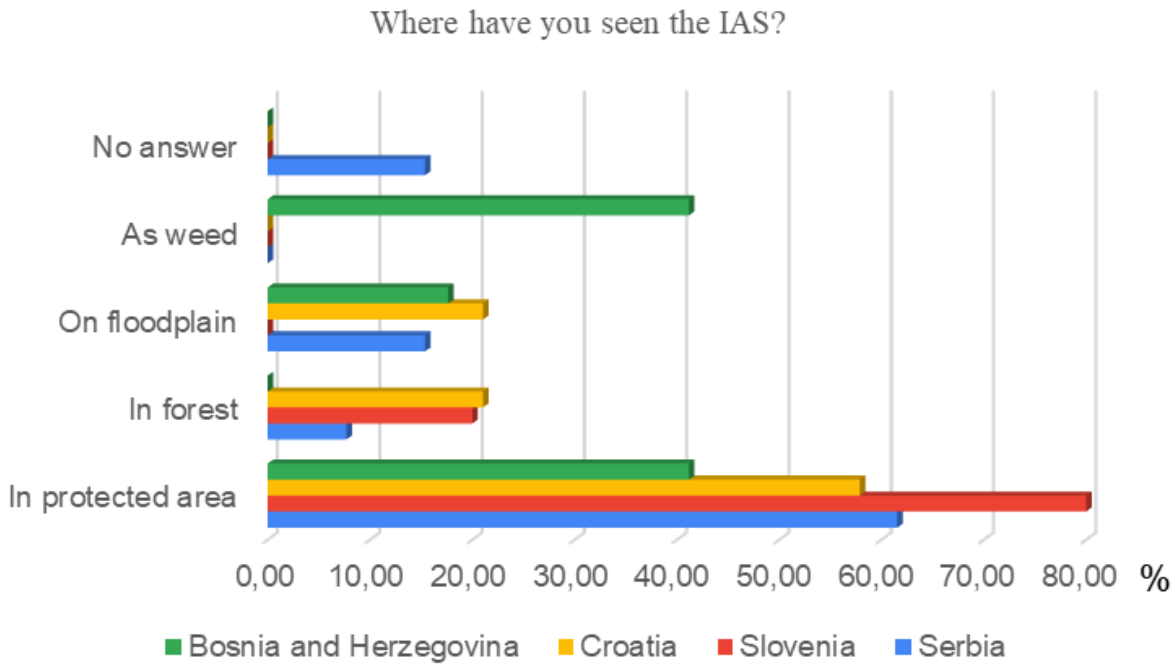

Figure 5: Previous experience with invasive species

The largest number of responses to this question was: “In the protected area’’ (57.69%), followed by “In a floodplain area“ (17.31%). The answers received from Bosnia and Herzegovina, according to which the weeds on agricultural land were reported as invasive species, deviate the most from the above-mentioned description. This statement could indicate the problem about protected area management in terms of weeds in ruderal zones of protected areas.

3. The third question (Figure 6) helped determine whether the respondents recognized the damage caused by invasive species: "**Have you experienced income loss due to the introduced species (e.g. weeds, pests, invasive fish species, aggressive wooden or herbaceous species) since you started growing crops, managing forests, meadows, fish ponds**)? "

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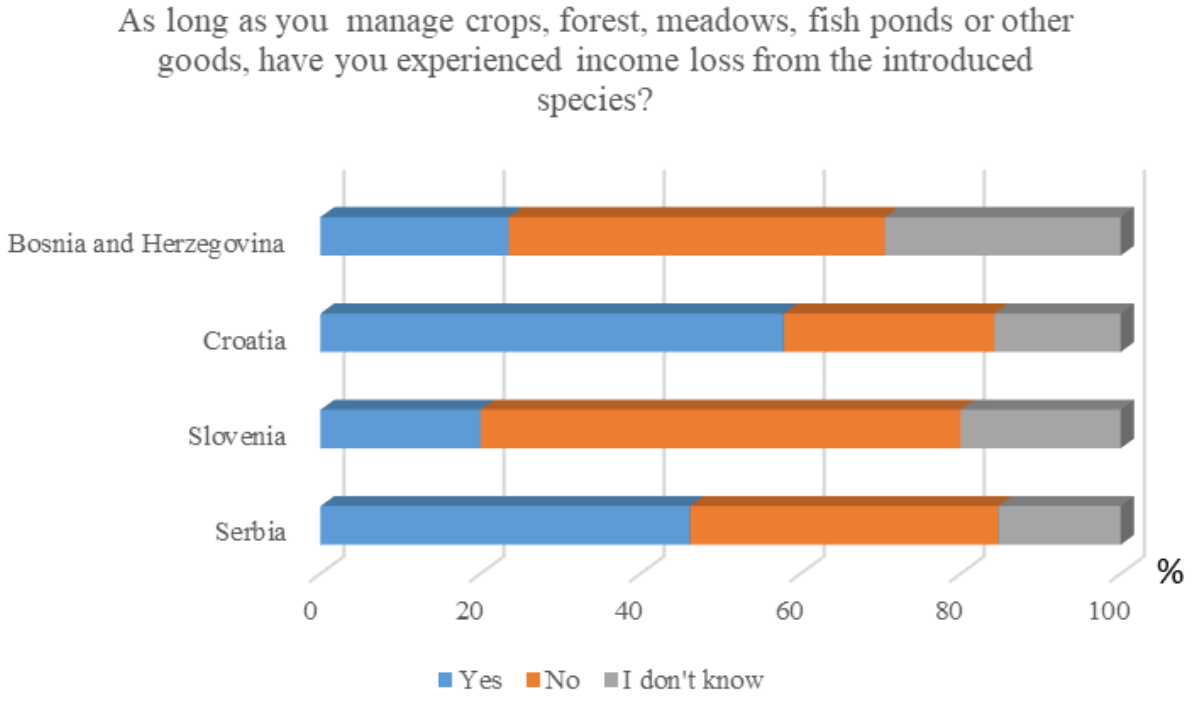

Figure 6: Potential damage from invasive species

The percentages of respondents who reported income losses in Serbia and Croatia were 46.15% and 57.89%, respectively, and the respondents from other countries mostly reported that they did not suffer or did not know that they had suffered the loss of income caused by invasive species. According to the answers, 26.32 % of them in Croatia did not suffer any losses, and that percentage was up to 60% in Slovenia. This result is certainly the consequence of landscape characteristics because the floodplains in the upper basin of the Sava River (Slovenia), which are suitable for invasive species spreading, occupy smaller areas.

It is also important to mention that 20.37% of respondents stated they did not know if they had suffered a loss from invasive species, in Serbia that percentage was 15.38%, in Croatia 15.79%, and the highest percentage of 29.41% was recorded in Bosnia and Herzegovina. This response indicates the need to train land users to recognize these species and the damage they cause so they could react in a timely manner and avoid or reduce the damage.

The sub-question "**Which species" caused the losses** provided different responses (Figure 7) according to which 12 species were on the list of 32 most harmful species that the managers of protected areas in the Sava River Basin had identified as the species with the greatest harmful potential.

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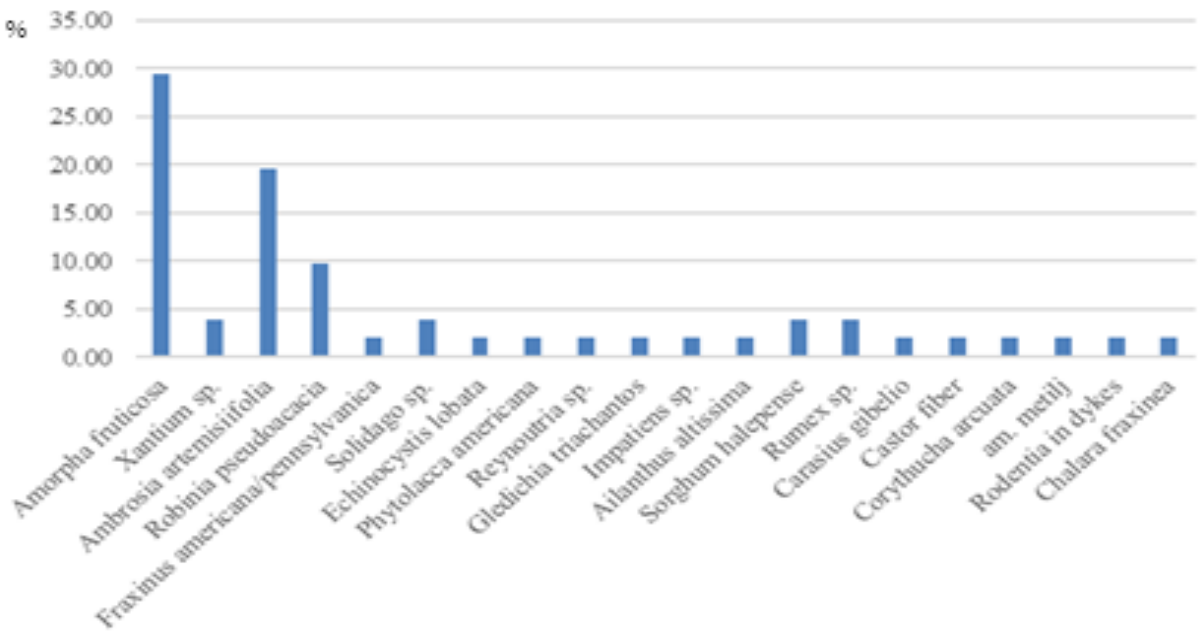

Figure 7: Species causing damage

Most respondents reported a loss caused by the false indigo bush (Amorpha fruticosa), then from the ragweed (Ambrosia artemisifolia), and the black locust (Robinia pseudoacacia) was in the third place. Typical weed species such as sorghum and sorrel, pathogens and parasites (the American liver fluke and oak lace bugs), as well as rodents that cause damage to dykes were also listed individually.

4. The next question revealed the degree of importance that respondents attach to invasive species: "**Do you check your land for the presence of any invasive species**?“

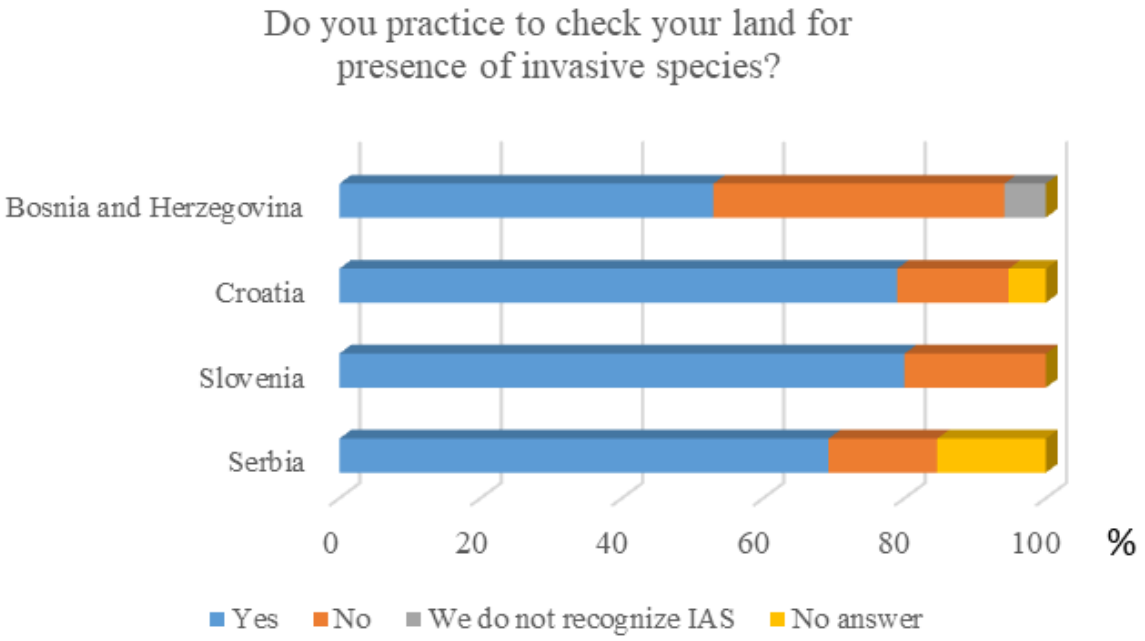

Figure 8: Detection of invasive species presence

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The plots were mostly checked for the presence of invasive species (Figure 8), with some exceptions for Bosnia and Herzegovina where the number of positive and negative responses was almost equal, indicating that there was no differentiation of invasive species. Respondents from Serbia and Croatia did not provide answers to this question.

After further analysis and dividing the respondents into groups of those who did not check the presence of invasive species and those who did not distinguish invasive species, it was concluded that some of those respondents were engaged in activities that could encourage the spread of invasive species: 20% of them mow and all of them who excavate or transfer soil in protected areas (correlation with question 7) also maintain green areas (correlation with question 8).

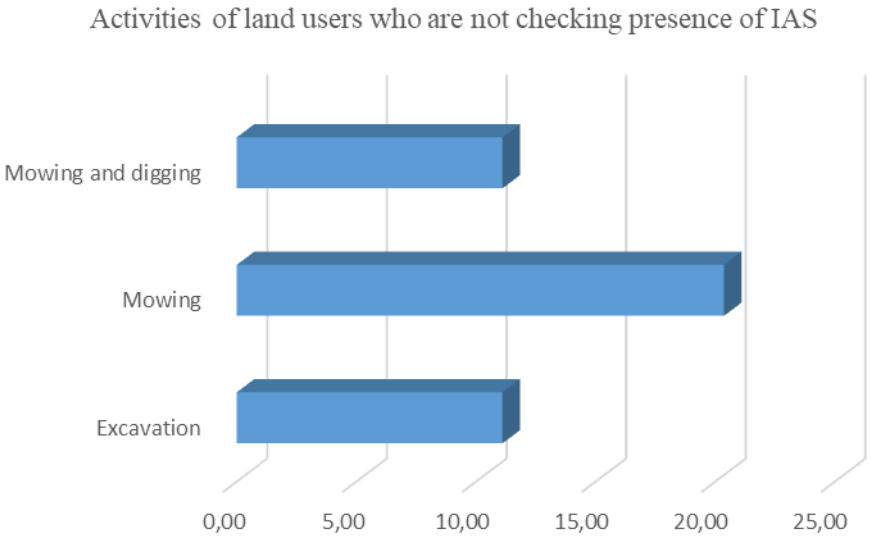

Figure 8a: Activities of users who do not check the presence of invasive species

It was also important to determine the reactions of users who reported losses from invasive species. With regard to that, the following sub-question was posed: **"In case of damage from the invasive species, has your organization/farm developed plans and techniques to minimize the damage? (e.g. supression and alike)?"**

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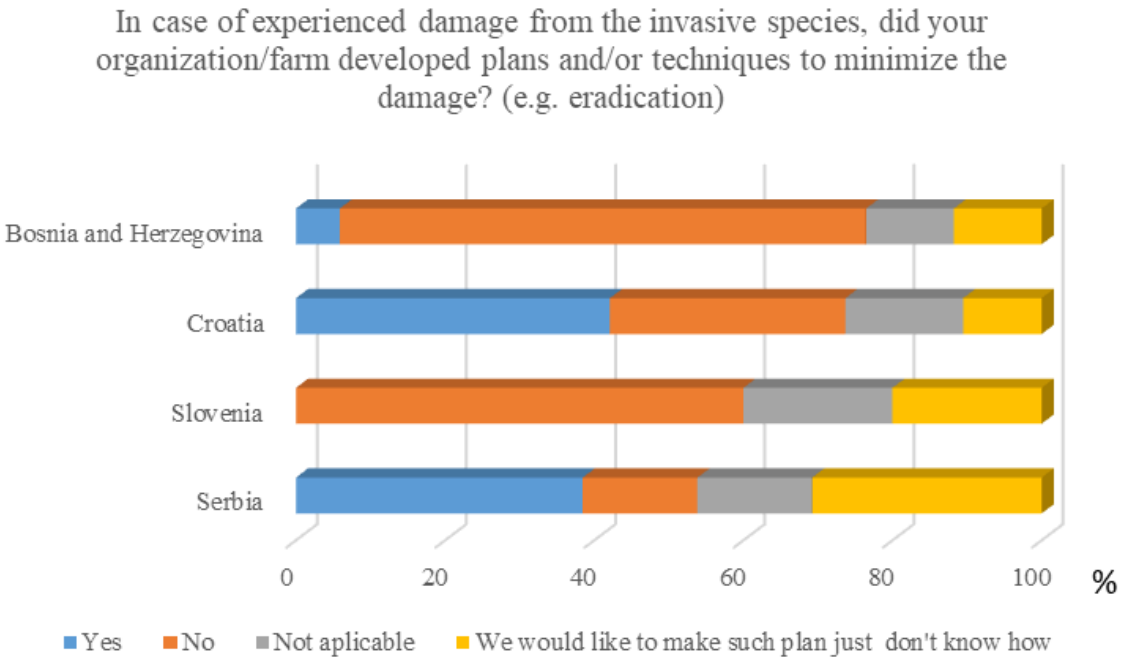

Figure 9: Are there any mitigation measures in case of damage suffered from invasive species?

In case of damage suffered from invasive species (Figure 9), the most common response from Serbia and Croatia was that the plans to repair the damage were developed, while in Slovenia and Bosnia and Herzegovina no plans were developed. A certain number of respondents in each country stated that they would like to make a plan, but they did not know how to do it. Also, 12 to 20% of respondents in each country believed that plans of this type were not applicable, that is, regulations and support measures for the management of invasive alien species (IAS) must be changed.

5. **Does your company/farm have any plans for the management (use) of land, either as an owner or a user?**

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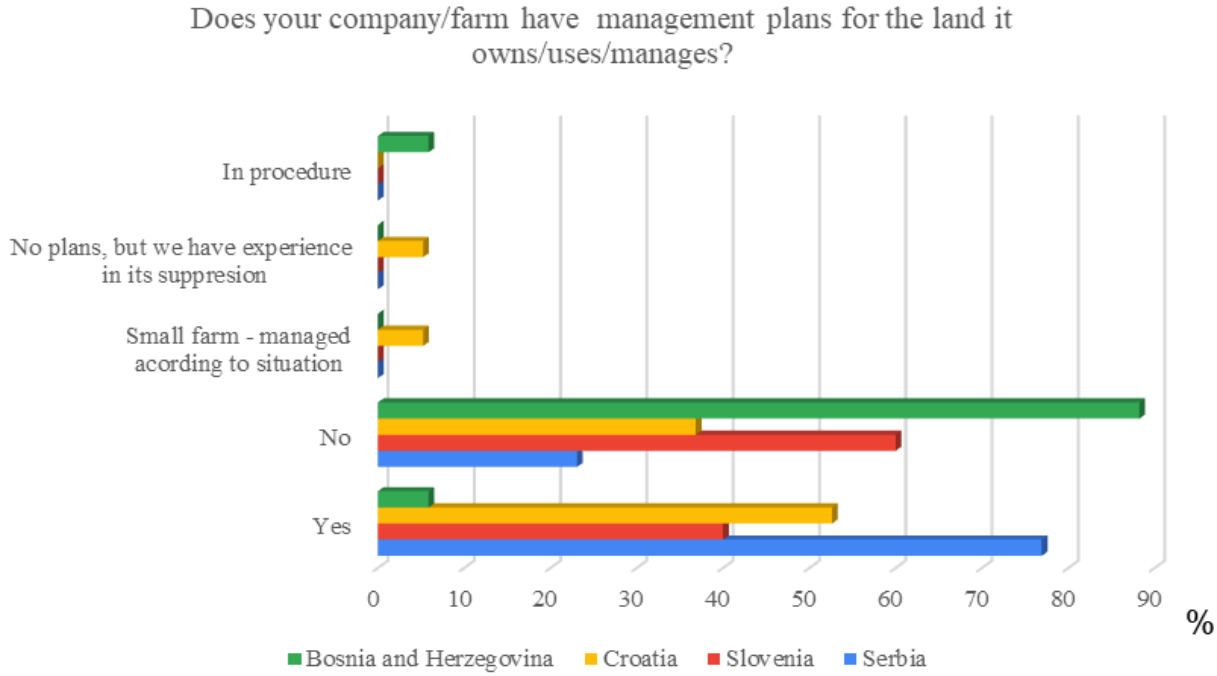

Figure 10: Land management planning

Most respondents from Serbia answered that they had a land management plan in contrast to those from Bosnia and Herzegovina and Slovenia, where the largest number of respondents did not have any plan (Figure 10). This result can be explained by a small number of responses from Slovenia and a higher percentage of private landowners (legal entities have more liabilities and the capacity to develop plans compared to natural persons).

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6. The question was: **" If your answer to the previous question was 'yes', does the plan consider possible damage or income loss from invasive species?"**

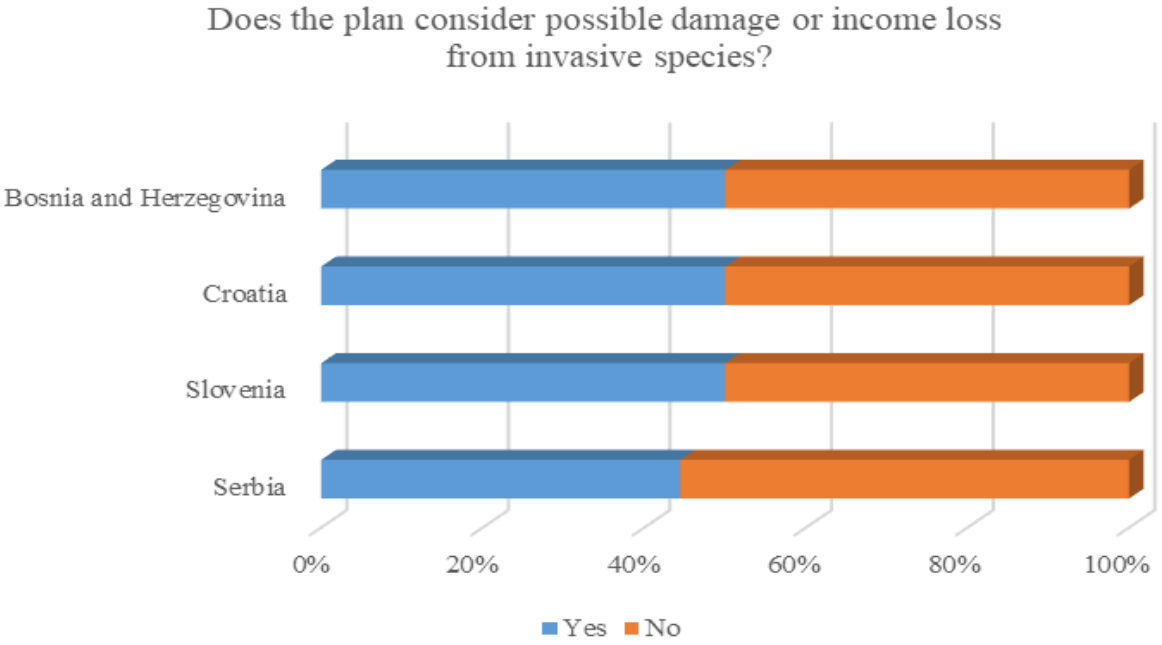

Figure 11: Does the plan consider damage from invasive species?

When asked if the plan considers a possible loss (Figure 11), the respondents gave similar answers in all countries with an approximately equal number of positive and negative answers.

The next two questions helped identify activities that either positively or negatively affect the spread of invasive species.

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7. **Does your company/farm performs soil excavation or soil transportation to other locations (e.g. for the maintenance of embankments, canals, roads, railways, etc.)?**

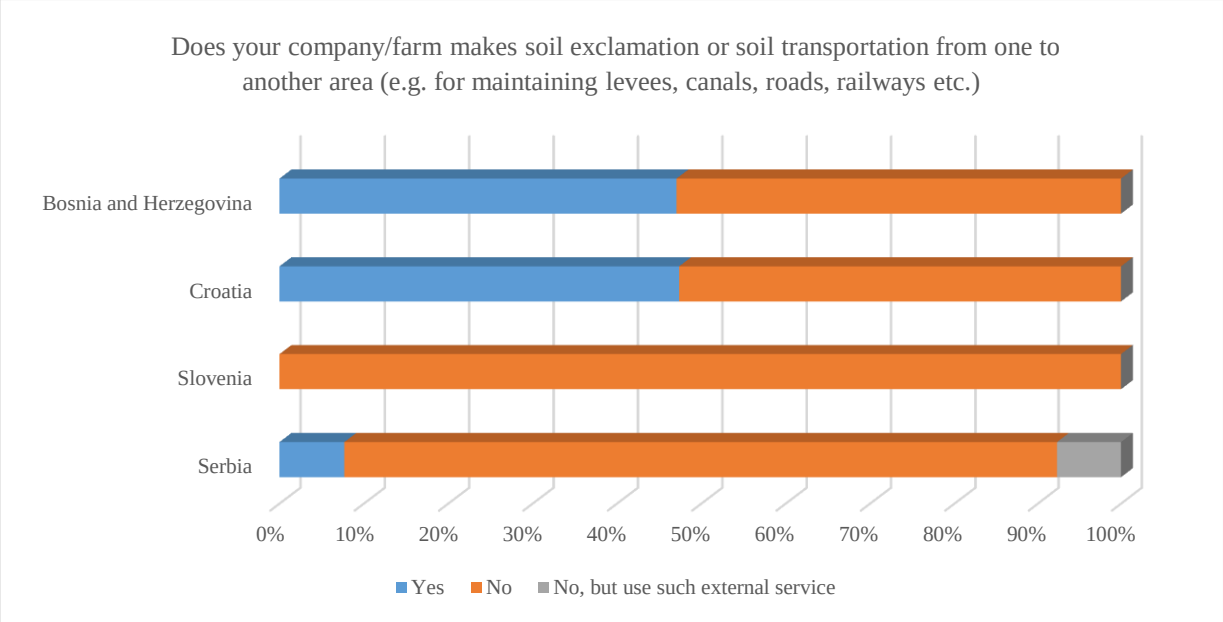

Figure 12: Excavating and/or transporting soil

Both in the total number of responses and in the group that recognized invasive species, most respondents from Serbia and Slovenia stated that they were not engaged in soil excavation. Unlike Serbia and Slovenia, half of the respondents from Croatia and Bosnia and Herzegovina stated that they were engaged in excavation/transport of soil (Figure 12). This result can be explained by greater participation of spatial planning organizations from local self-government and public companies in the forestry and water management sector in the excavation/transfer of soil.

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8. Does your organization maintain green areas?

Most respondents from all countries gave a positive answer to this question (Figure 13) thus indicating the significant importance of organization/respondents who participated in programs and activities in the management and control of invasive species.

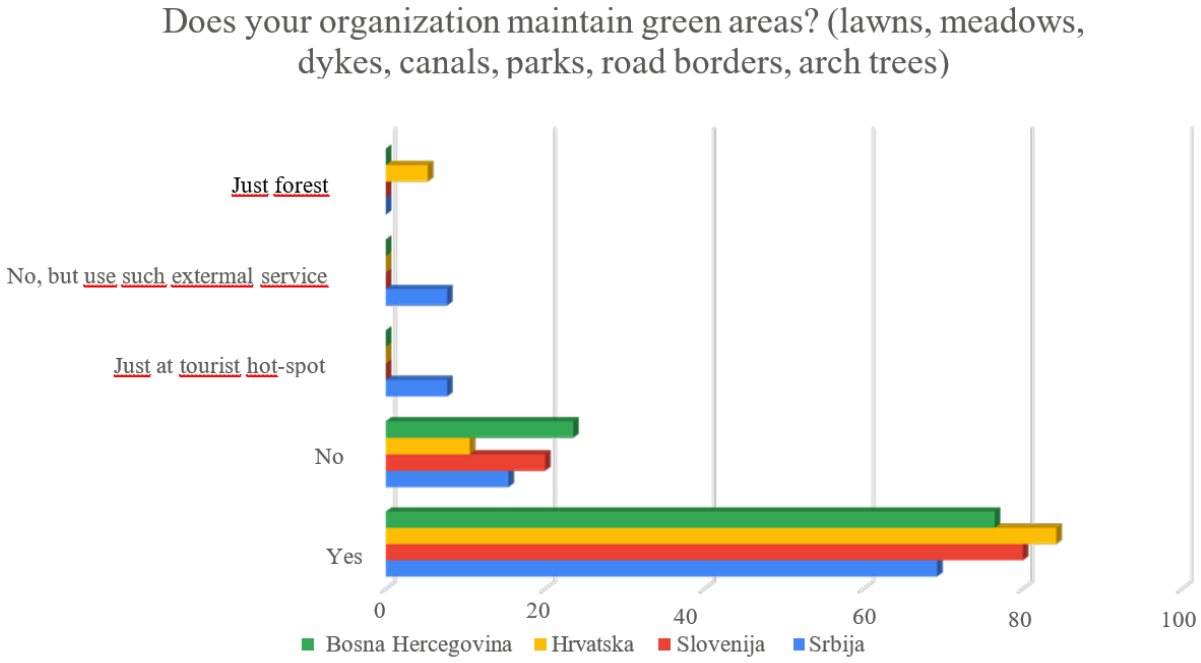

Figure 13: Maintenance of green areas

In most cases, respondents were engaged in maintaining green areas (Figure 13).

Figure 8 previously showed the activities in which users who do not check invasive species are engaged.

9. **If the answer to the previous question was ''Yes", in what way?**

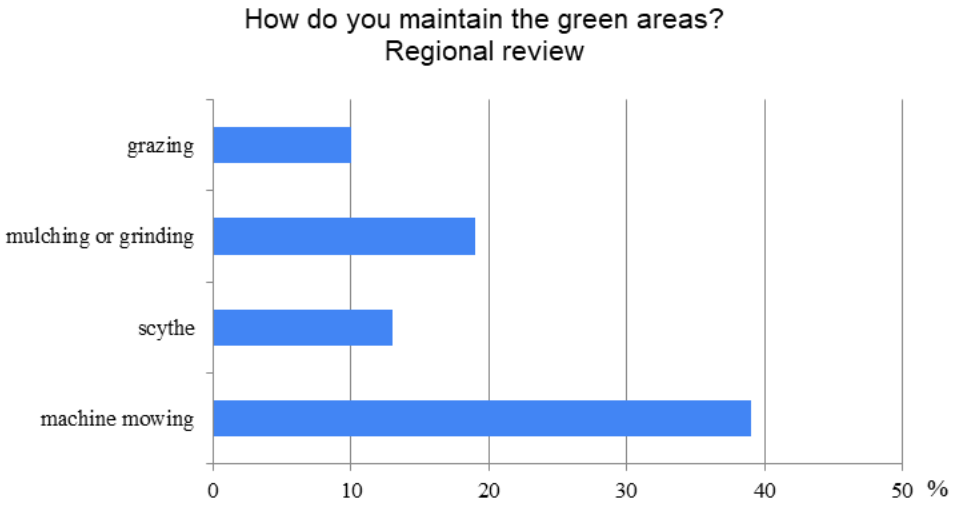

Figure 13a: Maintenance of green areas in the region

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The answer to this question gives an insight into the ways of maintaining green areas (Figure 13a). Around 60% of respondents in the region use machines for maintaining green areas and a small number of them claim that they apply traditional methods such as grazing.

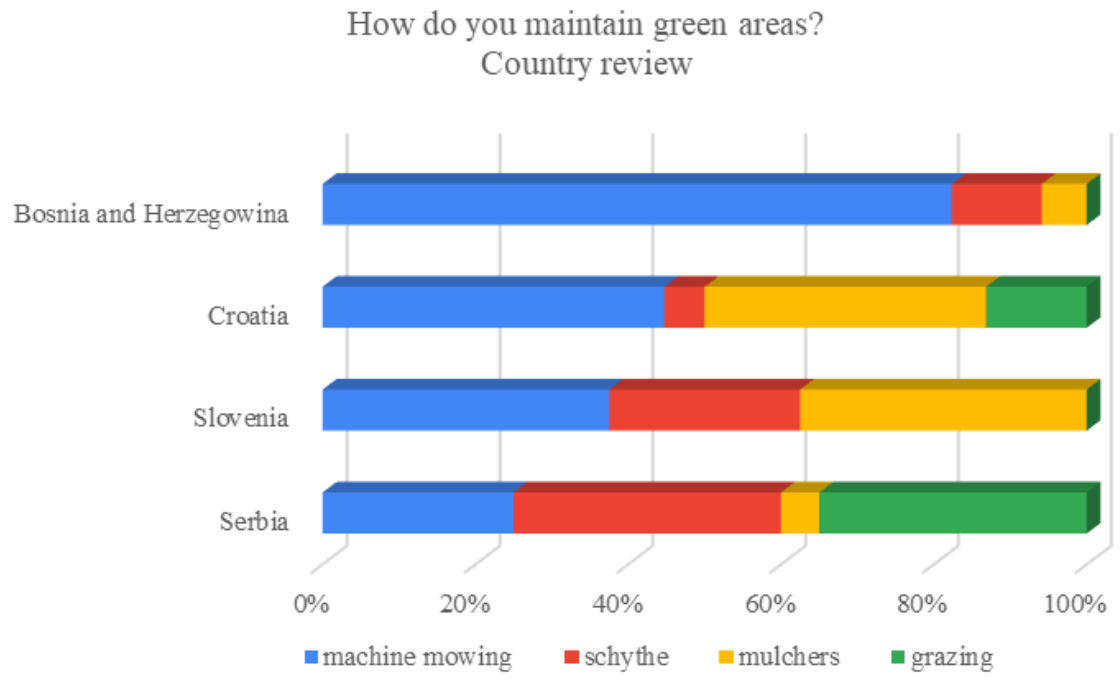

Figure 13 b: Ways of maintaining green areas by countries

After conducting further analysis by country (Figure 13b), it was determined that mowing machines were most used in the protected areas in Bosnia and Herzegovina and least in Serbia, while grazing and mowing with a scythe are methods mostly used in Serbia. This can be explained by a higher percentage of individual landowners in Serbia.

10. The purpose of this question is to determine **the way in which biomass (grass, weeds or bushes) produced in the mentioned way is used and where it is disposed of.**

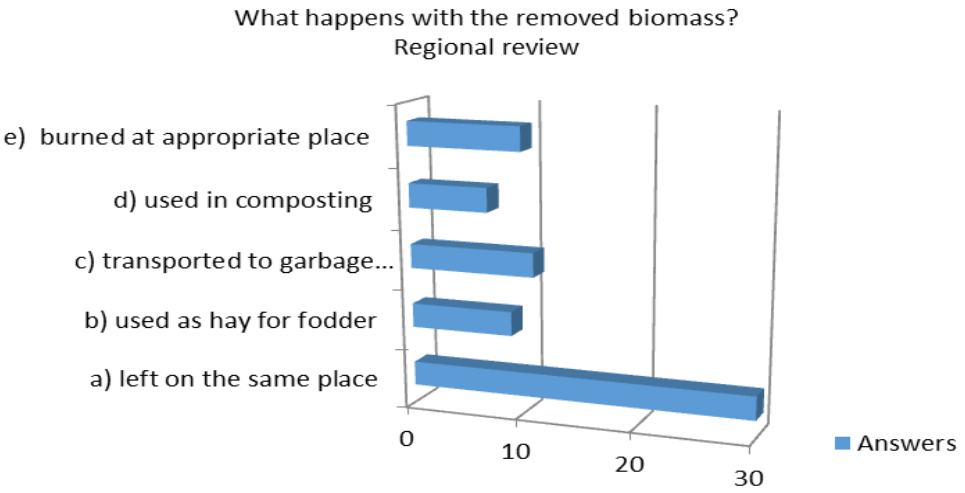

Figure 14a: How is the biomass from green areas (weeds, bush, grass) used - combined results

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Most users in protected areas leave mowed biomass on site (30%), and an insignificant number of them use it for composting. If mowing is done before seed maturation this finding could be positive in terms of controlling and reducing the possibility of spreading invasive species to new surfaces.

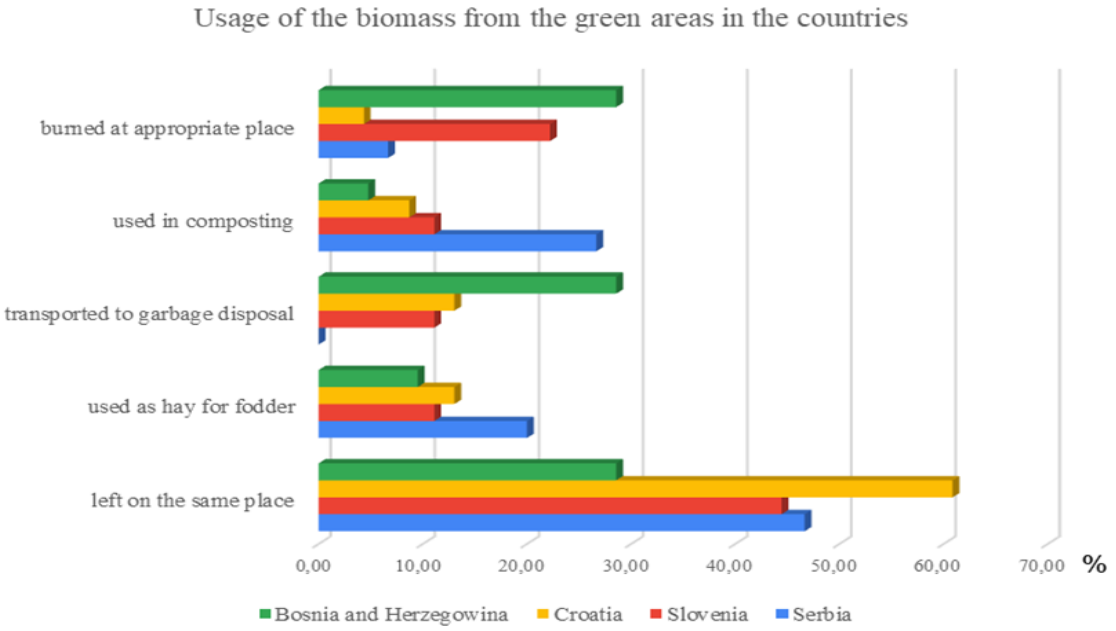

Figure 14b: How is the biomass from green areas (weed, bush, grass) used – by countries

The analysis of answers by country (Figure 14b) showed that the option "we leave it at the same place" was most often selected in Croatia, and it was least selected in Bosnia and Herzegovina, whereas, the option "we transport it to the landfill" was the most common one.

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11. Does your organization (or you, if you own the land) transport plant products (e.g. cereals, hay, game food, wood) from one area to another as part of the land management practice?

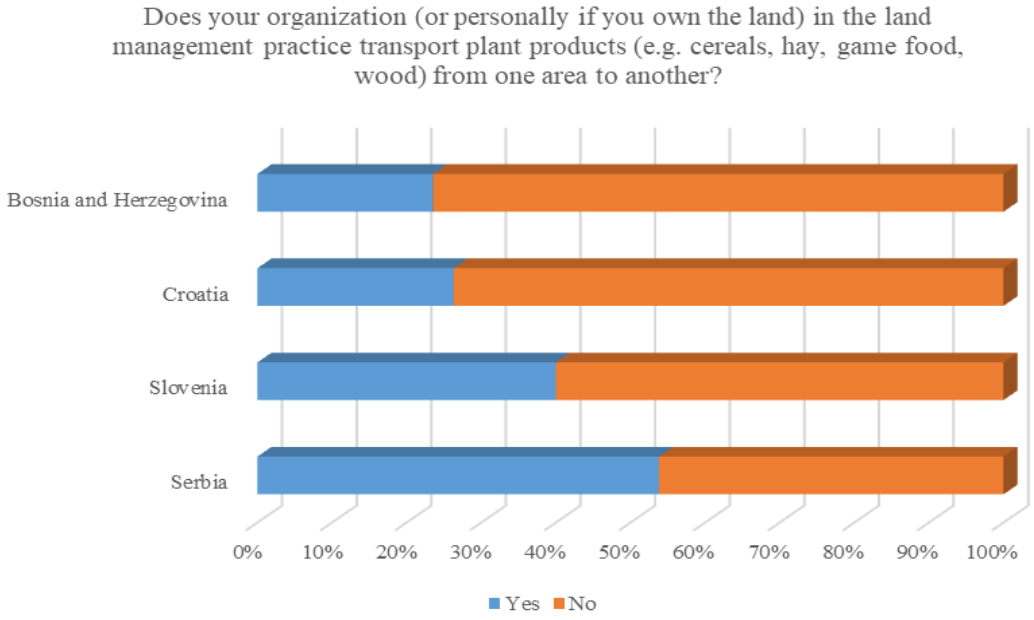

Figure 15: Transport and introduction of plant products

When asked whether their organizations (or they individually, if they own the land) transport plant products (e.g. cereals, hay, game food, wood) from one area to another as part of their land management practice, all respondents gave similar answers, even the ones who did not know anything about invasive species (Figure 15). One third of respondents in the region transported plant products.

12. If the answer to questions 7, 8 or 11 is "Yes", how far is the soil/biomass/product transported?

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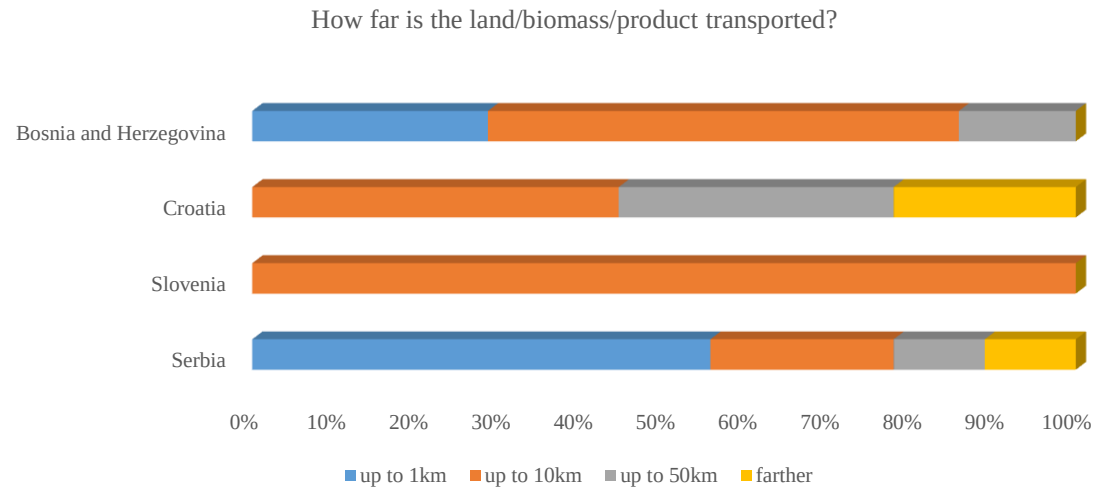

Figure 16: The transporting distance of plant products/soil

In case the biomass/product/soil is transported, it is done to a distance of up to 10 km (Figure 16). However, we obtained different answers from Croatia, where the transportation of a plant product was greater than 10 km. These responses indicate a predominantly local spread of IAS that are present in the environment, that is, there is little possibility of the invasion of new species from distant areas.

13. In your opinion, should the problem of invasive species be addressed at the national level? (e.g. subsidizing supression and prescribing preventive measures)

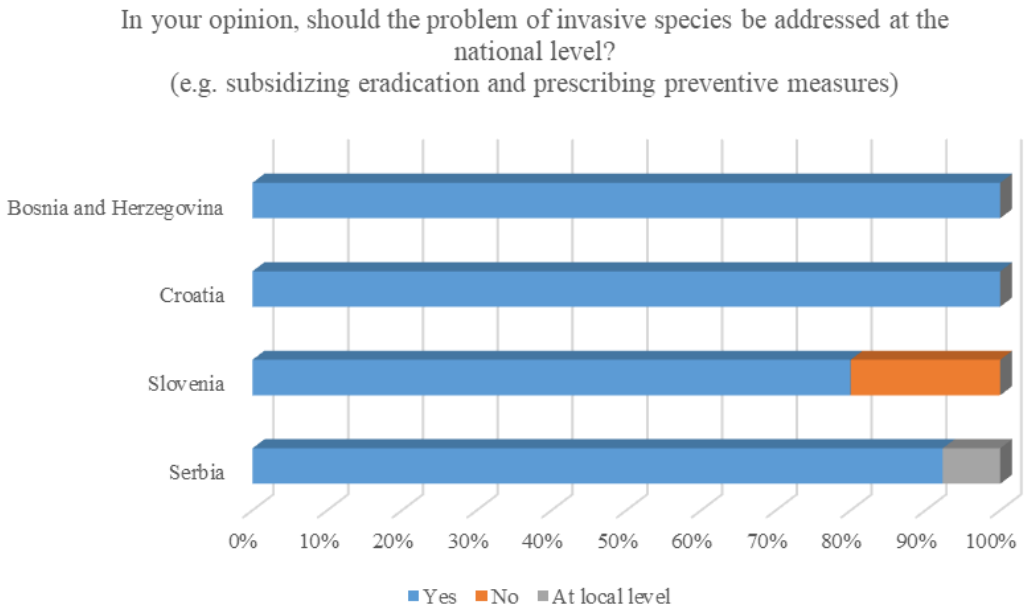

Figure 17: Should the problem of invasive species be solved at the national level?

Most respondents believe that the problem of invasive species should be addressed at the national level (Figure 17). There were slight deviations from these results in Slovenia where

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around 20% of respondents gave negative answers to this question and about 10% of respondents in Serbia stated that they addressed this problem at a local level.

14. Are you interested in learning more about invasive species, how they affect our society, economies, nature, and what actions we can take?

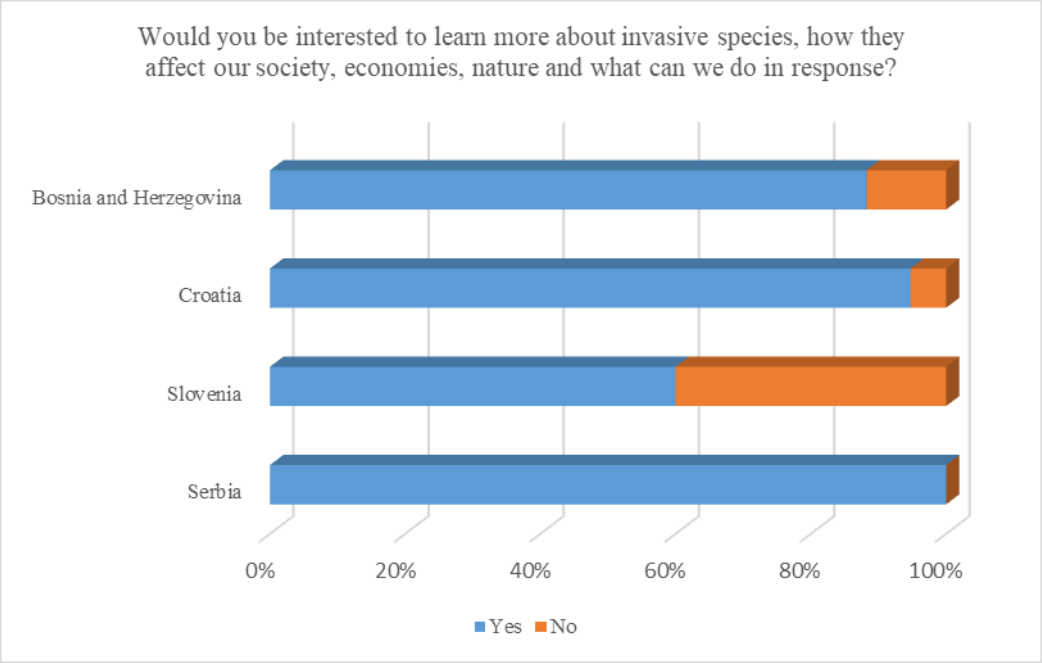

Figure 18: The expressed interest for learning and cooperation

Most respondents claimed they were interested in broadening their knowledge about invasive species and measures for controlling them. The respondents who answered negatively to this question were mostly private landowners and a few cases of local self-governments.

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Part 3 – Forest productivity study

In the first phase, the preparation of the Forest Productivity Study included a preliminary selection of the areas suitable for the analysis. Before starting fieldwork, an analysis of available data on these areas was performed, as well as their structural characteristics according to the data from forest management plans. More than 15 areas were taken into account for the selection. These areas had approximately the same characteristics so that they could be compared for further analysis. Upon the completion of preliminary assessment, the fieldwork started and the selected experimental fields were surveyed on the basis of sample circles, measuring the diameter of all trees in the range. The detailed survey method obliges measuring the heights of at least five dominant trees, and for the purposes of this analysis, ten dominant trees (diameters and heights) were measured on each surface, which were then sampled for the analysis of diameter increment. A statistically significant sample was provided for further analysis in this way. Although the terms of reference required at least four research areas, the analysis was performed on nine areas and it also included a soil analysis as it determined land productivity.

Pedological profiles of the experimental fields were prepared. The soil type was defined based on soil classification in Yugoslavia (Škorić, 1985), and WRB (2014) classificreeation.

In accordance with the terms of the Contract, the soil testing methodology was adjusted for certain physical and chemical properties.

a) Physical properties of soil were determined by the following methods:

-granulometric composition (%) by the international B-pipette method with the preparation in sodium pyrophosphate, and

-Atterberg limits were used for classifying the particles of granulometric composition.

b) Chemical properties were determined by the following methods:

-humus (%) by Tjurin, modification of Simakov 1957,

-CaCO3 (%) volume formed in Scheibler calcimeter,

- pH in H2O, electrometrically, using a combined electrode on the Radiometer pH meter

Productivity and dendrochronological research

Stands of pedunculate oak and poplar plantations, whose productivity can be analyzed based on age, composition, and other characteristics, were selected in cooperation with the Institute of Nature Conservation of the Vojvodina Province. The study included the existing

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experimental fields where different vegetation structures were determined based on the intensity of grazing, which allowed diversity in wetland habitats suitable for threatened and protected plants but also reduced presence of invasive plant species (Molnar, 2018).

The stands were selected to represent the general condition of forests in the subject area, in which areas of threatened ecological stability were dominant. In such conditions, besides the listed invasive species, other species can be invasive, too.

The figures presenting increment values show differences between the width of tree-rings and the basal area increment on the grazed land and the control area (non-grazing areas). Values are expressed in [mm] and [cm2], respectively. The figure marked "rang" shows the difference between the value of the increment in the grazed area and the control area.

Table.1 Location of analyzed trees

Type	Coordinates	
Pedunculate oak	44.97357	19.195146
Pedunculate oak	44.973662	19.195139
Pedunculate oak	44.973606	19.195206
Pedunculate oak	44.973737	19.195187
Pedunculate oak	44.97374	19.195111
Pedunculate oak	44.973832	19.195008
Pedunculate oak	44.97374	19.194958
Pedunculate oak	44.973584	19.194908
Pedunculate oak	44.973605	19.195129
Pedunculate oak	44.973459	19.195213
Pedunculate oak	44.970799	19.256343
Pedunculate oak	44.970855	19.256249
Pedunculate oak	44.970983	19.256213
Pedunculate oak	44.970819	19.256176
Pedunculate oak	44.970909	19.256503
Pedunculate oak	44.97076	19.256482
Pedunculate oak	44.970812	19.256256
Pedunculate oak	44.9707	19.256282
Pedunculate oak	44.970513	19.256342
Pedunculate oak	44.970619	19.256111
Populus	44.643505	19.981383
Populus	44.643331	19.981432
Populus	44.643304	19.981383
Populus	44.64341	19.981309
Populus	44.643487	19.981469
Populus	44.643314	19.981564
Populus	44.643424	19.981339
Populus	44.643632	19.981325
Populus	44.643571	19.981385
Populus	44.643574	19.981291
Populus	44.695449	19.9849
Populus	44.695282	19.984887
Populus	44.695339	19.984849

Type	Coordinates	
Populus	44.6871	20.023281
Populus	44.687084	20.02343
Populus	44.687121	20.02337
Populus	44.68724	20.023289
Populus	44.687281	20.023468
Populus	44.687127	20.023577
Populus	44.687183	20.023691
Populus	44.686954	20.023559
Populus	44.686898	20.023799
Pedunculate oak	44.956454	19.236762
Pedunculate oak	44.956458	19.236813
Pedunculate oak	44.956524	19.236994
Pedunculate oak	44.956552	19.236918
Pedunculate oak	44.956518	19.237049
Pedunculate oak	44.956459	19.237021
Pedunculate oak	44.956316	19.23689
Pedunculate oak	44.956424	19.236722
Pedunculate oak	44.956543	19.236651
Pedunculate oak	44.956584	19.236653
Pedunculate oak	44.927546	19.212416
Pedunculate oak	44.927752	19.212351
Pedunculate oak	44.927671	19.212435
Pedunculate oak	44.927848	19.212185
Pedunculate oak	44.927805	19.212204
Pedunculate oak	44.927636	19.212013
Pedunculate oak	44.92754	19.211992
Pedunculate oak	44.927559	19.212089
Pedunculate oak	44.927459	19.212204
Pedunculate oak	44.927443	19.212718
Pedunculate oak	44.927446	19.212716
Pedunculate oak	44.975256	19.253276
Pedunculate oak	44.975239	19.253183
Pedunculate oak	44.975219	19.253284

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Populus	44.695482	19.984812
Populus	44.695474	19.984868
Populus	44.69539	19.985021
Populus	44.695344	19.985015
Populus	44.695316	19.985116
Populus	44.695375	19.985269
Populus	44.695426	19.98535
Populus	44.687059	20.02338
Pedunculate oak	44.956647	19.19482
Pedunculate oak	44.956583	19.194918
Pedunculate oak	44.956624	19.195069
Pedunculate oak	44.956596	19.195049
Pedunculate oak	44.956411	19.194537

Pedunculate oak	44.975101	19.252967
Pedunculate oak	44.974849	19.25292
Pedunculate oak	44.97521	19.252837
Pedunculate oak	44.97529	19.253152
Pedunculate oak	44.975442	19.253119
Pedunculate oak	44.975407	19.25355
Pedunculate oak	44.975372	19.253555
Pedunculate oak	44.956688	19.194611
Pedunculate oak	44.956438	19.194287
Pedunculate oak	44.956504	19.194337
Pedunculate oak	44.956595	19.194249
Pedunculate oak	44.956741	19.194402

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Productivity and dendrochronological research of poplar plantations

A comparative study of the productivity of grazed and non-grazed areas, as well as a study on the presence of invasive species depending on the duration of grazing, was performed when the productivity of poplar plantations was assessed. For this purpose, two areas in which grazing was performed at different times were selected as well as a control surface area where there was no influence of the considered anthropogenic factors (Figure 1).

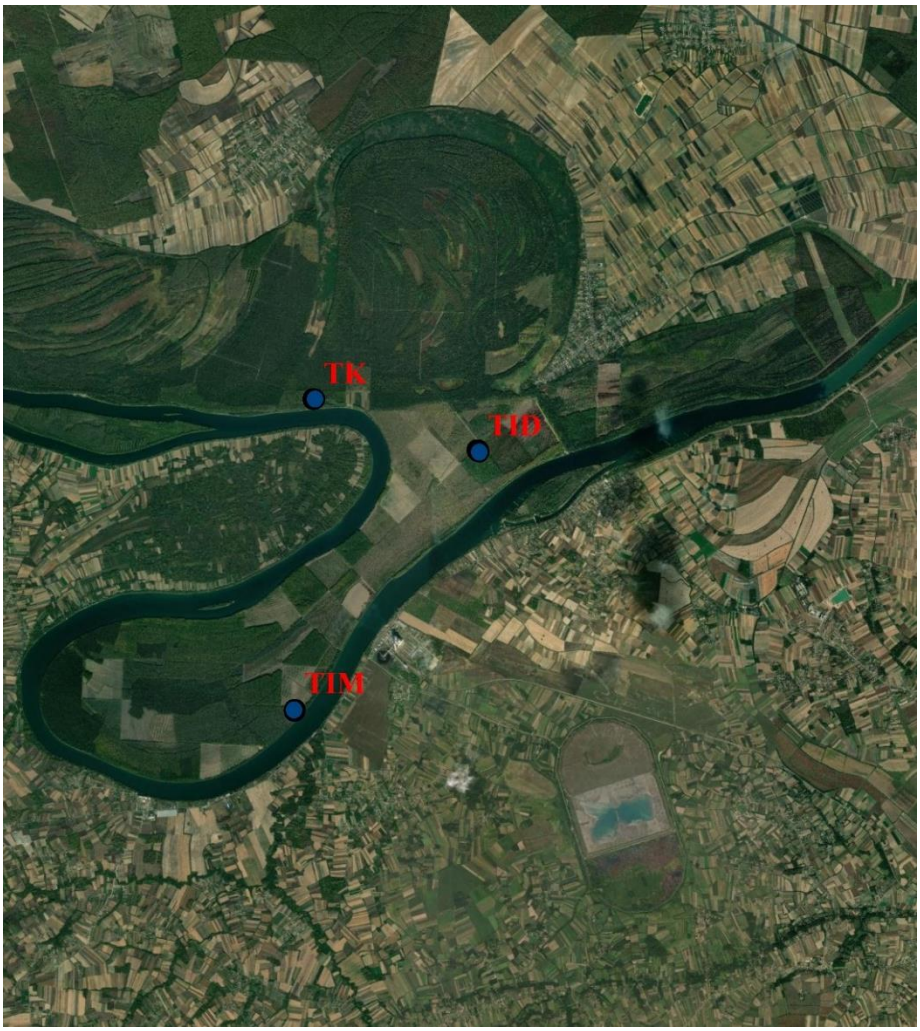

Figure 1. The location of experimental fields of the poplar plantations: TK – the control surface area within a poplar plantation; TIM and TID poplar plantation on grazing land

According to the history of use of experimental fields, confirmed by forestry experts, forest rangers and local cattle breeders, the number of domestic cattle in the grazed experimental areas was large until 2004, and the number of Podolian cattle that remained there until 2013/2014 was smaller. After that, the use and restoration of poplar plantations forced the cattle out of the forest. Forestry experts claim that a small number of livestock were occasionally reported in the control area, which is confirmed by the greater height and density of understory plants.

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Habitat conditions in the poplar plantations are determined and presented in the text below.

P32KKT/20

Position according to the map, TIM symbol
Terrain: flat
Vegetation: a poplar plantation
Groundwater depth: not determined at 140 cm, which was the depth to which the profile was dug
Parent substrate: alluvial deposit
Soil type: Humofluvisol
Morphology: A – C
A (0 - 10 cm): brown loam, no structure, low content of humus, with the main mass of the root system at this depth, physiologically active, the horizon gradually passes into
C (10 -100 cm): light brown sandy loam, physiologically active

P34KKT/20

Position according to the map, TID
Terrain: flat
Vegetation: a poplar plantation
Groundwater depth: not determined at 140 cm, which was the depth to which the profile was dug
Parent substrate: loess-derived alluvium
Soil type: Meadow black soil on loess-derived alluvium deposit
Morphology: A – C
Aa (0 - 83 cm): brown loam, no structure, low content of humus, with the main mass of the root system at this depth, physiologically active, the horizon gradually passes into
C (83 -140 cm): yellow loess-derived alluvial deposits

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P35KKT/20
Position according to the map, TK
Terrain: flat
Vegetation: a poplar plantation
Groundwater depth: not determined at 150 cm, which was the depth to which the profile was dug
Parent substrate: alluvial deposit
Soil type: Humofluvisol
Morphology: A – C
A (0 - 13 cm): light brown sandy loam, no structure, low content of humus, with the main mass of the root system at this depth, physiologically active, the horizon gradually passes into
C (13 -100 cm): light brown sandy loam

The following soil types were recorded in the investigated poplar plantations: humofluvisol and gleyed chernozem (meadow black soil). Humofluvisol was formed on alluvial deposits, and gleyed chernozem was formed on the parent substrate of loess-derived alluvium. A common characteristic of the granulometric composition is that the fraction of total sand is predominant in humofluvisol compared to the fraction of silt + clay, and in the chernozem soil it is completely different (the fraction of silt + clay is predominant). The granulometric composition also determines soil composition, which was sandy loam in humofluvisol (total sand content from 56.5 to 61.2%), and clay loam in gleyed chernozem (total sand content of 36.2%). The content of humus, as an indicator of the accumulation of organic matter, indicates that the humus content in all investigated soil types was average (2.46 to 4.96). The carbonate content (CaCO3) in the humus-accumulative horizon was low (ranging from 5.60 to 8.41%), and the reaction of the soil solution (pH value from 7.52 to 7.73) was basic. The presented properties indicate that the grazing area and the control surface area on humofluvisol soil have similar production characteristics and that a comparative study can be performed for these three areas.

The diameter structure in the control surface area indicates the presence of invasive species *F. pennsylvanica* and *Acer negundo* over the taxon boundary, that is, it is present in the total tree trunk mass.

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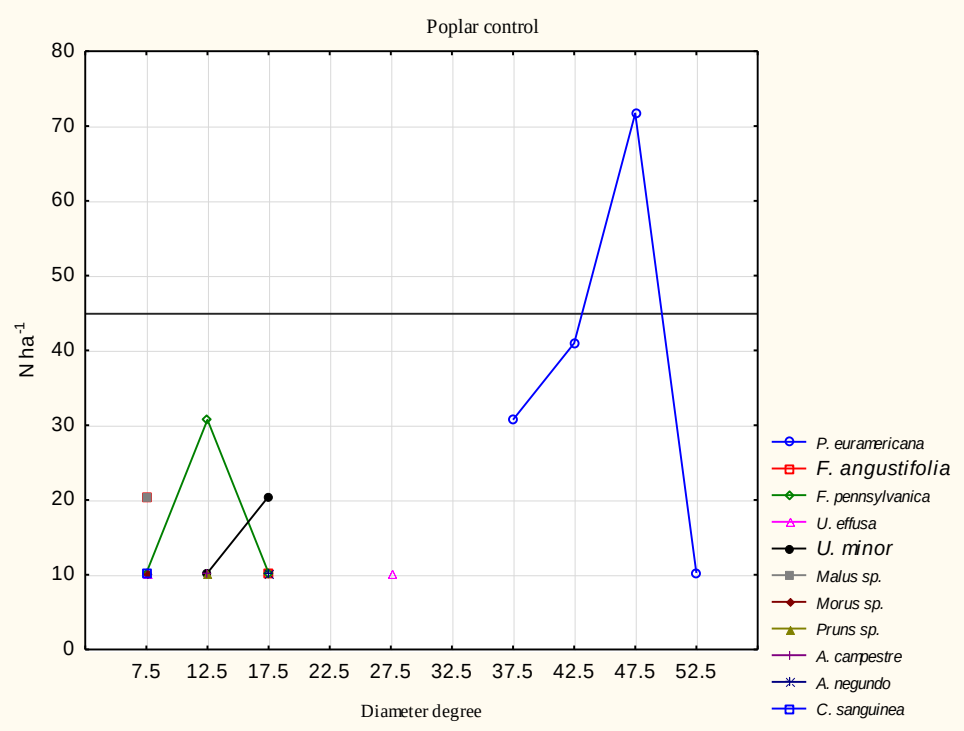

Figure 2. Diameter structure in the control area

Concerning the above mentioned, only the species of Acer negundo was recorded in the tree layer when measuring was performed in the areas where grazing was above the taxon boundaries.

In the bush layer, the control area had a 50% coverage with the highest percentage of the false indigo bush (A. fruticosa) amounting to 20%, boxelder maple (A. negundo 20%), common dogwood (C. sanguinea 5%), and field maple (A. campestre), European crab apple (Malus sylvetris), white mulberry (Morus alba) and European white elm (U. laevis). The height of the false indigo bush was up to 3 meters.

The cover of the bush layer on grazing land areas was 60% and 70%, where a large number of species was recorded in the first layer: the false indigo bush (A. fruticosa 20%), field elm (U. minor 10%), common dogwood (C. sanguinea 20%), as well as narrow-leafed ash (F. angustifolia 5%), and false indigo bush were recorded in the second layer in groups of up to 2.5 meters in hight, and the common dogwood was recorded as an individual species. The presence of the false indigo bush in all experimental fields of poplar plantations is explained by the fact that grazing was banned over the last ten years, which resulted in spontaneous overgrowth.

The difference in bush layers between the areas that were under grazing for a long time and non-grazing areas is in height and density, especially with the false indigo bush and boxelder maple which are larger in experimental fields in non-grazing areas.

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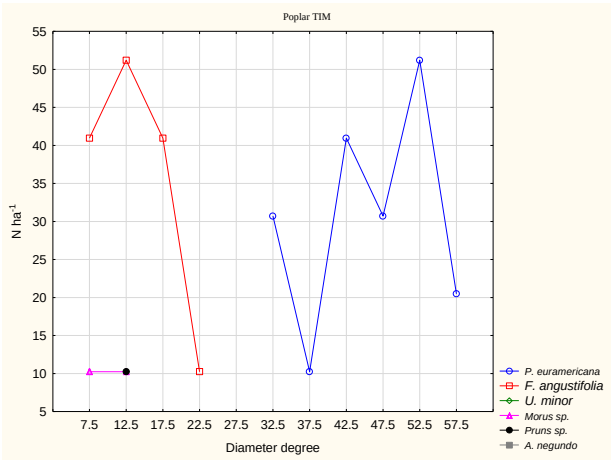

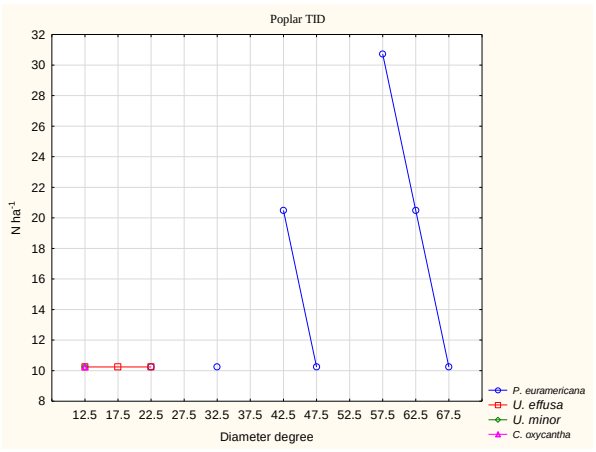

Figures 3a and 3b: Diameter structure in grazing areas

The breast height diameter (D1,3) of dominant poplar trees in the experimental fields was smaller in the control surface area compared to the grazing areas. In addition, the values of standard deviation and the coefficient of variation were lower in the control area compared to the grazing land.

Table 2. The diameter of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Poplar plantation on grazing land	54.3	40.0	66.0	7.45	13.73
Control surface area	47.0	41.0	52.0	3.85	8.19
Poplar plantation on grazing land	54.0	44.5	70.0	7.49	13.89

The height of dominant trees was more or less equal, that is, the values of standard deviation and coefficient of variation were lower.

Table 3. Height of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Poplar plantation on grazing land	36.1	31.5	42.0	3.31	9.18
Control area	36.4	34.0	38.4	1.44	3.97
Poplar plantation on grazing land	37.8	36.0	40.0	1.29	3.40

The value of standard deviation and coefficient of variation was the highest for crown length in the control surface area in experimental fields.

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Table 4. Crown length of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Poplar plantation on grazing land	13.6	11.9	17.0	1.57	11.53
Control surface area	13.6	10.1	15.9	2.14	15.69
Poplar plantation on grazing land	15.4	11.9	18.9	2.11	13.73

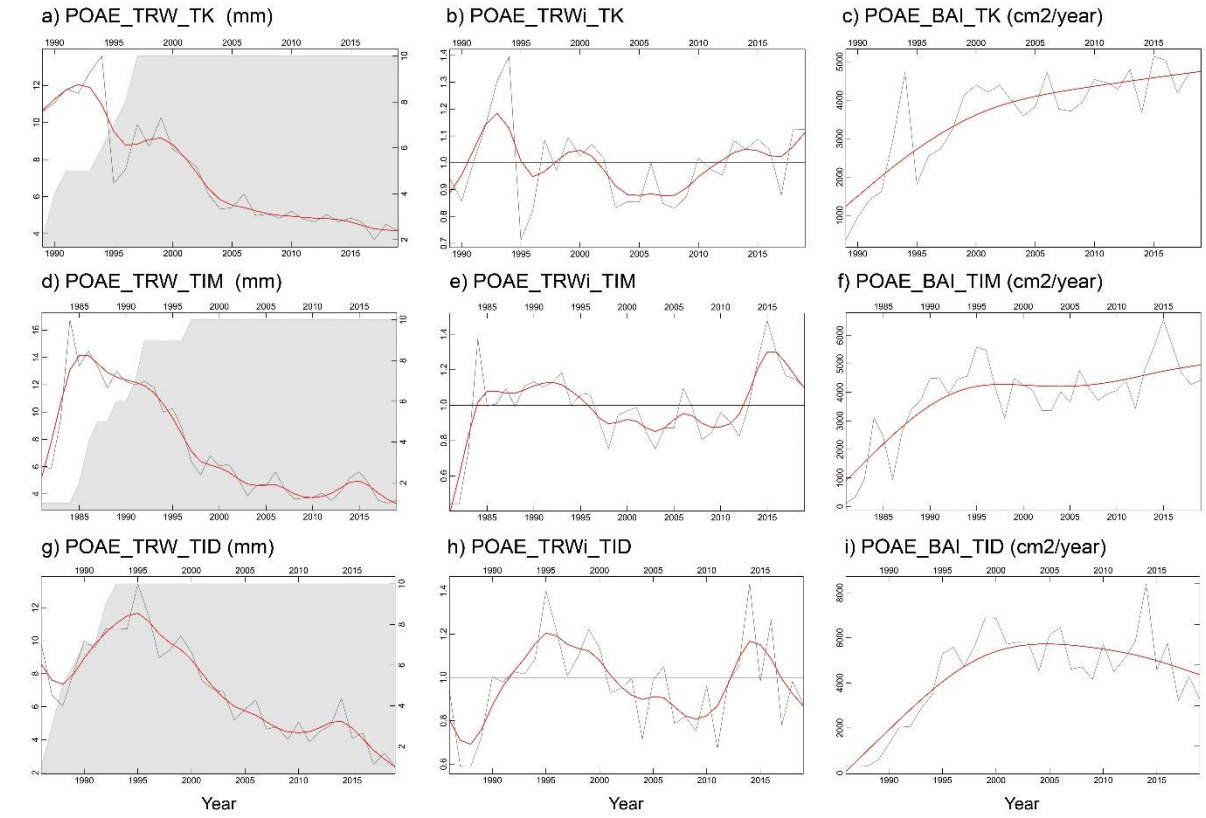

Figure 4: Ring widths (a,d,g), detrended ring width (b,e, h), and basal area increment (c,f, i) of Euroamerican poplar on grazing land (d-i) and non-grazing land (a-c).

The width of the rings in the control area ranged from 4.23 to 14.63 mm in the previous period, and the width of rings of trees on grazing land was from 3.82 to 14.40 mm, that is, from 2.97 to 13.53 mm. The differences in tree-ring width, in the same period, on the TID grazing land and TK control area can be explained by different stages of development of these two stands, because the stand on the grazing land has experienced an increase in diameter increment.

The basal area increment was higher or the same on the grazing land during most of the observation period. The average value of the tree-ring width during the development of stands in experimental fields and the control surface area indicates a higher average value of diameter increment in the experimental area, on grazing land (Figure 4), which means that there is a positive correlation between diameter increment and grazing at the same planting

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density and under similar habitat conditions.

The figure shows that the values of basal area increment on grazing land and the control area were similar after grazing was completely banned.

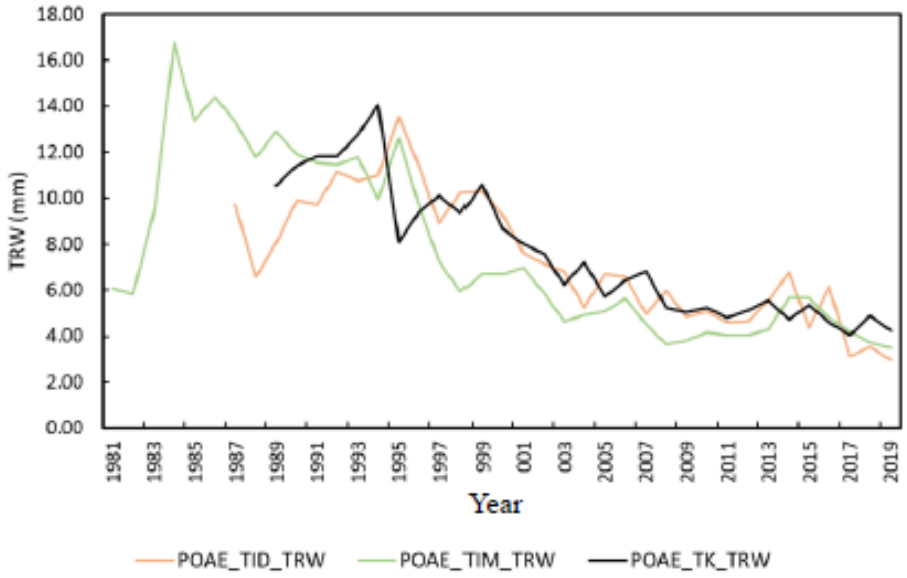

Figure 5: Tree-ring width (TRW) of the Euroamerican poplar at three sites.

The basal area increment indicates slightly higher values of the tree-ring width on grazing land (TID and TIM) compared to the control area (TK).

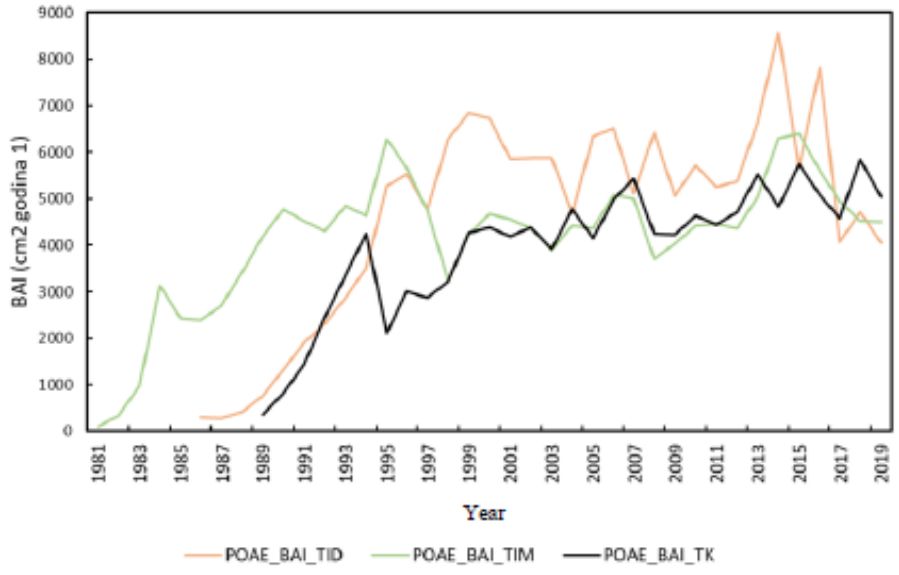

Figure 6. Basal area increment (BAI) of the Euroamerican poplar at three sites.

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Productivity and dendrochronological research on pedunculate oak stands

All forest management units in the area of Ravni Srem that are under the authority of Forest Offices (hereinafter: FO) Morović and Višnjićevo have been checked in compliance with the criteria set in the Contract so that the experimental fields in the forest of the pedunculate oak can be selected. From a list of over 40 potential stands, 6 experimental fields were chosen where sampling of pedunculate oak trees and soil was performed in consultations with the client of the study.

The history of land use was determined by consulting the forestry experts and district foresters from the area of FO Morović and FO Višnjićevo. The subject experimental fields are included in standard forest management, which involves the application of preservation and protection measures. People have been engaged in traditional extensive pig farming on the experimental fields in grazing areas for more than 50 years, with an occasional increase or decrease in the number of pigs and cattle, which was confirmed by the owners.

The habitat conditions in pedunculate oak stands are defined in the text below. The location of the experimental fields is presented in Figure 7.

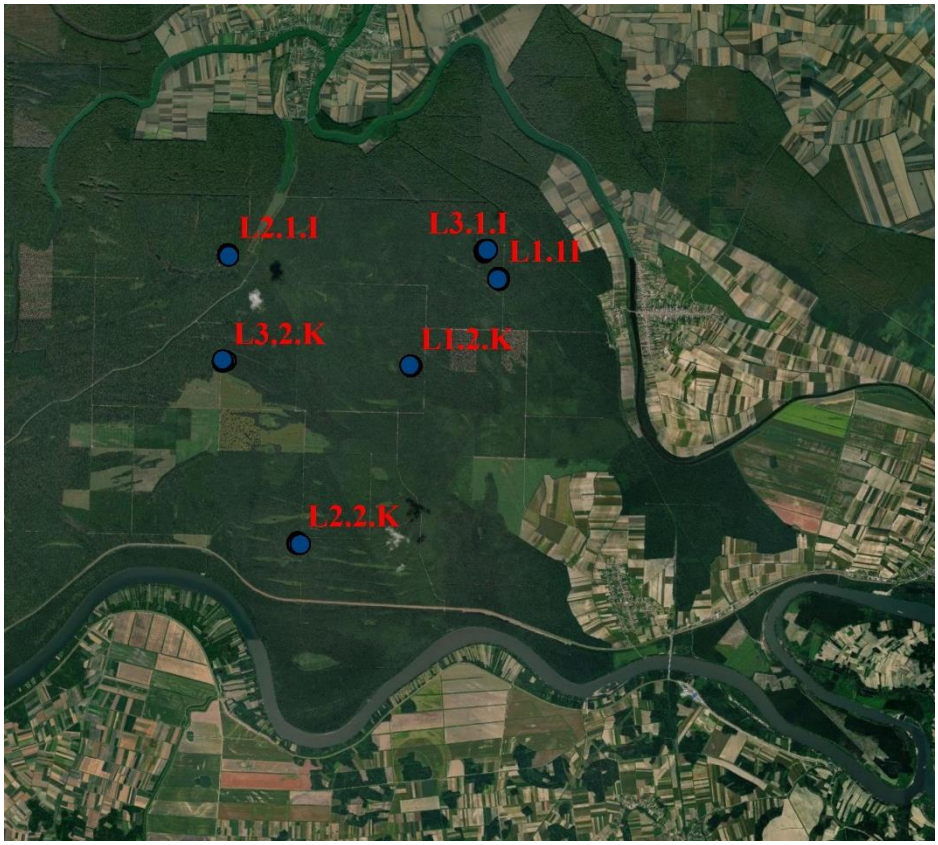

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Figure 7: Location of the experimental fields of the pedunculate oak L1.1.I., L2.1.1I, L331.I – grazing areas, L1.2.K, L2.2.K and l3.2.K-control areas

P1ST/20
Position according to the map
Terrain: flat
Vegetation: a pedunculate oak stand
Groundwater depth: not determined at 140 cm, the depth up to which the profile was dug
Parent substrate: loess, with thin layers of alluvial deposits
Soil type: gleyed chernozem – meadow black soil
Morphology: A – C
Aa (0 - 56 cm): gray black clay loam, without structure, humus content, with the root system of the plants at this depth, physiologically active, the horizon gradually passes into
C (56-130 cm): yellow loess without signs of physiological activity, with a concentration of carbonate and high $CaCO_3$ content

P2ST/20
Position according to the map
Terrain: micro-elevation
Vegetation: a pedunculate oak stand
Groundwater depth: not determined at 130 cm, the depth up to which the profile was dug
Parent substrate: loess
Soil type: gleyed chernozem – meadow black soil
Morphology: A – ACG -C
Aa (0 - 70 cm): brown loam, with the main mass of the root system at this depth, humus content, no structure, gradually passing into
ACG (70-83 cm): light yellow loam, physiologically active, gradually passes into
C (83 -130 cm and deeper): light yellow silt loam

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P3ST/20
Position according to the map
Terrain: micro-elevation
Vegetation: pedunculate oak stand
Groundwater depth: not determined at 130 cm, the depth up to which the profile was dug
Parent substrate: loess, with thin layers of alluvial deposits
Soil type: gleyed chernozem – meadow black soil
Morphology: A – C
Aa (0 - 55 cm): brown clay loam, with the main mass of the root system at this depth, humus content, no structure, the horizon gradually passes into
C (55 -130 cm): yellow loess, not physiologically active to 100 cm

P4ST/20
Position according to the map
Terrain: flat
Vegetation: a pedunculate oak stand, the most productive type
Groundwater depth: not determined at 170 cm, the depth up to which the profile was dug Parent substrate: loess
Soil type: gleyed chernozem – meadow black soil
Morphology: A – C - CG
A (0 - 89 cm): brown loam, with main mass of the root system at this depth, humus content, no structure, the horizon gradually passes into
C (89 -123 cm): yellow loess, physiologically active to 100 cm, gradually passes into
CG(123-130 cm): loess with wetting marks

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P5ST/20
Position according to the map
Terrain: flat
Vegetation: a pedunculate oak stand
Groundwater depth: not determined at 170 cm, the depth up to which the profile was dug
Parent substrate: loess
Soil type: gleyed chernozem – meadow black soil Morphology: A – C
A_a (0 - 63 cm): brown loam, with main mass of the root system at this depth, humus content, no structure, the horizon abruptly passes into
C (63 -110 cm and deeper): yellow loess, not physiologically active

The depth of horizon marked with accumulated humus on selected soil ranged from 55 to 89 cm. According to the granulometric composition, this humus-accumulative horizon was characterized by the dominance of soil + clay fractions (the content ranged from 58.5 to 66.1 %), which was then defined as loam or clay loam soil based on texture. The CaCO3 content in the humus-accumulative horizon was low (from 0.83 to 1.67%). According to the content of humus, the soil is classified as being poorly to moderately provided with humus (0.91 to 4.39%), and as for soil reaction, it is acidic (pH value ranged from 5.93 to 6.72).

Comparative research 1

Production characteristics and dendrochronological studies

The number of trees in the comparative research 1 indicates that the following tree species were registered in both areas over the taxon boundaries: the pedunculate oak (Q. robur), hornbeam (C. betulus) and hawthorn (C. oxyacantha). In comparative studies, the following species that cross the taxon boundaries can be found on the grazing land: the tatar maple (A. tataricum), European crab apple (Malus sylvestris), European wild pear (Pyrus pyraster), that is, narrow-leafed ash (F. Angustifolia), European white elm (U. laevis), field maple (A. campestre), hawthorn (C. oxyacantha) and field elm (U. minor) in the control surface area. The shrub layer on the grazing land was 65 % with the highest percentage of hawthorn (C. oxyacantha 45%), common dogwood (C. sanguinea 5%), Tatar maple (A. tataricum 5%), field maple (A. campestre 5%), hornbeam (C. betulus 5%) and field elm (U. minor). The cover of the shrub layer in the control area was 95% with the highest percentage of hawthorn (C. oxyacantha 80%), hornbeam (C. betulus 5%), field maple (A. campestre 5%) and field elm (U. minor 5%) as well as Tatar maple (A. tataricum), rose (Rosa sp.), wild privet (L. vulgare), European wild pear (Pyrus pyraster) and guelder rose (Viburnum opulus).

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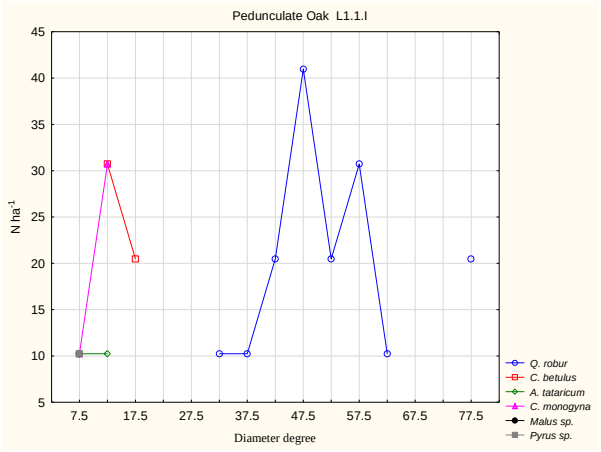

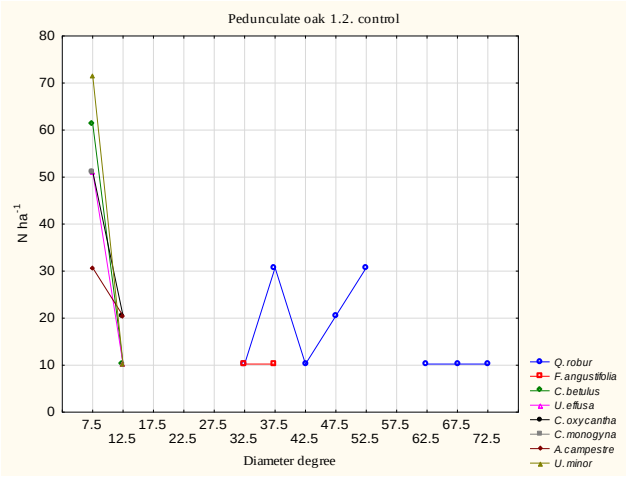

Figures 8a and 8b: Diameter structure

The mean value of the diameter of dominant trees was higher on the grazing land compared to the one of the trees in the control area. Higher minimum values and lower maximum values were recorded in the control area, that is, there were minor differences between the standard deviation and coefficient of variation.

Table 5. Diameter of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of Pedunculate oak on grazing land L1.1.I	62.1	47.0	76.00	9.34	15.04
Control area	57.8	48.0	72.00	8.30	14.37

The mean value of the dominant tree height was slightly higher in the control area compared to the grazing area. Higher maximum and minimum values were recorded in the control surface area, that is, there were minor differences between the standard deviation and coefficient of variation.

Table 6. Height of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of Pedunculate oak on grazing land L1.1.I	33.0	28.5	34.5	1.87	5.65
Control area	33.4	31.0	36.2	1.58	4.72

The mean value of the crown length of dominant trees was higher on the grazing land compared to the control surface area. Higher minimum and maximum values were recorded in the control area, that is, there were minor differences between the standard deviation and coefficient of variation.

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Table 7. Crown length of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of Pedunculate oak on grazing land L1.1.I	13.6	11.0	16.4	1.94	14.31
Control area	10.6	7.0	14.5	3.02	28.54

The average width of the tree rings in the grazing area ranged from 1.05 to 3.56 mm, and the width of the rings in the control area was from 0.91 to 2.92 mm.

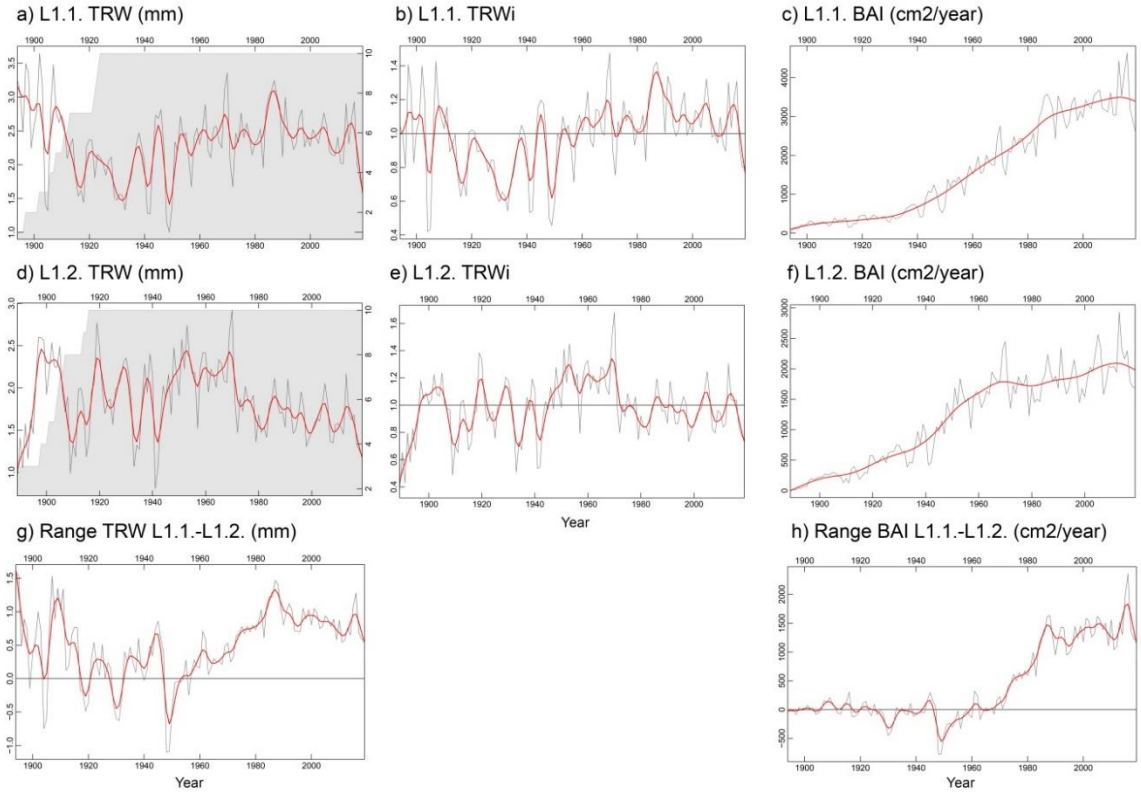

Figure 9: Sites of the pedunculate oak with grazing (L 1.1.) and where there was no grazing (L 1.2.):the rings' width (a,d), detrended ring width (b,e), basal area increment (c,f) and the difference between the tree-ring width (g) and basal area increment (h) at grazing sites and sites where there was no grazing.

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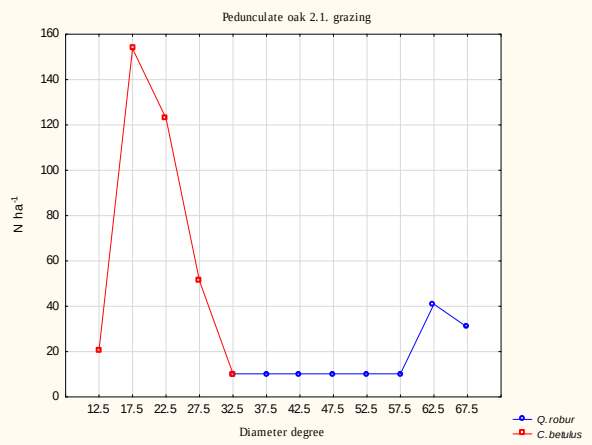
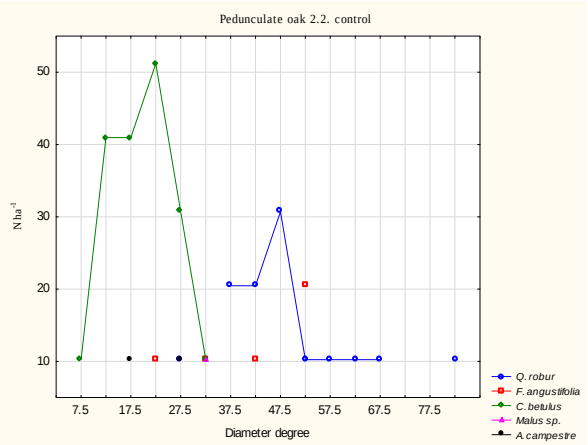
Comparative research 2

Production characteristics and dendrochronological studies

The pedunculate oak (Q. robur) and hornbeam (C. betulus) that exceeded taxonomic boundaries were registered in the comparative research 2. In addition to these two species, there were other species above the taxonomic boundaries in the control area and they were included in the scope of survey as marginal trees: the field maple (A. campestre), narrow-leafed ash and crab apple. The hawthorn (C. oxyacantha) was registered on the grazing land in the shrub layer with covering 5% of the area, and the cover of the shrub layers in the control area was 50% with the highest percentage of the hawthorn (C. oxyacantha 30%), field maple (A. campestre 10%), common dogwood (C. sanguinea 5%), hornbeam (C. betulus 5%) and field elm (U. minor).





Figures 10a and 10b: Diameter structure

A mean value of the diameter of dominant trees was higher on the grazing land compared to the one of the trees in the control area. Lower minimum values and higher maximum values were recorded in the control surface area, that is, there were considerable differences between the standard deviation and coefficient of variation.

Table 8. Diameter of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of Pedunculate oak on grazing land L2.1.I	66.9	57.0	80.00	6.72	10.05
Control area	61.9	51.0	83.00	10.01	16.16

The mean value of the dominant trees height was higher in the control area compared to the grazing area. Higher maximum and minimum values were recorded in the control area, that is, there were minor differences between the standard deviation and coefficient of variation.

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Table 9. Height of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of Pedunculate oak on grazing land L2.1.I	34.9	32.0	37.3	1.82	5.22
Control area	35.7	33.1	38.5	1.77	4.97

The mean value of the crown length of dominant trees was higher on the grazing land compared to the control surface area. Lower minimum and higher maximum values were recorded in the control surface area, that is, there were significant differences between the standard deviation and coefficient of variation.

Table 10. Crown length of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of Pedunculate oak on grazing land L2.1.I	15.8	13.6	18.7	1.42	9.03
Control area	15.1	11.9	20.0	2.75	18.19

The average width of the tree rings in the grazing area was from 1.01 to 4.38 mm, and the width of the rings in the control surface area was from 1.28 to 4.18 mm.

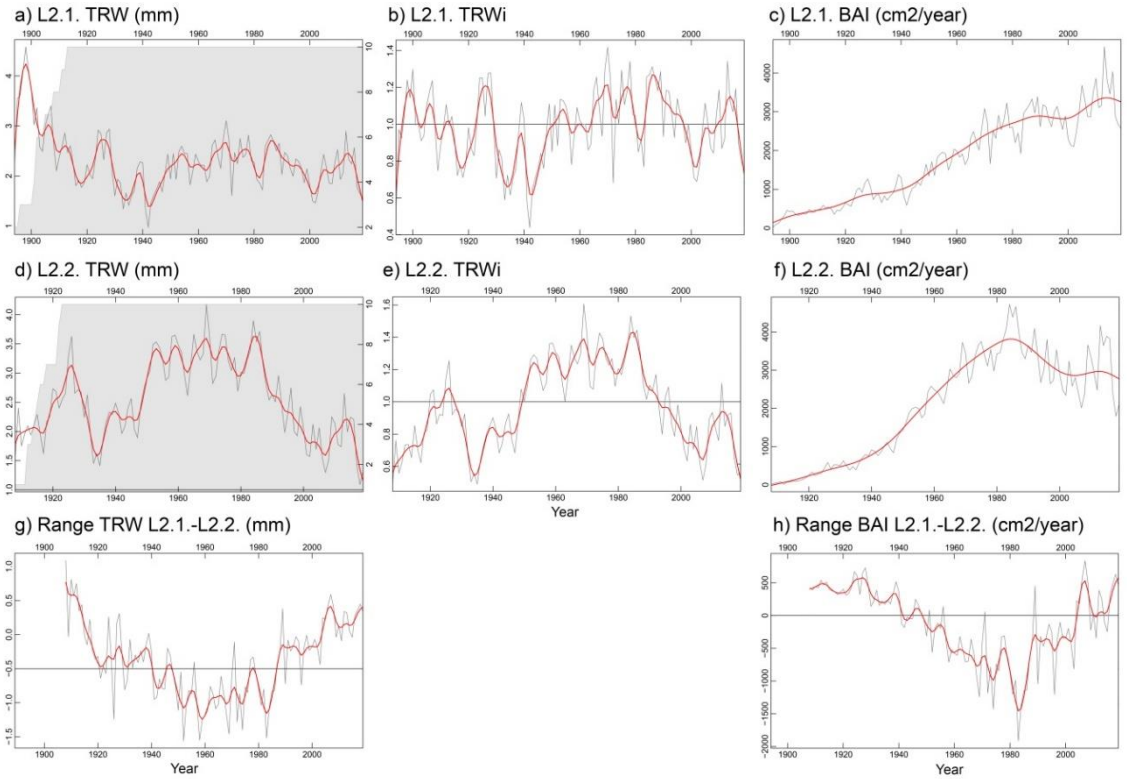

Figure 11: The sites of the pedunculate oak with grazing (L 2.1.) and where there was no grazing (L 2.2.): the ring width (a,d), detrended ring width (b,e), basal area increment (c,f) and the difference between tree-ring width (g) and basal area increment (h) at grazing sites and sites where there was no grazing.

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Comparative research 3

Production characteristics and dendrochronological studies

The pedunculate oak (Q. robur), narrow-leafed ash (F. angustifolia) and hornbeam (C. betulus) with exceeded taxonomic boundaries were registered in comparative research 3. In addition to these species, other species with exceeded taxonomic boundaries were registered as well: the field maple (A. campestre), European white elm (U. laevis), field elm (U. minor), and hawthorn (C. oxyacantha).

The cover of the shrub layer in the grazing area was 10%, and the species registered were the common hawthorn (C. monogyna 5%) and hornbeam (C. betulus 5%), and the coverage of the shrub layers in the control surface area was 50% with the highest percentage of the hornbeam (C. betulus) 30%, hawthorn (C. oxyacantha) 15% and sporadic occurrence of field maple (A. campestre) and common dogwood (C. sanguinea).

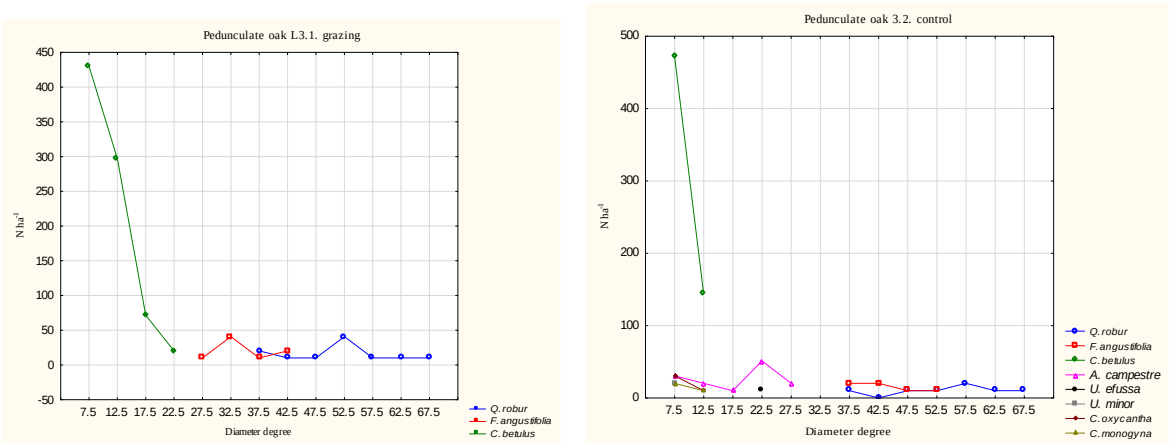

Figure 12a and 12 b: Diameter structure

A mean value of the diameter of dominant trees was higher on the grazing land compared to the one of the trees in the control surface area. Lower maximum values were recorded in the control surface area, that is, there were minor differences between the standard deviation and coefficient of variation.

Table 11. Diameter of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of the pedunculate oak with grazing L3.1.I	64.1	52.0	74.00	7.46	11.65
Control area	57.2	52.0	67.00	4.32	7.54

The mean value of the dominant tree height was higher in the control area compared to the grazing area. Higher maximum values were recorded in the control area, that is, there were significant differences between the standard deviation and coefficient of variation.

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Table 12. Height of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of the pedunculate oak with grazing L3.1.I	32.1	29.9	35.2	1.73	5.38
Control area	33.3	29.9	37.0	1.87	5.62

The mean value of the crown length of dominant trees was higher in the control area compared to the grazing area. Lower minimum and higher maximum values were recorded in the control area, that is, there were significant differences between the standard deviation and coefficient of variation.

Table 13. Crown length of dominant trees

	Mean value	Minimum value	Maximum value	Standard deviation	Coefficient of variation
Stands of the pedunculate oak with grazing L3.1.I	13.7	11.0	16.8	1.88	13.74
Control area	15.0	8.8	20.0	3.32	22.10

The average width of the rings of the trees in the grazing area was from 1.37 to 4.46 mm, and the width of the rings in the control area was from 1.29 to 3.93 mm.

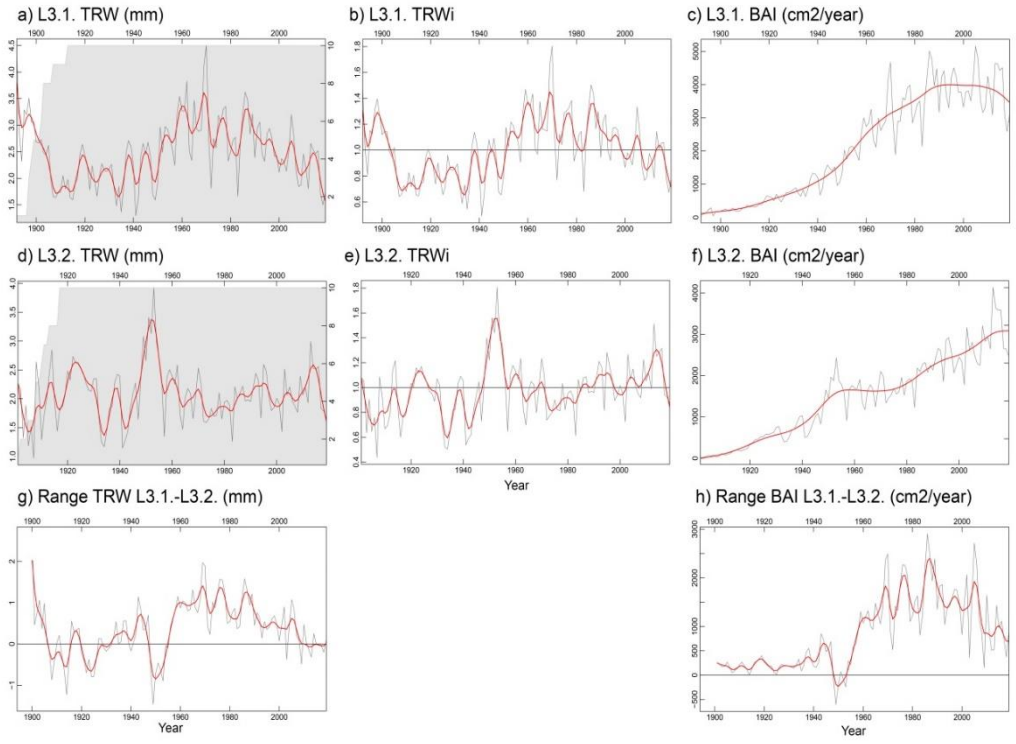

Figure 13: The sites of the pedunculate oak with grazing (L 2.1.) and without grazing (L 2.2.): the rings' width (a,d), detrended ring width (b,e), basal area increment (c,f) and the difference between tree-ring width (g) and basal area increment (h) at grazing sites and sites where there was no grazing.

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The difference between the tree-ring width and basal area increment, i.e. the values that prevail, were determined within the framework of dendrochronological research. The results obtained by the analysis of the difference between the width of the rings and the increment of the basal area indicate that the difference has increased over the last 60 years (positive values in the figure 14) in the comparative studies 1 and 3 in grazing areas (L1.1.I and L.3.1I), and in the comparative study 2 (L2.2.I) it has been slightly higher on the grazing land over the last 15 years. The most probable explanation for the deviation of the results in the comparative study 2 is the physiologically active depth of the profile, however, soil coherence properties and water properties need to be analyzed for a more detailed explanation.

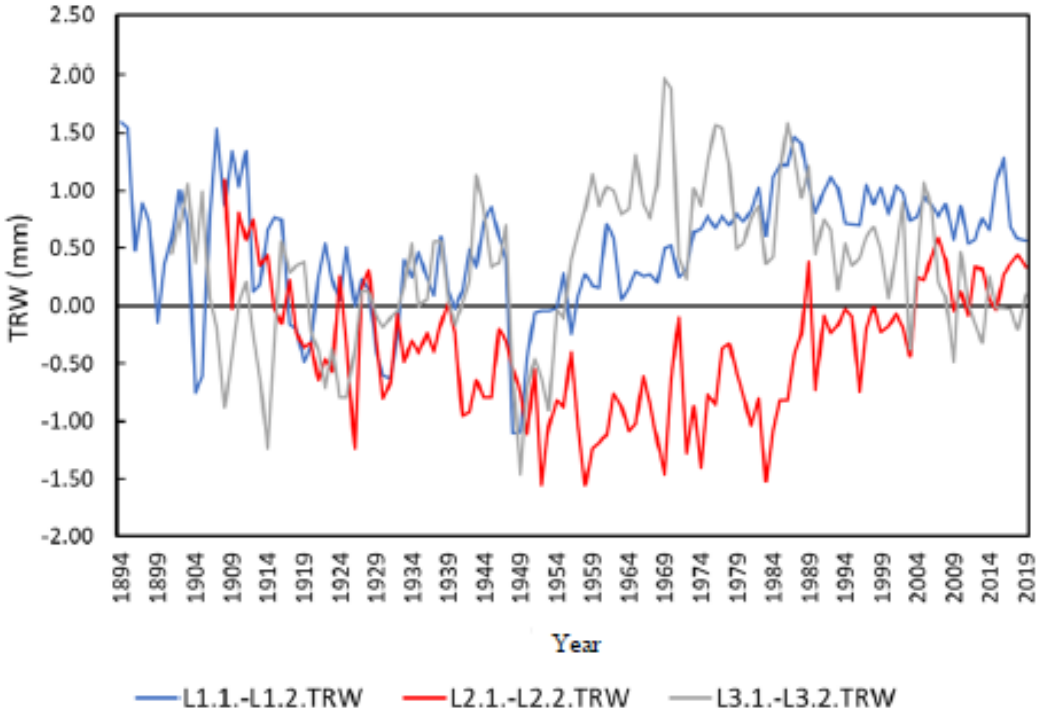

Figure 14. Difference in the tree-ring width (TRW; mm) of the pedunculate oak at grazing sites and at non-grazing sites, observed for the same type of forest.

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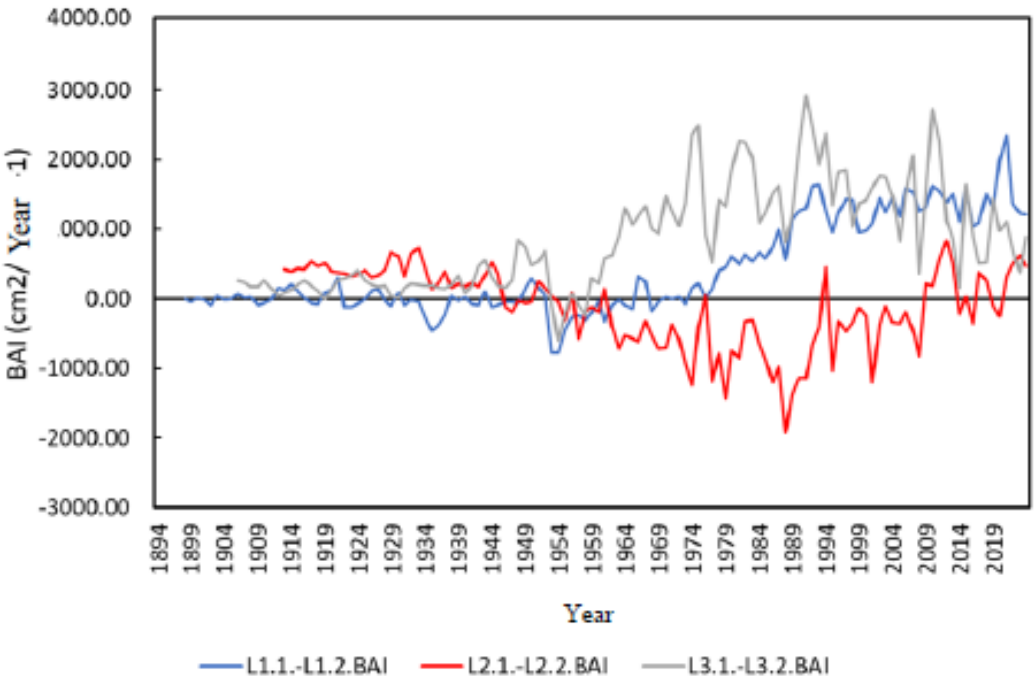

Figure 15: The difference in basal area increment (BAI; cm2 year-1) of the pedunculate oak at grazing sites and non-grazing sites, observed for the same type of forest.

Overview of main results

Part: Land use change maps

- The key changes in land use and land cover since XIX century have been reflected in a decrease in areas covered in grass and marshland and their transformation into forests and poplar plantations, that is, a transitional type of woody vegetation.

- The changes in the upper part of the Sava River Basin (Una and Ljubljansko barje) are minor but there has been a decrease in areas covered in grass.

- After analyzing the linear elements of the landscape (canals, riverbanks) and infrastructure (roads, railways), it was determined that both categories ran through natural grass areas and rural areas in the XIX century and through forests and forest plantations in the XX century. The analysis shows a decrease in the total length of roads and canals in protected areas compared to the XIX century.

Part: Review of protected land use practices

- Spreading of invasive species is happening mostly at local level, indicating necessity of habitat management in the protected areas and other ecologically important sites threatened by the invasive species.

- There is an equal number of users who have and who still do not have land/property management plans, which opens up the possibility for upgrading the existing planning practice.

- The most common invasive species that users have reported having caused harm are false indigo bush and common ragweed, which indicates the fact that they are widely spread and cause considerable economic damage (forestry, agriculture, people's health). The species

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that are not harmful to forestry and agriculture are not considered invasive.

The interest of users in learning more about invasive species is encouraging for the development of intersectoral collaboration and joint education programs for the control of invasive species.

Part: Forest productivity study

- The comparative analysis of the basal area increment in similar habitats confirmed by soil sampling showed that the basal area increment was higher in the poplar plantations on the land of similar type with the approximately same production characteristics. A slightly positive to neutral trend was reported in the years when there was no grazing.

- The shrub layer with invasive species was reduced on the land where cattle graze in agro-forestry areas (the poplar plantations). The occurrence of smaller false indigo bush, boxelder maple and green ash with an understory stand structure can be explained by the history of use, according to which it was determined that cattle breeding was forbidden ten years ago.

- The differences in basal area increments are greater in pedunculate oak stands with traditional grazing of pigs compared to the control areas on the same type of land of the approximately similar characteristics. The resulting differences can be examined closely by defining other water-air properties (water capacity, aeration).

- A higher basal area increment was reported in the control area 2 of the pedunculate oak for a long period of time compared to the grazing area. The changes in the trend, from declining to the increasing one in favor of the grazing area, were recorded 30 years ago. The increment of the tree basal area on the grazing land has been slightly higher compared to the control surface area for the last 15 years, despite the higher production potential of land in the control area.

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Sources of data

Molnár Zs., Demeter, L., Kiš, A., Szabados K., Marinkov, J., Babai, D. , Ulicsni, V., Biró, M. (2018): Traditional pig grazing in the Bosut forest (Serbia) - ethnoecological and conservational perspectives. 7BBC, Novi Sad, 2018. September 10-14. (oral presentation)

Szabados, K., Kiš, A.., Baković, D., Galambos, L., Vukelić, M. (2011): Land use practices and plant invasions in the Sava River floodplain in Serbia. 11th International Conference on the Ecology and Management of Alien Plant Invasions (XI EMAPI)., 30. August – 03. September 2011. Szombathely, Hungary, Abstracts, p. 150.

Schwarz, U. (2016): Sava White Book. The River Sava: Threats and Restoration Potential. Radolfzell/Wien: EuroNatur/Riverwatch.

Škorić, A., Filipovski, G., Ćirić, M (1985).: Klasifikacija zemljišta Jugoslavije (in Serbian). Akademija nauka i umjetnosti Bosne i Hercegovine, Sarajevo. p. 1-66

The Questionnaire: 54 answers from land users in the protected areas in the Sava River Basin, from the territory of Republic of Slovenia, Republic of Croatia, Bosnia and Herzegovina and Republic of Serbia.

Dendrochronology (based on tree coring samples): Determining the growth of the main tree species in the experimental fields in the pedunculate oak stands and poplar plantations

Zingstra, H.L., Kis, A., Ribaric, A., Ilijas, I., Jeremic, J., Predic, T. (2010): Protection of Biodiversity of the Sava River Basin Floodplains: The relevance of farming and farmland for maintaining the landscape and biodiversity of the Sava floodplains. Wageningen University Holland. https://www.wageningenur.nl/en/Publication-details.htm?publicationId=publication-way-343032313931.

Annexes

Annex 1 – **Questionnaire** for land users in the Sava River Basin

Your country:

1.Slovenia

2. Bosnia and Herzegovina

3. Croatia

4. Serbia

5. English version

1. Your role:
   a) Government body
   b) Local or regional government / Municipality
   c) PE (Public company) or other natural resource manager (e.g. game manager)
   d) Private land owner
   e) other

1a Sector/Profession:

   a) Agriculture
   b) Forestry (including game management)
   c) Water management
   d) other

2. Have you come across the term of Invasive Alien Species by now, personally or professionally
   a) Yes
   b) No

2a If the previous answer was confirmative, how?

   a) In a protected area
   b) In a forest
   c) On a floodplain
   d) As weed on fields
   e) Other

3. During the time you have managed crops, forest, meadows, fish ponds or other goods, have you experienced income loss from the introduced species? (e.g. weeds, pests, invasive fishes, aggressive wooden or herbaceous species)
   a) Yes
   b) No
   c) I don't know

3a If "yes", from which species? (please list domestic names)

4. Do you check your land for the presence of invasive species?
   a) Yes
   b) No
   c) No recognition of invasive species

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4a. In case of experienced damage from the invasive species, has your organization/farm developed plans and/or techniques to minimize the damage? (e.g. eradication)

a) Yes
b) No
c) Not applicable
d) We would like to make such a plan, but don't know how

5. Does your company/farm have management plans for the land it owns/uses/manages?
a) Yes
b) No

6. If your previous answer was "yes", does the plan consider possible damage or income loss from invasive species?
a) Yes
b) No

7. Does your company/farm make soil excavation or soil transportation from one area to another (e.g. for maintaining levees, canals, roads, railways etc.)?
a) Yes
b) No

8. Does your organization maintain green areas? (lawns, meadows, dykes, canals, parks, road borders, arch trees)
a) Yes
b) No
c) other

9. If the answer to the previous was "yes", in which way?
a) machine mowing
b) mowing with a scythe
c) mulching or grinding
d) grazing animals

10. Biomass of grass, weeds or bushes, produced it this way, is usually:
a) left on the same place
b) used as hay for fodder
c) transported to garbage disposal
d) used in composting
e) burned at an appropriate place
f) something else

11. Does your organization (or you personally if you own the land) transport plant products (e.g. cereals, hay, game food, wood) from one area to another in its land management practice?
a) Yes
b) No

12. If you answered "Yes" to questions 7, 8 or 11, how far is the land / biomass / product transported?
a) up to 1 km

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b) up to 10 km
c) up to 50 km
d) farther

13. In your opinion, should the problem of invasive species be addressed at the national level? (e.g. subsidizing eradication and prescribing preventive measures)
a) Yes
b) No

14. Would you be interested to learn more about invasive species, how they affect our society, economies, nature and what we can do in response?
a) Yes
b) No

15. Would you like to add something about invasive species?

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Annex 2: Example of fixed and scanned tree corings Euroamerican poplar and Pedunculate oak for measuring the width of rings of sampled trees

Figure 1. A sample of prepared and scanned core of Euroamerican poplar for measuring the tree-rings width.

Figure 2. Photo of Euroamerican poplar core, site TK.

Figure 3. Photo of Euroamerican poplar core, site TID.

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Figure 4. A sample of prepared and scanned pedunculate oak core for measuring tree-ring width.

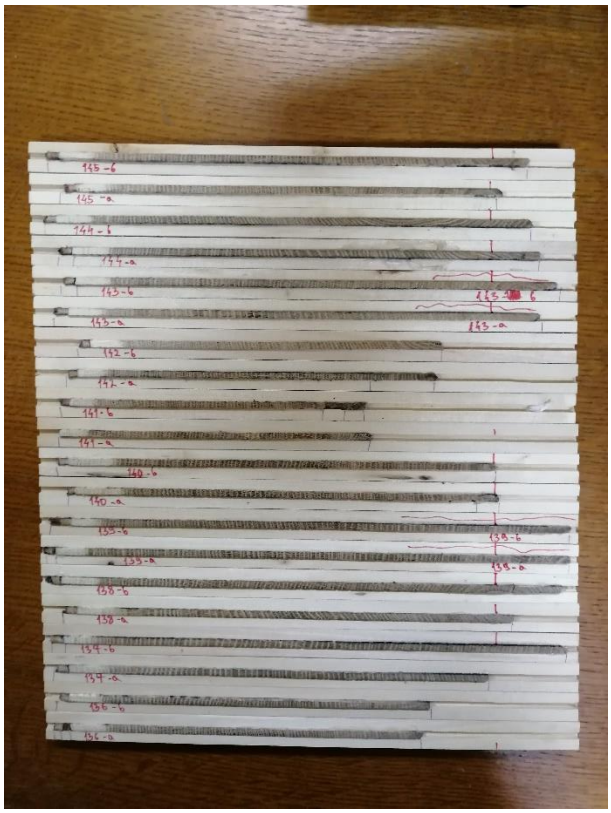

Figure 5. Photo of pedunculate oak core, site L 1.1.

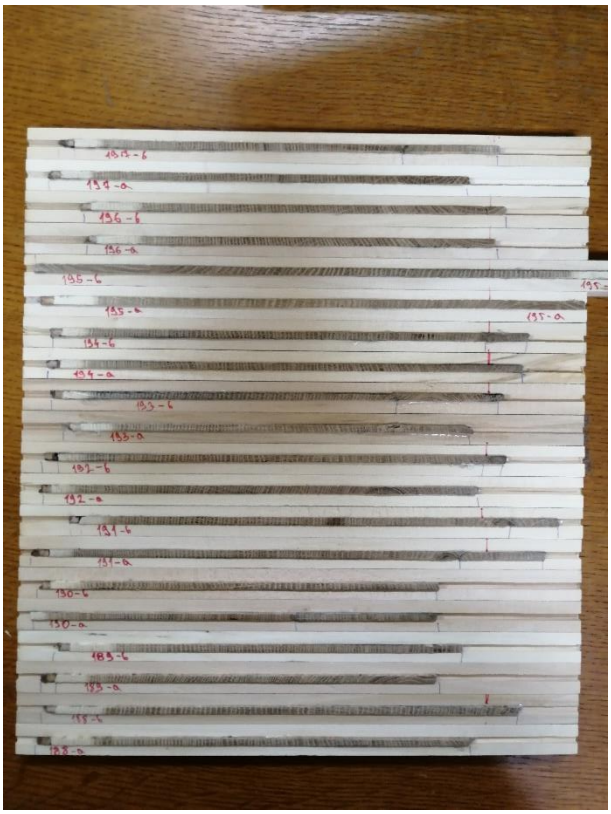

Figure 6. Photo of pedunculate oak core, site L 1.2.

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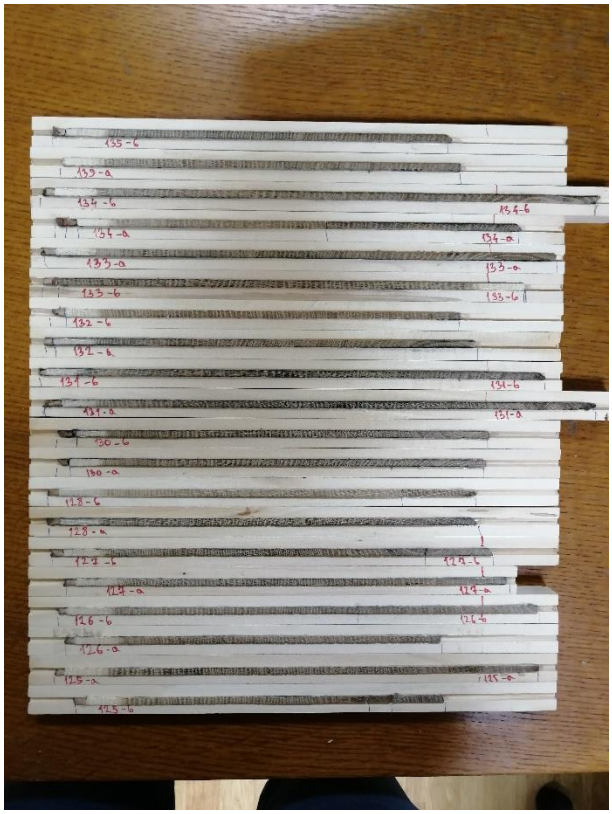

Figure 7. Photo of pedunculate oak core, site L 2.1.

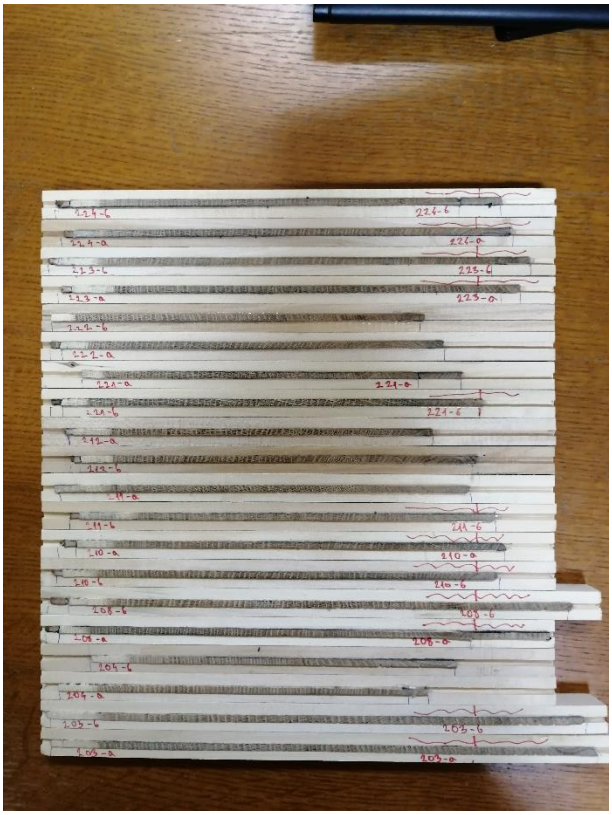

Figure 8. Photo of pedunculate oak core, site L 2.2.

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Figure 9. Photo of pedunculate oak core, site L 3.1.

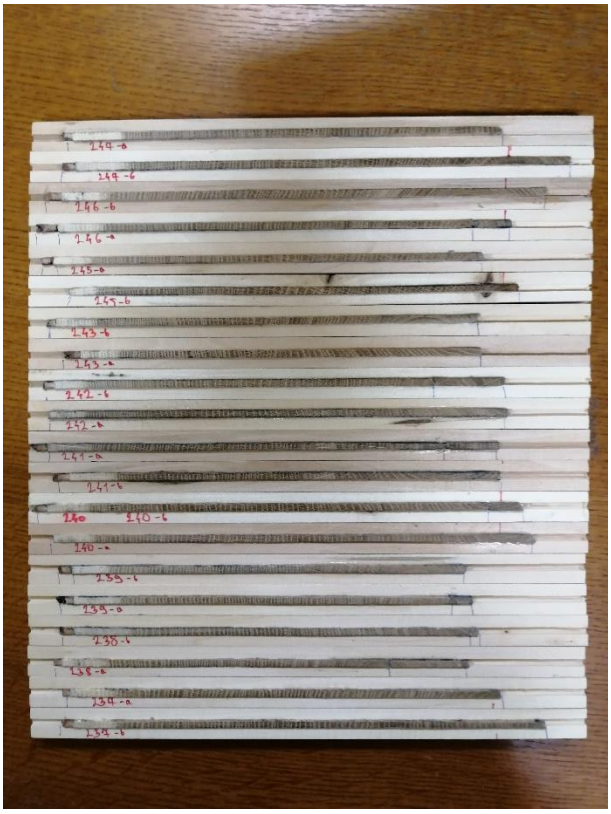

Figure 10. Photo of pedunculate oak core, site L 3.2.

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LAND USE CHANGE ANALYSES IN SAVA RIVER BASIN

Interreg
Danube Transnational Programme
Sava TIES

SI river section

Ljubljansko barje

Odransko polje

Lonsko polje

HR river section

HR/BA river section

BA river section

Una

Tisina

RS river section

RS river section

Obedska bara

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Legend
- Sava River Basin
- River section
- Mapped protected areas

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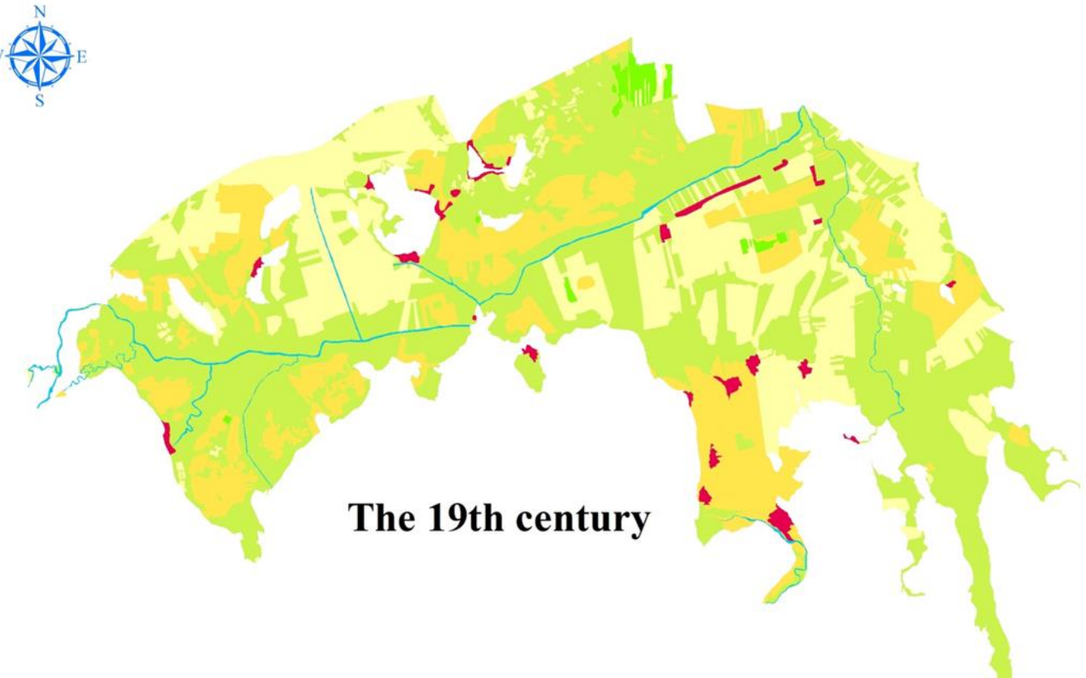

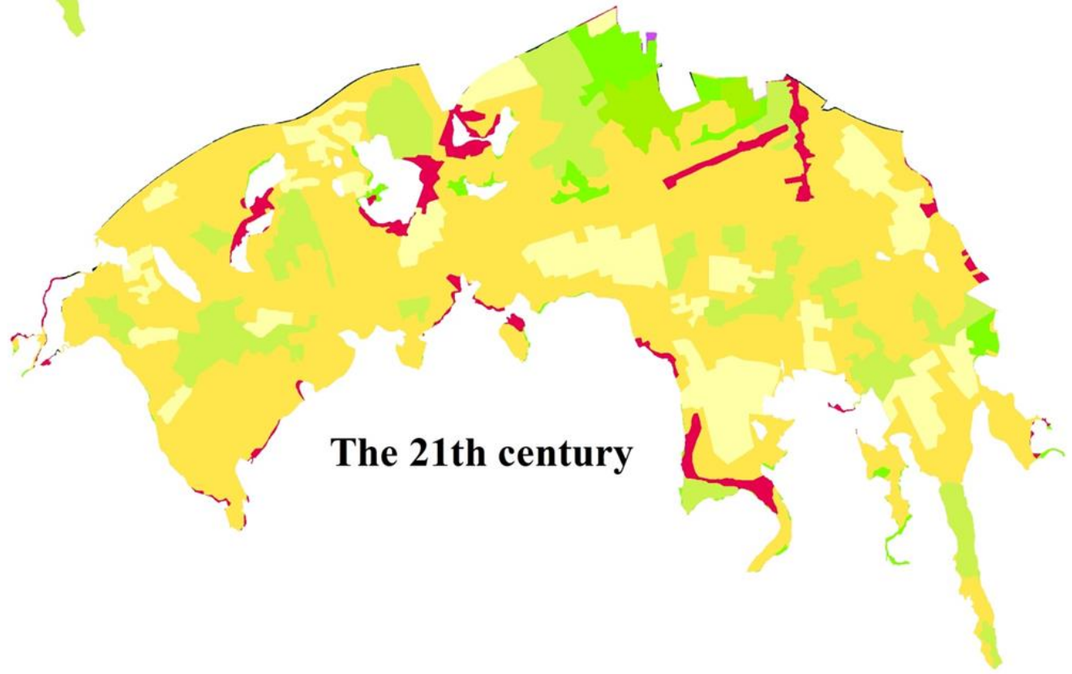

Interreg
Danube Transnational Programme
Sava TIES

SLOVENIA

Lubljansko barje

Map 1

Legend

land use change

- Other artificial
- 111: urbanised settlements
- 121: Industrial or commercial units
- 141: Green urban areas
- 211: Non-irrigated arable land
- 242: Complex cultivation patterns
- 311: Forest
- 321: Natural grasslands
- 324: Transitional woodland-shrub
- 331: Beaches, dunes, sands
- 511: Water courses
- 512: Water bodies

0 3.75 7.5 15 Kilometers

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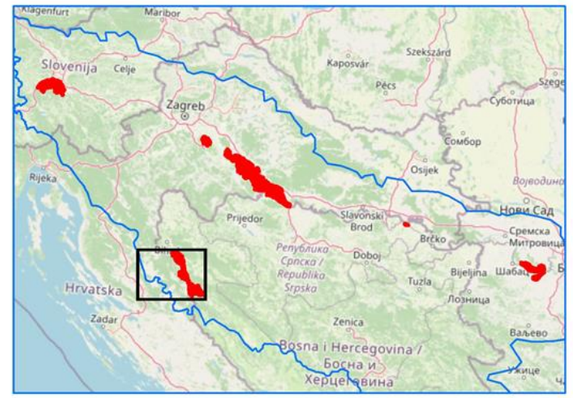
The 19th century

The 21th century



Interreg
Danube Transnational Programme
Sava TIES

BOSNIA AND HERZEGOVINA

Una

Map 2

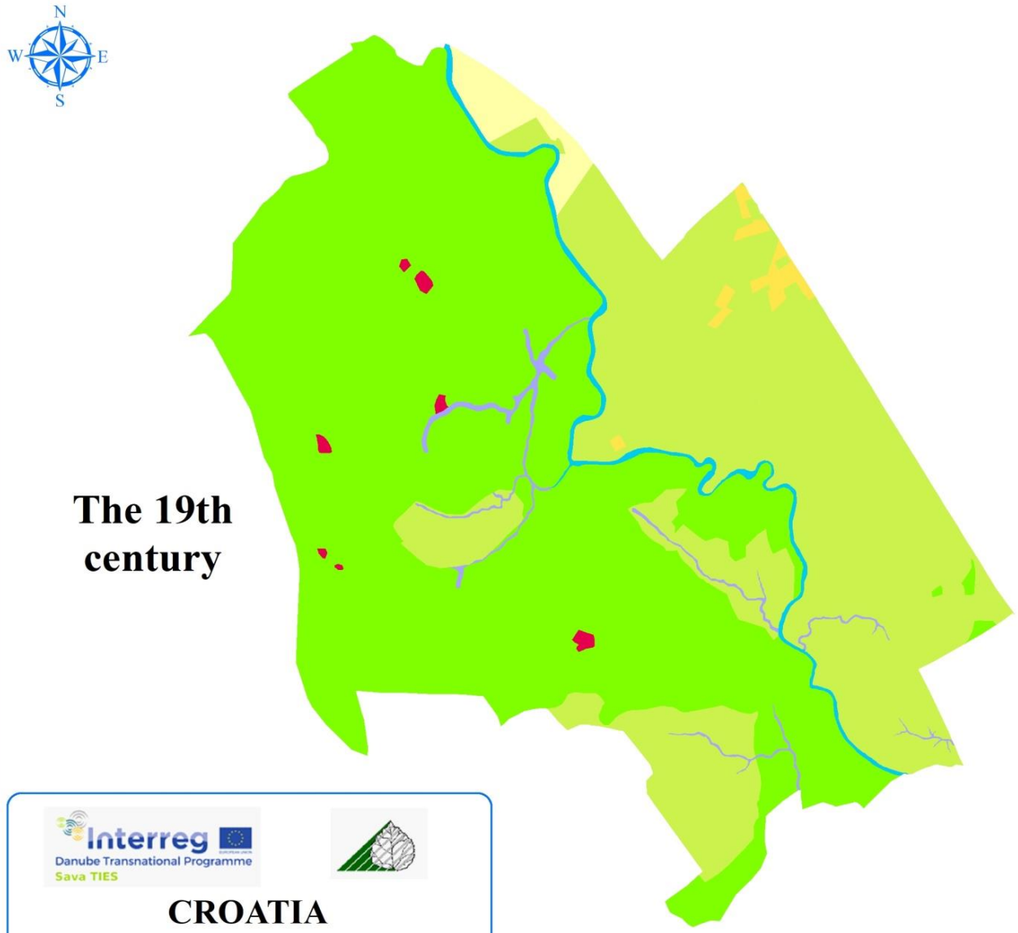
Legend

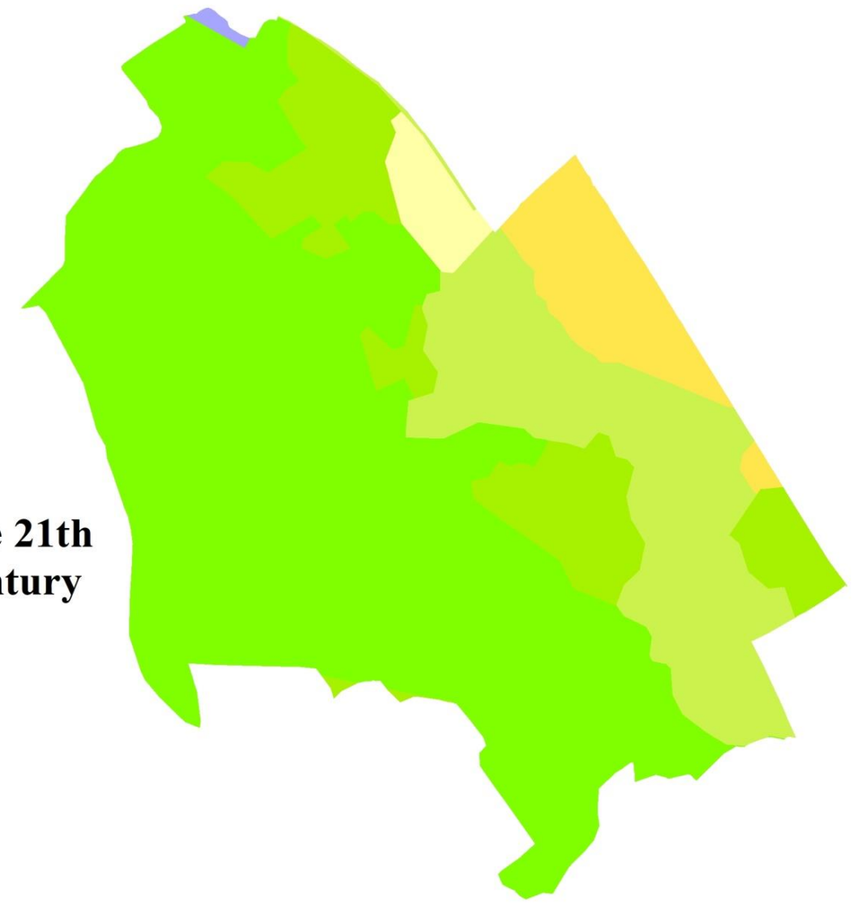
land use change

land use

- Other artificial
- 111: urbanised settlements
- 121: Industrial or commercial units
- 141: Green urban areas
- 211: Non-irrigated arable land
- 242: Complex cultivation patterns
- 311: Forest
- 321: Natural grasslands
- 324: Transitional woodland-shrub
- 331: Beaches, dunes, sands
- 511: Water courses
- 512: Water bodies

0 5 10 20 Kilometers





Interreg
Danube Transnational Programme
Sava TIES

CROATIA

Odransko polje

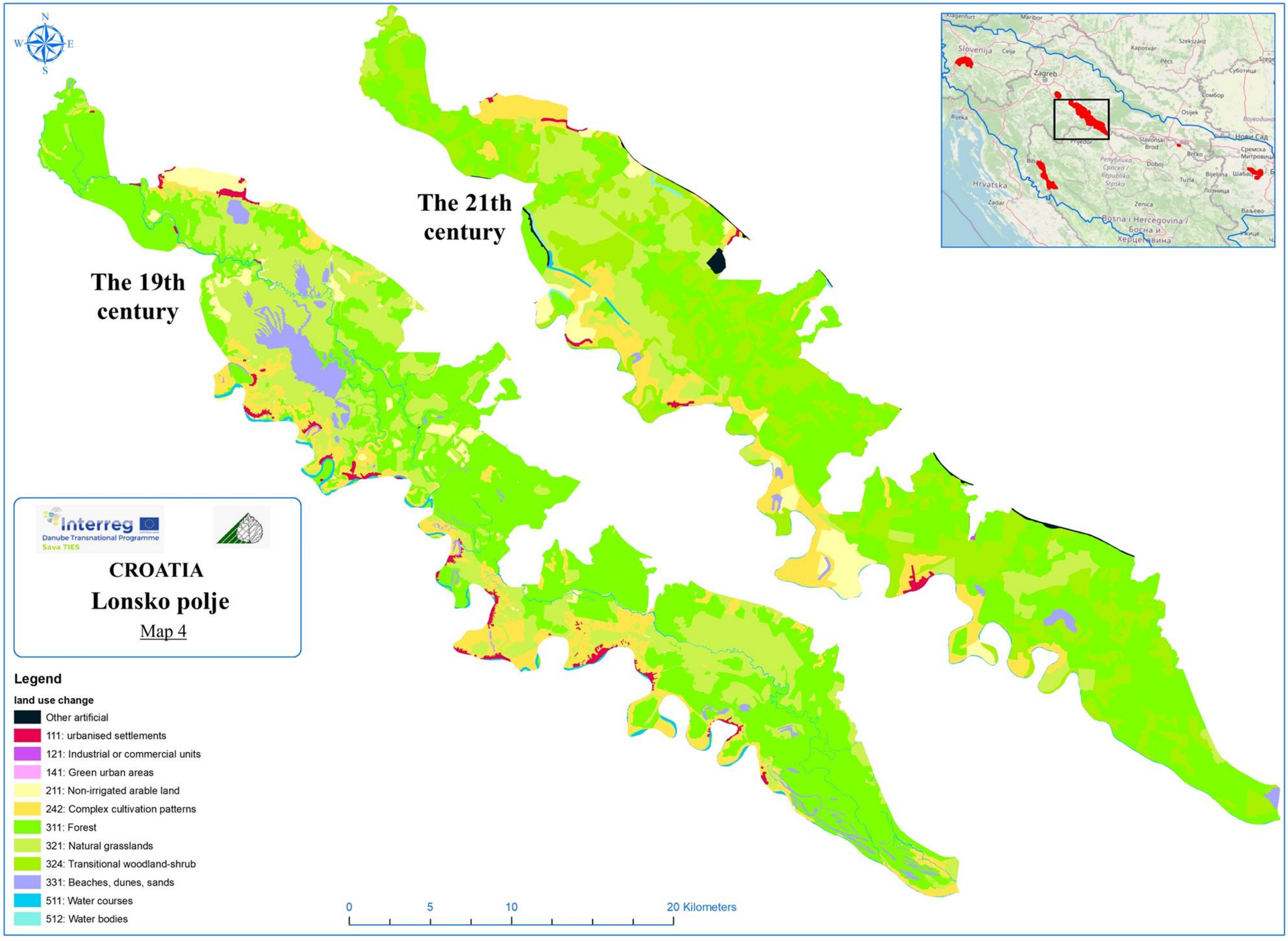
Map 3

Legend

land use change

- Other artificial
- 111: urbanised settlements
- 121: Industrial or commercial units
- 141: Green urban areas
- 211: Non-irrigated arable land
- 242: Complex cultivation patterns
- 311: Forest
- 321: Natural grasslands
- 324: Transitional woodland-shrub
- 331: Beaches, dunes, sands
- 511: Water courses
- 512: Water bodies

0 1.25 2.5 5 Kilometers


N
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The 19th century
The 21th century
Slovenija
Celje
Zagreb
Kaposvár
Pécs
Szekszárd
Rijeka
Osijek
Hrvatska
Zadar
Bosna i Hercegovina / Босна и Херцеговина
Zenica
Doboj
Tuzla
Bijeljina
Brčko
Slavonski Brod
Nови Сад
Сомбор
Суботица
Република Српска / Republika Srpska
Interreg
Danube Transnational Programme
Sava TIES
CROATIA
Lonsko polje
Map 4
Legend
land use change
Other artificial
111: urbanised settlements
121: Industrial or commercial units
141: Green urban areas
211: Non-irrigated arable land
242: Complex cultivation patterns
311: Forest
321: Natural grasslands
324: Transitional woodland-shrub
331: Beaches, dunes, sands
511: Water courses
512: Water bodies
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20 Kilometers

Interreg
Danube Transnational Programme
Sava TIES

BOSNIA AND HERZEGOVINA

Tišina

Map 5

N
W E
S

The 19th century

The 21th century

Legenda

land use change

- Other artificial
- 111: urbanised settlements
- 121: Industrial or commercial units
- 141: Green urban areas
- 211: Non-irrigated arable land
- 242: Complex cultivation patterns
- 311: Forest
- 321: Natural grasslands
- 324: Transitional woodland-shrub
- 331: Beaches, dunes, sands
- 511: Water courses
- 512: Water bodies

0 0.5 1 2 Kilometers

Interreg
Danube Transnational Programme
Sava TIES

SERBIA

Obedska bara

Map 6

N
W E
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The 21th century

The 19th century

Legenda

land use change

- Other artificial
- 111: urbanised settlements
- 121: Industrial or commercial units
- 141: Green urban areas
- 211: Non-irrigated arable land
- 242: Complex cultivation patterns
- 311: Forest
- 321: Natural grasslands
- 324: Transitional woodland-shrub
- 331: Beaches, dunes, sands
- 511: Water courses
- 512: Water bodies

0 3.75 7.5 15 Kilometers

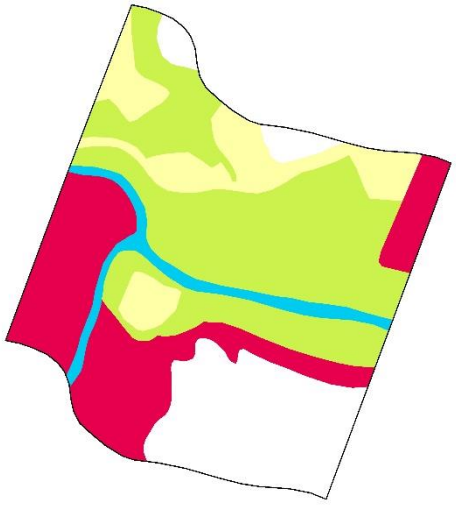
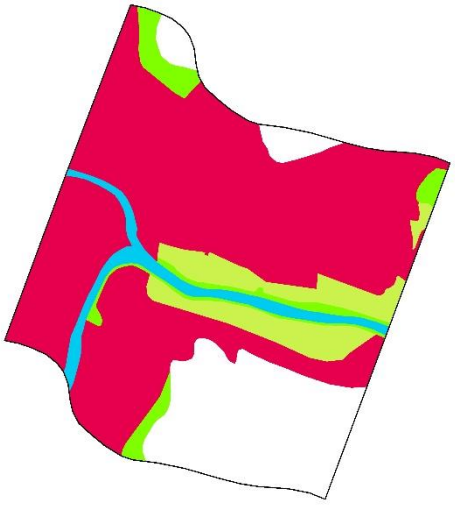
THE MAPS OF RIVER SECTIONS

The maps and the tables bellow them gives insight in land use (change) at selected river sections as the ecological corridors – XIX century compared to XXI century

Map title: **Land use change at Škofja Loka, Slovenia**

Location: downstream of historical center in city of Škofja Loka

Altitude: 332 m to 360 m

XIX c	XXI c
	
River section from the Third Military Survey with mapped polygon	River section from Google satellite images with mapped polygon
	
Land use map XIX century	Land use map XXI century

Land use change Skofja Loka	P (ha)	%
111: urbanised settlements	24.27	31.1
211: Non-irrigated arable land	12.63	16.2
321: Natural grasslands	36.91	47.2
511: Water courses	4.33	5.5
Total	**78.14**	**100.0**

Road length: 5.833 m

Bridge: 77 m

Land use change Skofja Loka	P (ha)	%
111: urbanised settlements	60.41	77.3
311: Broad-leaved forest	5.05	6.5
321: Natural grasslands	8.66	11.1
511: Water courses	4.02	5.1
Total	**78.14**	**100.0**

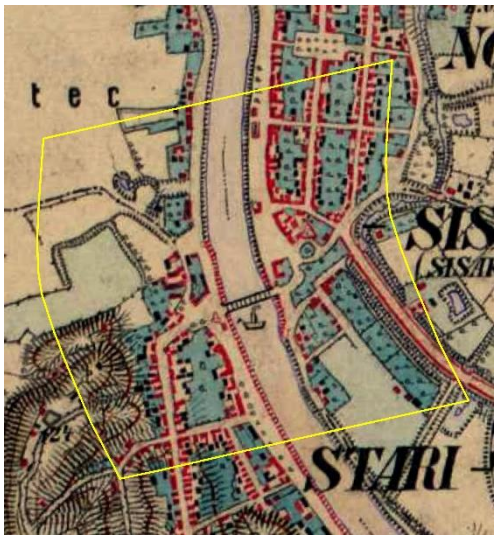
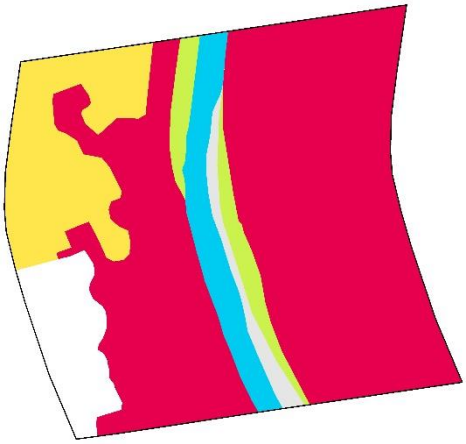
Road length: 8.960 m

Bridge: 54 m

Map title: **Land use change at Sisak, Croatia**

Location: at city of Sisak

Altitude: 97 m to 107 m

XIX c	XXI c
	
River section from the Third Military Survey with mapped polygon	River section from Google satellite images with mapped polygon
	
Land use map XIX century	Land use map XXI century

Land use change Sisak	P (ha)	%
111: urbanised settlements	55.96	61.8
242: Complex cultivation patterns	14.57	16.1
321: Natural grasslands	9.70	10.7
511: Water courses	10.27	11.3
Total	**90.50**	**100.0**

Road length: 5.481 m

Bridge: 116 m

Land use change Sisak	P (ha)	%
111: urbanised settlements	63.83	70.5
242: Complex cultivation patterns	13.71	15.1
321: Natural grasslands	4.25	4.7
331: Beaches, dunes, sands	2.24	2.5
511: Water courses	6.47	7.1
Total	**90.50**	**100.0**

Road length: 6.140 m

Levee: 669 m

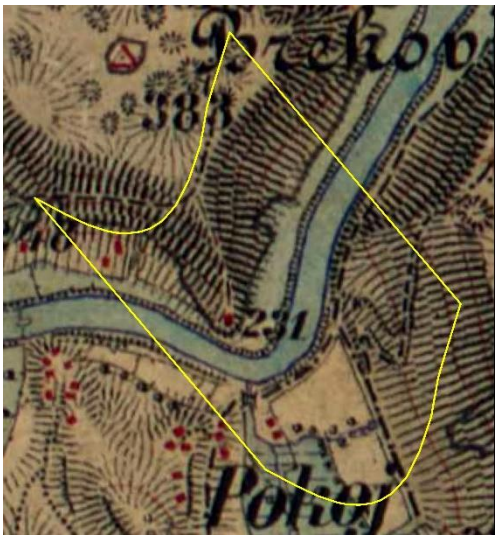
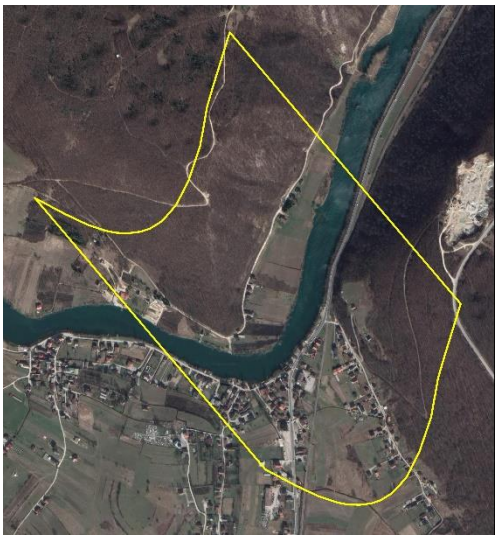
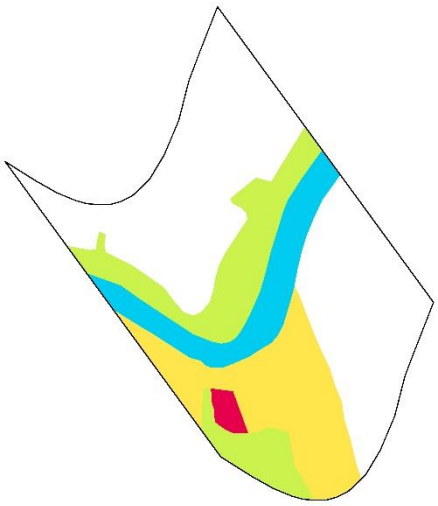
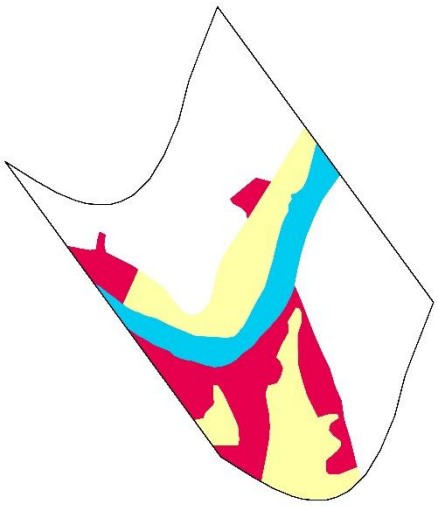
Levee with road 1.329 m

Bridge: 88 m

Map title: **Land use change at Pokoj (Una), Bosnia and Herzegovina**

Location: at Pokoj settlement

Altitude: 211 m to 228 m

XIX c	XXI c
 River section from the Third Military Survey with mapped polygon	 River section from Google satellite images with mapped polygon
 Land use map XIX century	 Land use map XXI century

Land use change Pokoj BiH	P (ha)	%
111: urbanised settlements	0.80	2.4
242: Complex cultivation patterns	12.55	38.1
321: Natural grasslands	12.12	36.8
511: Water courses	7.48	22.7
Total	**32.95**	**100.0**

Road length: 2.239 m

Canal: 592 m

Land use change Pokoj BiH	P (ha)	%
111: urbanised settlements	11.45	34.8
211: Non-irrigated arable land	14.96	45.4
511: Water courses	6.54	19.9
Total	**32.95**	**100.0**

Road length: 3.960 m

Canal: 524 m

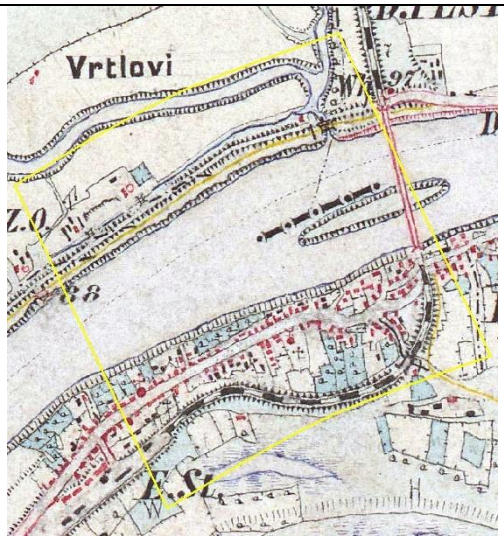
Railway: 854 m

Map title: **Land use change at Slav. Brod-Bos. Brod, Croatia - Bosnia and Herzegovina**

Location: cities of Slavonski Brod – Bosanski Brod

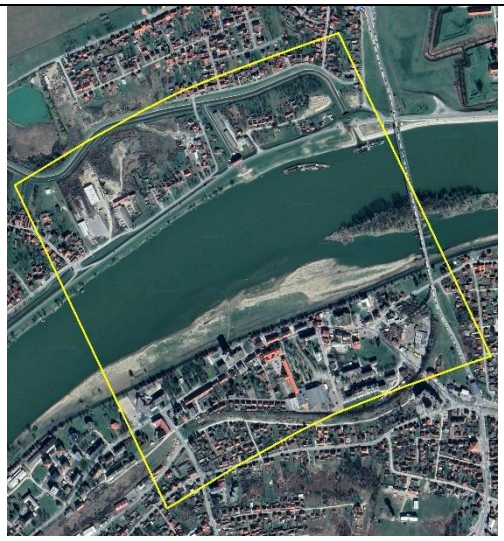
Altitude: 75 m to 85 m

XIX c

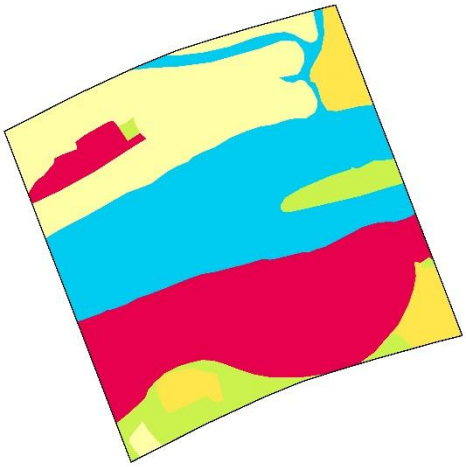


River section from the Third Military Survey with mapped polygon

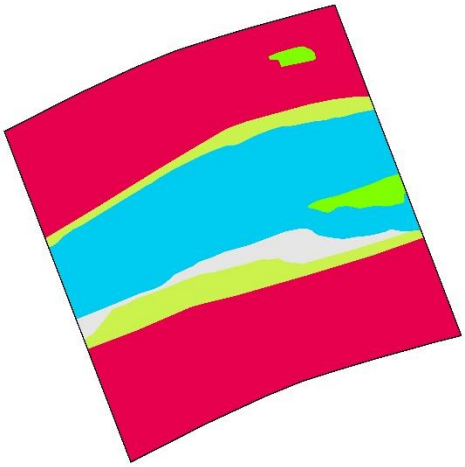
XXI c



River section from Google satellite images with mapped polygon



Land use map XIX century



Land use map XXI century

Land use change Brod	P (ha)	%
111: urbanised settlements	30.71	30.7
211: Non-irrigated arable land	22.49	22.5
242: Complex cultivation patterns	7.14	7.1
321: Natural grasslands	7.72	7.7
511: Water courses	31.97	32.0
Total	**100.03**	**100.0**

Road length: 3.874 m

Railway: 1.185 m

Bridge: 269 m

Land use change Brod	P (ha)	%
111: urbanised settlements	57.66	57.6
311: Broad-leaved forest	1.89	1.9
321: Natural grasslands	9.25	9.2
331: Beaches, dunes, sands	3.82	3.8
511: Water courses	27.41	27.4
Total	**100.03**	**100.0**

Road length: 4.266 m

Levee: 1.002 m

Levee with road: 1.016 m

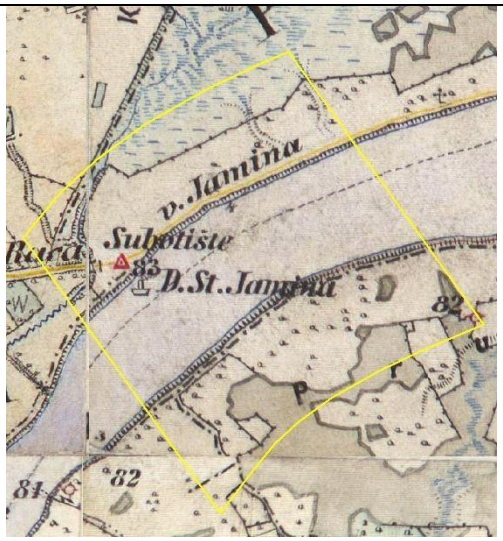
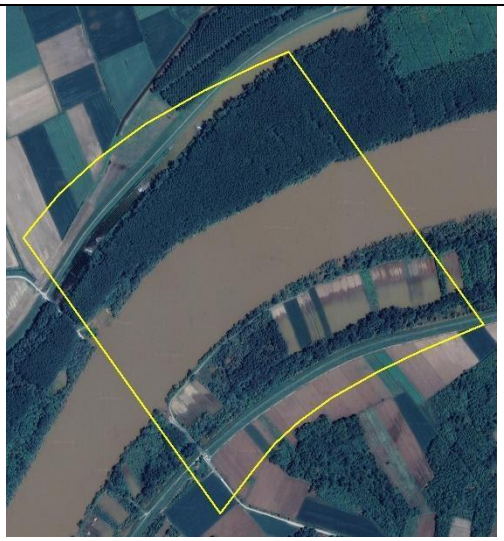
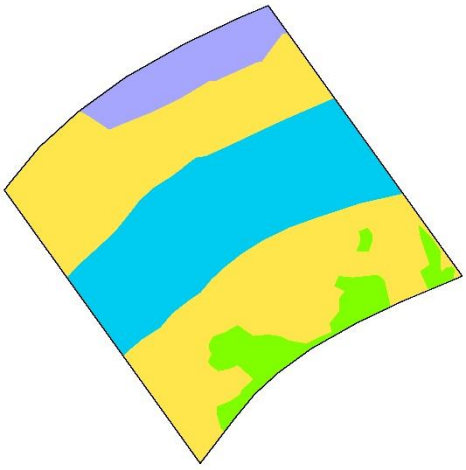
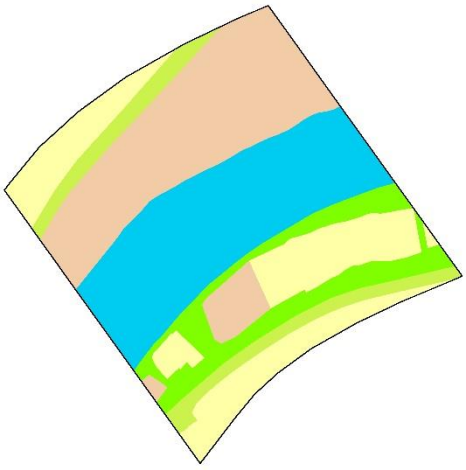
Bridge: 242 m

Canal: 1.190 m

Map title: **Land use change at Jamena Serbia – Bosnia and Herzegovina**

Location: at Jamena settlement

Altitude: 75 m to 81 m

XIX c	XXI c
 River section from the Third Military Survey with mapped polygon	 River section from Google satellite images with mapped polygon
 Land use map XIX century	 Land use map XXI century

Land use change Jamena	P (ha)	%
242: Complex cultivation patterns	52.00	52.5
311: Broad-leaved forest	7.38	7.5
411: Inland marshes	8.30	8.4
511: Water courses	31.29	31.6
Total	**98.97**	**100.0**

Road length: 2.020 m

Canal: 647 m

Land use change Jamena	P (ha)	%
211: Non-irrigated arable land	21.71	21.9
244: Agro-forestry areas	29.81	30.1
311: Broad-leaved forest	11.28	11.4
321: Natural grasslands	7.71	7.8
511: Water courses	28.46	28.8
Total	**98.97**	**100.0**

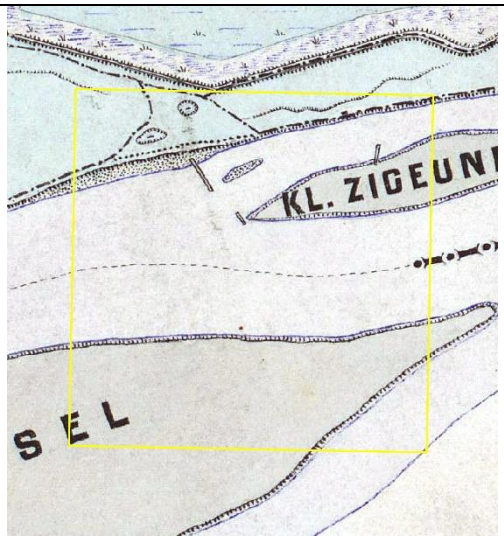
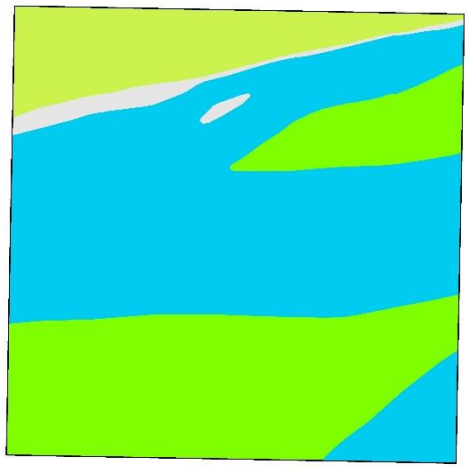
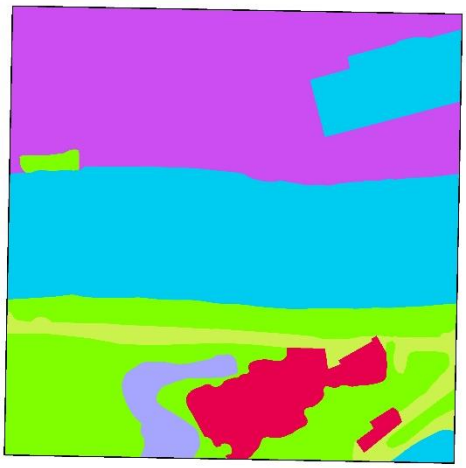
Road length: 963 m

Levee with road: 1.802 m

Map title: **Land use change at Belgrade, Serbia**

Location: Beograd

Altitude: 66 m to 81 m

XIX c	XXI c
 River section from the Third Military Survey with mapped polygon	 River section from Google satellite images with mapped polygon
 Land use map XIX century	 Land use map XXI century

Land use change Belgrade SRB	P (ha)	%
311: Broad-leaved forest	35.01	34.9
321: Natural grasslands	12.64	12.6
331: Beaches, dunes, sands	2.53	2.5
511: Water courses	50.26	50.0
Total	**100.44**	**100.0**

Road length: 1.534 m

Land use change Belgrade SRB	P (ha)	%
111: urbanised settlements	6.09	6.1
121: Industrial or commercial units	31.20	31.1
311: Broad-leaved forest	21.03	20.9
321: Natural grasslands	4.85	4.8
411: Inland marshes	2.76	2.7
511: Water courses	34.51	34.4
Total	**100.44**	**100.0**

Road length: 1.338 m

Levee with road: 1.285 m