Vegetation mapping to classify floodplain habitats and historical analysis of forest developments in the nature reserve “Stockerauer Au” in Lower Austria

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Vegetationsökologische Kartierung zur Bewertung des Auenwaldes und historische Analyse der Waldentwicklungen im Naturschutzgebiet “Stockerauer Au” in Niederösterreich

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Abstract

Since the 19th century, the floodplain habitats along the Austrian Danube have been heavily altered by river regulation, hydropower constructions, forestry as well as land use changes. In the absence of the hydrological dynamics - essential for natural floodplain ecosystems - progressive drying and subsequent vegetation succession continue unabated. Additional stressors such as ash and elm dieback, the spread of invasive neophytes, climate change and global species loss are causing significant changes in forest communities within a short period. Nature reserves aim to preserve these valuable habitats in good condition or restore them to such a state which constitutes a considerable challenge given the numerous stress factors. Regular monitoring is necessary and in scientific interest regarding possible future developments.

The aim of this study is to document the conservation grade as well as the state of several ecological factors from a nature conservation perspective and to evaluate the changes within vegetation types since 1990. After comparing the results, this study aims to derive possible potentials and limits regarding future developments, as well as management practices concerning the site.

Within the vegetation mapping in the Stockerauer Au 30, biotope types were identified, with oak-elm-ash forest comprising about 50% and ash-poplar forest 21% of the total protection area. About 62% of the study site was covered by a Natura 2000 forest habitat type (91E0 or 91F0), however the forest was assessed as ecologically degraded (state C). Reasons for the degradation are found in the loss of hydrodynamics, in herbivory, ash and elm dieback, as well as increasing occurrence of invasive species. Native regeneration is limited, while invasive trees such as *Juglans nigra* and *Robinia pseudoacacia* proliferate. Comparison with 1990 mapping data suggests that half of the ash-poplar forest in 1990 transitioned into the next succession stage: oak-elm-ash forest.

The study concludes that there needs to be a major change in the hydrological dynamics to fulfill the objectives of the nature protection site. Austria is obligated by law to restore and preserve these floodplain habitats and without recurring primary successions, the forest will steadily develop towards a non-alluvial climax stage (Hornbeam dominated forest), comprising the loss of endangered species and habitats. The actual reforestations in form of clearcuttings show a severe disruption of natural processes and are not conducive to achieving long-term environmental sustainability.

These and other described management practices will determine the prospective ecological functions of the site (eg. as drinking water reserve). Especially regarding climate change and biodiversity loss these decisions will have great effect on future generations.

***Key words**: habitat assessment, floodplain forest, Danube floodplains, historical analysis, succession, loss of hydrodynamic*

Zusammenfassung

Besonders seit dem 19. Jahrhundert werden die österreichischen Auenhabitate entlang der Donau durch Flussregulierungen, Kraftwerksbauten, Forstwirtschaft und veränderter Landnutzung stark verändert. Ohne der für natürliche Auenlebensräume essentiellen hydrologischen Dynamik, schreitet die Austrocknung und somit die Sukzession der Vegetation immer weiter voran. Zusätzliche Stressoren wie das Eschen- und Ulmensterben, die Ausbreitung invasiver Neophyten und der Klimawandel sowie das Artensterben führen in kurzer Zeit zu erheblichen Veränderungen der Waldgesellschaften. Naturschutzgebiete haben das Ziel diese wertvollen Lebensräume in gutem Zustand zu erhalten oder wieder in diesen zu versetzen – dies stellt in Hinblick auf die vielen Stressoren eine Herausforderung dar und bedarf regelmäßiger Untersuchungen.
Im Rahmen dieser Arbeit wird der Wald des Naturschutzgebiets “Stockerauer Au” mittels einer vegetationsökologischen Kartierung naturschutzfachlich bewertet. Faktoren wie der Zustand der Eschen, der Neophyten, des Totholzes oder die Artenzusammensetzung wurden mit vielen weiteren aufgenommen und zeigen die aktuelle Situation. Darüberhinaus erfolgte ein Vergleich mit aufgenommenen Vegetationstypen aus dem Jahr 1990 sowie eine Literaturrecherche, um die historische Entwicklung des vorherrschenden Auenwaldes besser zu verstehen. Diese Erkenntnisse werden genützt, um die zukünftige Entwicklung des Gebiets besser einschätzen zu können und Empfehlungen für mögliche Managementpraktiken davon abzuleiten.
30 Biotoptypen wurden identifiziert, wobei Eichen-Ulmen-Eschenauen etwa 50% und Eschen-Pappel-Auen 21% der Fläche einnehmen. Rund 62% des Untersuchungsgebiets wurde als Natura 2000 Lebensraumtyp kategorisiert, jedoch konnte der gesamte Waldbestand nur als ökologisch dedradiert (Zustand C) klassifiziert werden. Zu den wesentlichen Stressoren zählen die gestörte hydrologische Dynamik, Wildverbiss, das Eschen- und Ulmensterben sowie die zunehmende Ausbreitung invasiver Arten. Die natürliche Verjüngung autochthoner Baumarten ist stark eingeschränkt, während sich gebietsfremde Arten wie *Juglans nigra* und *Robinia pseudoacacia* ausbreiten. Der Vergleich mit Kartierungsdaten aus dem Jahr 1990 zeigt, dass etwa die Hälfte der damaligen Eschen-Pappel-Bestände in eine spätere Sukzessionsphase – den Eichen-Ulmen-Eschen-Auwald – übergegangen ist.
Die Studie kommt zu dem Schluss, dass die Erhaltungsziele des Gebiets nicht erfüllt werden können, wenn die für ein Auensystem entscheidende hydrologische Dynamik weiterhin ausbleiben würde. Der Auwald würde sich sukzessive in Richtung eines Klimaxstadiums (Hainbuchenwald, kein Auwald mehr) entwickeln. Dies würde mit dem Verlust vieler geschützten Arten und Lebensräume sowie der Veränderung ökologischer Funktionen (zB. Trinkwasserspeicher) einhergehen. Österreich verpflichtet sich dazu, geschützte Habitate in degradiertem Zustand wieder zu restaurieren und sie in gutem Zustand zu erhalten. Der Waldumbau mittels Kahlschlägen erweist sich als starker Eingriff und wenig zielführend. Insbesondere im Hinblick auf den Klimawandel und den Verlust der biologischen Vielfalt spielt das Management eine entscheidende Rolle für zukünftige Generationen.

Schlüsselwörter: FFH-Bewertung, Auwald, Donauauen, historische Analyse, Sukzession, Verlust hydrologischer Dynamik

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Abbreviations

BT	biotope type
CZ	core protection zones
DBH	diameter at breat height
DW	dead wood
FFH	Fauna-Flora-Habitat
GIS	geographic information system
HT	habitat type
HWF	hard wood forest
PNV	potential natural vegetation
SS	study site
SWF	soft wood forest
VT	vegetation type

1. INTRODUCTION

Floodplain ecosystems are among the most species-rich as well as structurally complex habitats (Naiman et al. 2005) and simultaneously some of the most threatened habitats in Europe (Lazowski 1997a; Pühringer 2023:5–7). The 350-km-long Austrian Danube River section has been changed dramatically by channelization and hydropower plant constructions since the 19th century (Egger et al. 2007). This naturally has a substantial effect on floodplain forest habitats, which are already heavily affected by anthropogenic (Lazowski 1997a) as well as biotic (Barbl 2020) influences. The preservation and enhancement of floodplains is not only of great importance concerning nature conservation (Rahmstorf 2013; Pühringer 2023), research also shows that these ecosystems provide much more benefits for mankind in a long-term when left in or returned to a natural condition (Hübl 2020). Especially with regard to climate change and the biodiversity loss we're experiencing already nowadays, resilient ecosystems are better in adapting to the fast-changing environmental conditions (Falk et al. 2019). More than 60% of the floodplain areas in Austria were under protection in 2023, predominantly designated as EU Flora-and-Fauna-Habitats (Pühringer 2023) which focus on a good state of specific protected assets. Protection sites are managed via management plans that need to be updated regularly according to the current state of the area and the overall aim for the future. Vegetation mappings are the prevalently used tool to assess the flora and the conservation state of (Pühringer 2023) an area (Ellmauer et al. 2021) and by classifying them into habitat types, biotope types and vegetation types they can be not only compared to other areas but also over time to detect changes in the long-term.

Definitions of alluvial floodplain ecosystems ("Auen")

The term "Au", which means 'alluvial floodplain', was first described by E. A. Roßmäßler (1806–1867) as: "the forested area of plane, fertile areas that are situated within the high-water (peak flood) mark of rivers [...] (Pühringer 2023). Historically the term has referred to the "land by the water" encompassing riverine landscapes as well as river islands and the water bodies itself (Hemmer 2011). Indeed, it is water that shapes not only the perception of this landscape but also the functioning of its entire ecosystem (Rahmstorf 2013).

Today, the floodplains of nearly all Central European rivers have been severely restricted by embankments and hydraulic engineering. Therefore, the area that would naturally be flooded without human intervention is referred to as the *potential or original floodplain* (morphologische Aue). Areas that have already been cut off from regular inundation are known as *former floodplains* (Altaue). The bank zones still subject to flooding are termed *recent floodplains* (rezente Aue) (Hemmer 2011).

Whereas the term "Au" referred to often already wooded sedimentations surrounded by water, it today denotes a landscape that is now firmly integrated into the surrounding land (Hohensinner 2010). Thus, when it is spoken of near-natural floodplains/ floodplain forests nowadays, it is referred only to the modest remnants of what was once a thriving ecosystem (Hemmer 2011).

Critical factors for alluvial floodplain ecosystems

For alluvial ecosystems to function in a longterm, regular floodings as well as a shallow groundwater table are inevitable. Especially due to those two factors, a mosaic of interlinked aquatic, semi-terrestrial, and terrestrial habitats is continuously created (Dister 1998). Typical landscape features include sandbanks, gravel beds, islands, oxbow lakes, old cut-off side-arms, xeric alluvial grassland (Heißländen), willow-shrub vegetation and broadleaf forests of oak, ash, elm, and linden - flooded only during extreme floods (Margl 1973). Water level changes occur most frequently around the mean water line of a river. There, levels may fluctuate within hours and even changes of a few centimetres can cause dramatic shifts in habitat conditions. The shallow groundwater table is connected to gravel substrates, surface water bodies and coupled to the water level of the river with a time lag (Hemmer 2011). A high groundwater table can delay the drying-out of floodplain forests and thus the encroachment of non-native plant species. Thirdly, it is not enough for water merely to overflow the banks. Both transverse and longitudinal connectivity are prerequisites for the development of the typical zonation and succession states of riverine ecosystems (Hemmer 2011). This spatial and temporal flooding variability is particularly important for the site-specific enormous biodiversity of floodplains (Lazowski 1997a), but also for the transport of humus to the nutrient-scarce places (Wendelberger 1973).

Importance of riverine floodplains

Floodplains are highly functional, diverse, and dynamic ecosystems. Due to their structural and habitat diversity, they rank among the most species-rich and structurally complex ecosystems (Naiman et al. 2005).

Due to the *dynamic environment* a variety of life-history strategies, biogeochemical cycles and rates, as well as organisms adapted to disturbance regimes over broad spatial and temporal scales evolved (Naiman & Decamps 1997). Moreover, heterogeneous, mosaic-like structures, in which a diverse array of interconnected habitat types occur within a very small spatial scale were and are formed (Schneider et al. 2017). These species and processes are one of the main reasons why floodplain ecosystems in their natural state, are now recognised as national *biodiversity hotspots* (Robinson et al. 2002; Rood et al. 2005; Tockner et al. 2009). For many once widespread species, these areas represent their last remaining refuges and thus are of critical importance for the conservation of biodiversity, including habitat diversity, species richness, and genetic variability (Schneider et al 2017). For example, inundated floodplain forest areas containing deadwood are valuable habitats that have become increasingly rare (*Managementplan für das Europaschutzgebiet Tullnerfelder Donau-Auen* 2023). The unpredictability of a stream's or river's own distinctive hydrological dynamics poses a challenge to all organisms within the floodplain. Adjustments to a regular rhythm are not sufficient and effect a wide range of remarkable evolutionary adaptions (eg. Mudwort communities (Schlammlingsfluren)) (Hödl & Eder 1996).

Tab.1: Ecosystem services provided by floodplain ecosystems. *(Scholz et al. 2012)*

Supporting Services	Provisioning Services	Regulating Services	Cultural Services
- Nutrient cycling - soil formation - primary production (aquatic + terrestrial)	- wood resources - drinking water - fish production - game - agricultural prod. - medicinal resources	- groundwater recharge - flood retention - erosion control - sediment deposition - water purification - local climate regulation	- Recreational functions (tourism, local recreation) - knowledge-based functions (environmental education, scientific knowledge)

Furthermore, floodplains are among few other ecosystem types worldwide that provide a wide range of *ecosystem services* (Turner & Daily 2008; Pühringer 2023) valued by society (Hein et al. 2014). Even if many of floodplain habitats have been significantly altered by human activities, they still exceed ecosystem functions of other ecosystem types (Tab.1). For instance, the retention of nitrogen (14%) and phosphorus (11%) loads transported in rivers can be retained (Lautenbach et al. 2012).

The effects of *climate change* will not only raise the importance of alluvial floodplains, the threats they face are tremendously increasing. On the one hand, floodplains can buffer the effects of flooding and also can lessen the negative impacts of extreme low-flow periods on aquatic communities. Additionally, floodplains can positively influence the greenhouse gas balance of river systems (Hein et al. 2014), even restored floodplains can regain their role as carbon sinks (Rahmstorf 2013:359).

Despite profound changes over the past 120 years, Austria's floodplains along the free-flowing stretch of the Danube east of Vienna ("Tullnerfelder Donauauen") remains among the last large-scale remnants of this landscape type in Europe, particularly along the Upper Danube (Reckendorfer et al. 2005) and thus bears a high responsibility for the preservation of one of the most representative examples of this type within the EU (Ellmauer et al. 2021). Of the 970 km^2 of alluvial forest in Austria, half is occurring in Lower Austria (Pühringer 2023). An area of approximately 160 km^2 accounts to the FFH area Tullnerfelder Danube floodplains (Straka 1995) which simultaneously function as a significant *biogeographical crossroad* **-** an intersection of east–west and north–south ecological corridors biological communities in an otherwise ecologically impoverished landscape, thereby ensuring high levels of biodiversity (Hein et al. 2014). In this Flora-and-Fauna-habitat, several key animal and plant species protected under the Habitats Directive are present with significant occurrences in the area (Straka 1995). The area is home to 41 species of fish, 15 of which are endangered species in Austria. Another 70 endangered animal species such as kingfisher, hen harrier, cormorant, great white and grey heron, red and black kite, white stork, white-tailed eagle and osprey are also important conservation objects and in need of a preserved floodplain area (*Managementplan für das Europaschutzgebiet Tullnerfelder Donau-Auen* 2023).

1.1. Threats to Alluvial Forests

Within temperate regions of Europe, truly natural hardwood floodplain forests do not exist along large rivers anymore. Today, fewer than 10% of Germanys floodplains remain ecologically functional, and hardwood floodplain forests, which are particularly ecologically valuable, now cover only about 1% of their former extent (Schneider et al. 2017). According to Reif et al (2024) all present locations of this forest community have been heavily anthropogenically altered.

Within the last centuries floodplain habitats in Austria has been largely destroyed by human activities - the total area has declined by 15% of their former extent (Hein et al. 2014) and no reversal of this trend is currently in sight (Pühringer 2023). Except for small, naturally non-forested areas, the original floodplains of the Danube were once covered with dense broadleaf forests. These continuous riparian forests of ash, oak, and elm have been almost entirely displaced over the past centuries by meadows, pastures, arable land, settlements, industrial zones, and transport infrastructure. Although remnants of forest still exist and are often referred to as floodplain forests, they typically differ substantially in structure and biological diversity from the original state (Hemmer 2011).

Almost all remaining forests are now subject to forestry use - this includes nearly all of the remaining semi-natural riparian forests along the few river sections still affected by natural flood dynamics (Schneider et al. 2017). Even in these areas, however, natural hydrological processes are increasingly lost, as the water levels of all rivers are now regulated by weirs. As a result, many of

the once widespread floodplain forest, our natural heritage, is gradually drying out and being replaced by trees adapted to low soil moisture (Hemmer 2006).
These facts have been documented for decades. Already in 1975 it was stated by Wendelberger, that the essential high groundwater and periodical floods are impaired by men and streams will be a row of canalized damming ups. These regulations indeed help that industries and traffic thirves, but all at the cost of riparian forests (Wendelberger 1975).

The following quote from 1995 still gives a realistic overview of the situation within the Tullnerfelder Danube Floodplains (FFH site) (excl. the Stockerauer Au as it is under higher protection):

> "The entire area is used for forestry and parts for agriculture; the water bodies are used for fishing. Large sections (around 3,350 ha of hunting areas (Altenwörth -Korneuburg)) are primarily dedicated to game management. Gravel extraction is carried out mainly on economically unproductive forest areas (dry gravel terraces (Heißländen) and floodplain meadows), covering approx. 150 ha (Altenwörth -Korneuburg). Recreational infrastructure (such as the Danube cycle path, motorboat harbours, and bathing huts) occupy an area of approx. 250 ha (Tulln – Korneuburg)." – (Straka 1995)

To conclude alluvial floodplain habitats as biodiversity oases have been reduced by human intervention to mere fragments resulting in a need for improved management of the remaining sites (Hemmer 2011).

In the following, the main challenges are outlined in more detail.

Channelisation and hydropower use of the Danube
Altered river morphology due to regulatory interventions for flood protection and navigation, along with the construction of numerous hydropower plants is the main reason why Austrian Danube floodplains lost their natural hydrological state (Hein et al. 2014).
Prior to its major channelization/ straightening in 1875, the Danube formed an extensive braided river system between Vienna and Bratislava with highly variable discharge capacity (Hohensinner 2010) and 90–95% of the waterbodies were permanently flowing. The area available for floodwater discharge was considerably reduced from 350 km^2 to 95 km^2 which led to a significant diminution of water bodies – in extent but also afundamental alteration in type (Hohensinner et al. 2008). The same happened west of Vienna where the study site is situated.
Due to the drastic interventions in the 20th century, many gravel banks and softwood floodplain habitats have been lost. The reduction in base flow and flood dynamics, along with partial or complete damming, severely disrupted the natural water regime (Straka 1995, Auenland 2008).
In Austria, the Danube is regulated by 10 run-of-river power plants, some of which are now equipped with fish migration facilities (Jungwirth & Schmutz 1988).
Due to channelization, the Danube flows even faster and therefore drags along more sediments which result in a deepening of the river channel. This again results in the lowering of groundwater tables which are critical to functioning alluvial forests (Habersack et al. 2023). In many river catchments, there is an increasing discrepancy between sediment surplus and deficit which results in a heightened flood risk, restrictions on navigability, and reduced hydropower generation, while also negatively impacting the ecological integrity of the system (Habersack et al. 2023).

Changes in Floodplain Vegetation due to forestry practices

Nowadays, if any forests still exist along rivers, they are often heavily influenced by forestry activities, particularly through the widespread cultivation of hybrid poplars (Schneider et al. 2017). Remnants of traditional land-use practices - such as pollarded willows or coppicing - are only occasionally still visible (Straka 1995, www.stockerau.at). However, floodplain areas are predominantly occupied by artificially established forests composed of non-native or ecologically unsuitable species such as balsam poplar (*Populus balsamifera*) and Canadian poplar (*Populus × canadensis*). Even when native species like ash (*Fraxinus excelsior*), alder (*Alnus spp*.), or white willow (*Salix alba*) are planted homogeneously, they lack the structural complexity and diversity that characterises natural floodplain woodlands (Berner et al. 2022).

The primary driver of this transformation has been large-scale, intensive forestry focused on timber yield. Tree species selection is frequently based on economic profitability rather than ecological appropriateness, leading to the creation of forest stands that bear little resemblance to the site's natural vegetation. From a conservation standpoint, the ecological value of such plantations is typically low—and may, in some cases, even be detrimental. These afforestation practices not only threaten native habitats and species assemblages but can also disrupt essential landscape-level ecological processes (Finck & Schröder 1997).

From a forestry perspective, it faces significant challenges in the management of floodplain ecosystems. Key floodplain tree species, including ash (*Fraxinus excelsior*), field elm (*Ulmus minor*), and black alder (*Alnus glutinosa*) are threatened by diseases and climate change adds further uncertainties regarding the future suitability of floodplain tree species to meet ecological, site-specific, and economically viable forestry needs (Eisen et al. 2022).

Consequently, the typical species composition of hardwood floodplain forests, such as elm-oak or alder-ash communities, is unlikely to persist or be restored in the near future in Germany, primarily due to economically motivated afforestation, but also because of natural pressures (Berner et al. 2022).

Other human influences like hunting, agriculture, fishing, gravel extraction

Over the course of history, the Danube floodplain has been shaped by a range of human activities, including hunting interests, agriculture, fishing, gravel extraction, and recreational use, all of which have significantly influenced its ecological character and landscape structure.

Due to its proximity to Vienna and the route toward Prague, hunting has historically held high importance throughout the management area. Numerous game enclosures, some dating back to the 18th century, reflect this tradition and have led to the establishment of non-native populations of sika deer (Cervus nippon), fallow deer (Dama dama), occasionally mouflon (Ovis aries musimon), and pheasant (Phasianus colchicus) (Barbl 2020).

Biotic threats

Natural stressors, including invasive species, pathogens, and herbivory, are inherent components of ecosystem dynamics. Typically, ecosystems are adapted to these usual stressors, however, when species are introduced by humans or when the ecosystem becomes more vulnerable due to additional pressures such as climate change, these factors can play a critical role in shaping the structure of a community (Essl et al. 2002b).

A) Neozoa

Elm tree dieback (*Ulmus*)

The Dutch elm disease has been present in Austria since 1928 causing severe damage to native elm species. It is caused by two closely related ascomycete microfungi (*Ophiostoma ulmi* and *Ophiostoma novo-ulmi*), presumably originating from Asia as there the resistance of many Asian elm species is higher. The disease results in the trees wilting as their water-conducting vessels are blocked and is transmitted by various elm bark beetles, primarily the smaller elm bark beetle (*Scolytus multistriatus*) and the larger elm bark beetle (*Scolytus scolytus*) (Kirisitz & Konrad 2007). Due to the Dutch elm disease, *Ulmus minor* has virtually disappeared as a stand-forming tree (Bezirksforstinspektion Korneuburg 2010). Interestingly, *Ulmus laevis* is largely unaffected by epidemic-scale damage and pests, which makes it a valuable component of mixed floodplain forests - now and in the future (Müller-Kroehling 2004).

Ash tree dieback (*Fraxinus*)

Dieback of *Fraxinus excelsior* and *F. angustifolia* is a phenomenon present in many European countries. Due to its high flood tolerance, it represents a key species in alluvial forest ecosystems. In the beginning of the 1990s, *Fraxinus excelsior* covered up to 42% of hardwood forest within the Danube floodplains (Barbl 2020). Ash dieback is caused by the invasive fungus *Hymenoscyphus fraxineus with* its asexual stage *Chalara fraxinea* and originates from East Asia (Eisen et al. 2022). Because *Fraxinus excelsior* withdraws relatively few nutrients from its leaves before they fall to the ground, it contributes to a higher soil pH which again promotes soil biological activity (Mitchell et al. 2014). According to the report by the Joint Nature Conservation Committee (Mitchell et al. 2014) approximately 1,058 species are associated with ash trees or ash woodlands, and 44 of these species are considered obligately associated with either living or dead ash trees (Eisen et al. 2022). In Austria, ash dieback is occurring since approximately 2005 (Kowalski et al. 2010) and investigated by several projects to understand better how to counteract. Around 2008, ash dieback was first observed in the Stockerauer floodplain (Barbl 2020). Interestingly, even in severely affected ash stands, it is not uncommon to find individual trees that show no visible symptoms of the disease (Thomas & Hoyer-Tomiczek 2007). This and its high economical value may be reasons why it’s being investigated by several organisations and Universities. One of which is called Esche in Not (‘Ash under Threat’) in cooperation with the University of Natural Resources and Life Sciences and two of their experimental plots are situated in the Stockerauer Au. The idea is to find healthy, maybe resistant trees in severely affected forest stands and use them to generate resistant young ash trees (Heinze et al. 2017).

Oak trees (Quercus)

The so-called "Weinviertel oak decline", evident through crown thinning, appears to result from a combination of factors, including drought and mistletoe infestation (Bezirksforstinspektion Korneuburg 2010).

B) Neophytes

Neophytes, understood as all species that were introduced or immigrated to Austria after 1492, conquer a special position in floodplain forests. Due to their typical natural (and anthropogenic) disturbance regimes, conditions in these habitats facilitate neophytes to establish and occupying ecological niches of native species (Essl et al. 2002b).

Softwood floodplains of the lowlands are particularly rich in established neophytes (Margl 1973). For instance, *Acer negundo* is massively invading the tree layer of white willow (*Salix alba*) floodplains in the Pannonian region, while in the herbaceous layer, *Aster lanceolatus, Impatiens glandulifera*, and *Solidago gigantea* are common (Essl et al. 2002b).

Climate change

Floodplains are heavily impacted by climate change as the rising temperatures result in lower levels of the water table and higher water temperatures (Rahmstorf 2013). Especially isolated floodplain water bodies are affected and with them many already nowadays threatened amphibian, insect or plant species that depend on them as breeding sites (Schuster 2024). In the isolated oxbow lakes of the Lobau near Vienna, temperature maxima up to 5°C higher than those in the main channel of the Danube have already been observed (Hein et al. 2014).

Petermann et al. (2007) stated that among others, hard- and softwood forests as well as xeric habitats are especially under pressure due to climate change (Essl et al. 2002b). It is expected that favourable conditions for pathogens will increase and simultaneously weaken tree resilience through extreme weather events (Berner et al. 2022).

Conclusion

The anthropogeic and natural issues affecting floodplain ecosystems are multifaceted and intricately interlinked. Their existence, functionality and especially pristine condition of alluvial floodplains cannot at all be taken for granted. This underscores the importance of their protection, effective management, and ongoing monitoring of the remaining floodplain areas as well as revitalisation of deteriorated habitats (Schneider et al. 2017).

1.2. Motivation and research questions

Knowing that the alluvial forest west of Vienna, the “Tullnerfelder Donauauen” is one of the largest remenant alluvial forest habitats that is left in Europe and finding out that it is heavily under pressure due to various threats – especially mankind (Straka 1995; Rahmstorf 2013), I felt the urge of better understanding how this area can be managed in the future to sustain one of the richest ecosystems in terms of biodiversity and our natural heritage. Furthermore, we would profit in the future from preserved alluvial floodplains as they can play an important role in terms of climate change, water security, biodiverity crisis and effects like droughts and flooding (Rahmstorf 2013).

By getting in contact with the Federal municipality of Lower Austria, which is responsible for the management practices, it was declared that more data on the current state of the ecosystems is needed to update management plans. As the mapping of the whole FFH area “Tullnerfelder Donauauen” would be too extensive for a master’s thesis, it was agreed on the nature protection site “Stockerauer Au”. The last vegetation mapping dates back several years which makes it also valuable to record an updated situation of the site.

The “Stockerauer Au” is a national nature protection site since 1999 and protected under the EU Bird’s directive since 2004, as well as designated as Flora-and-Fauna Habitat in 2011 (name: “Tullnerfelder Donauauen”, code: AT1216000). Therefore, the management practices are restricted and the requirement of non-deterioration as well as the overall aim of preserving certain habitats and protected assests in a “good condition” need to be followed (European Parliament and Council 1992).

This work relates to surveys of the Tullnerfelder Donauauen (Haring 1887; Straka et al. 1986; Straka 1990; Ettwein 2015; Kurmann et al. 2017) and descriptions of the Danube Floodplain in general (Wendelberger-Zelinka 1952; Margl 1973; Wendelberger 1975), as well as the historical development of the Danube (Hohensinner 2010; Hohensinner et al. 2013; Drescher et al. 2014).

The objective of this study aims to investigate the conservation grade as well as the state of several ecological factors from a nature conservation perspective with the intention of gaining up-to-date knowledge of the state the protection site "Stockerauer Au" is in. To gain comprehensiveness of how the vegetation types have changed within the last decades (or even centuries), this master's thesis plans to evaluate historic vegetation mappings as well as indications of former species occurrences or management practices. By comparing the historical findings with the self-mapped data, this study sets out to derive possible potentials and limits regarding future developments, as well as management practices concerning the site.

The following research questions are stated for this study:

A) Current ecological status: what is the ecological state of the area, focussing on its forests and how should it be assessed in terms of nature conservation?

B) Historical development: how has the distribution of various vegetation types changed historically since at least 1990*?

C) Recommendations for future management: what can be deduced from the comparison of the answers to questions A and B and what potentials or limits arise regarding future management?

*The year 1990 was selected because from that year it was known that a mapping of the occurring vegetation types was carried out for the whole study site. Within a literature research it was aimed to include vegetation data from the last centuries, if possible, and data that has not been recorded as a map.

2. STUDY SITE

2.1 GEOGRAPHY

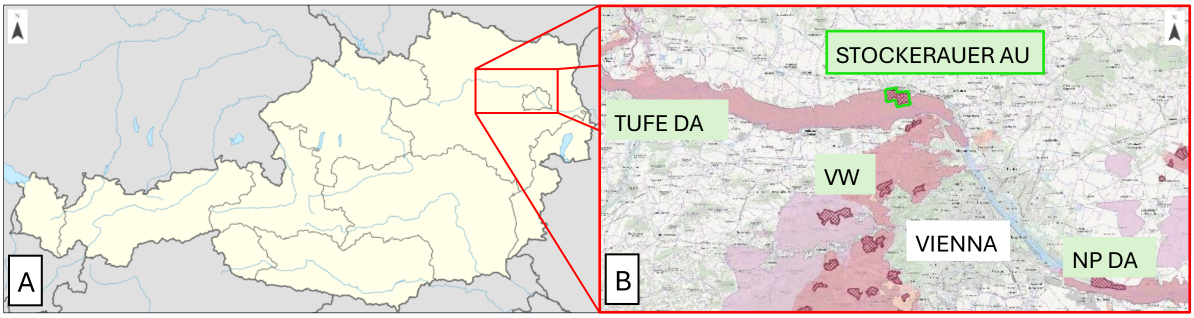


Fig.1: A: Map of Austria. *(NordNordWest, CC BY-SA 3.0 DE, Wikimedia Commons)*
B: Sourroundings of the site: *light red: Natura 2000 area; Dark red striped: national nature protection area; Vienna (white text box) and nature protection area (green text box) (STOCKERAUER AU = study site; TUFE DA = Tullnerfelder Danube Alluvial forest (FFH); NP DA = National park Danube Alluvial forest; VW = "Vienna Woods" (FFH)) (atlas.noe.gv.at)*

The study site is situated in Lower Austria, approximately 15 kilometers north-west of the city of Vienna (Fig.1). The "Stockerauer Au" is a nature protection site since 1999 with an area of 3,95km^2 and located within the Natura 2000 area "Tullnerfelder Donau-Auen", the largest connected alluvial forest in Austria. The Tullnerfelder Donau-Auen are protected under the Bird's Directive (code: AT1216V00) since 2004 and under the Habitat Directive (code: AT1216000) since 2011 (*Managementplan für das Europaschutzgebiet Tullnerfelder Donau-Auen* 2023). In the north of the site a highway separates the protection site and the build-up areas of the municipality of Stockerau which owns and manages the site. The south of the study area is marked out by a former side-arm of the Danube (Fig.2).

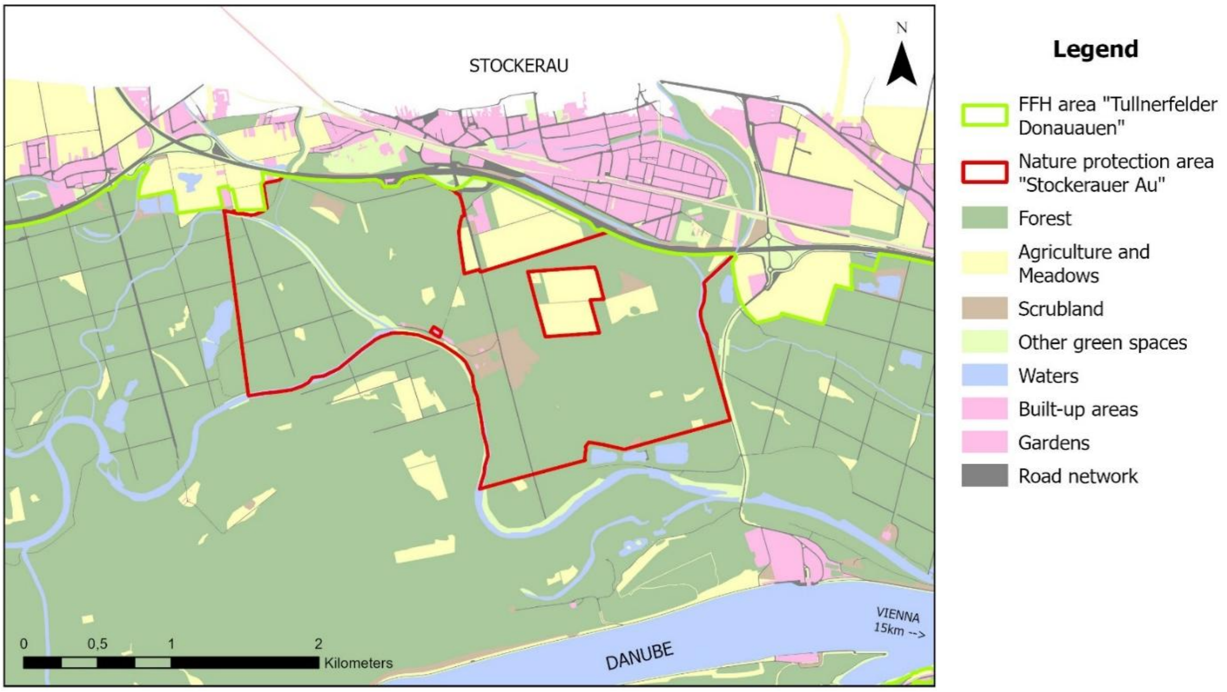


Fig.2: Cataster map showing the surroundings of the study site.
For better visualisation, gardens as well as build-up areas are shown in pink. (data source: Geoshop, Federal municipality of Lower Austria)

Soil characteristics

The soil texture is made up of sandy silt, silty loam, and loamy sand which leads to a high or very high permeability. The humus content is low to moderate with mull as the predominant humus form. With the soils being strongly calcareous, the soil pH lies between 7.0 and 7.25. The FAO soil type classifies the region as calcic Chernozem in the north and calcic Fluvisol out of undifferentiated alluvial deposits (eBOD).

Terrain

The Stockerauer Au is located at 160-190 meters above sea level (topographic-map.com) and its terrain characteristics is predominantly influenced by changes in the fluvial patterns of the Danube in the last centuries (Fetzmann 1963). Nowadays there are several trenches and little terrain level changes indicating former side-arms of the Danube which strongly has and still is influencing the vegetation patterns (Fig.3).

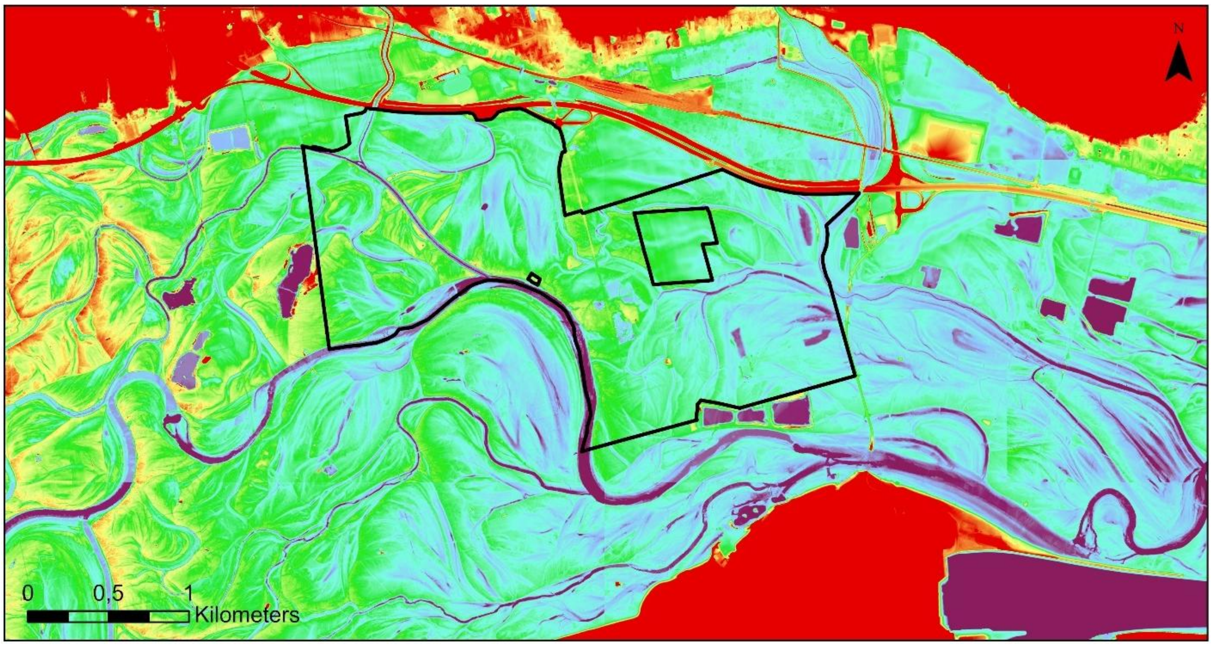


Fig.3: Digital elevation model (2019) showing former side-arms of the Danube.

Black outline: borders of the nature protection area Stockerauer Au; red: high elevations (north: municipality of Stockerau, west: Danube which has a mean water level change of 13 m at the power plant Greifenstein (power.verbund.com), blue and light purple: former side-arms of the Danube, dark purple: low elevations: side-arms of the Danube (data source: Geoshop, Federal municipality of Lower Austria).

Climate

Stockerau has a temperate continental climate with Pannonian influences (Straka 1995), characterized by warm summers, cold winters, and relatively low annual precipitation. The mean annual temperature is around 9–10 °C, and a mean annual precipitation of 500–600 mm per year. The vegetation period lasts approximately 200–220 days, with dry periods typically lasting 4–5 days, and maximum durations of up to 20–22 days (eHAÖ 2001).

Hydrology

The former side-arm of the Danube that is the southern border of the study site is called "Krumpenwasser" (Fig.4). Its water is taken from the Danube 22 km linear distance west, and after flowing through the Natura 2000 site it connects again to the Danube in Korneuburg, 6 km linear distance east of the study site. According to the classification "Ecological status of water bodies" (EU Water Framework Directive) (European Parliament and Council 2000; Keci 2024) it had a water quality of 2-3 in 2001 as soon as Göllersbach connects to it. Another small river namely Göllersbach flows through the site for 1.4 km until it reaches Krumpenwasser. In the very northeast of the site a small river called Senningbach reaches the sidearm right at the nature protection border. It had a water quality of 1 (2001) and its lowest water table in August (eHAÖ 2001).

Fig.4: Different kinds of waterbodies within the site. *A: ephemer pond, B: ephemer disconnected side-arm of the Danube, C: side-canal of a small stream (Senningbach), D: small stream (Göllersbach), E: river/ former Danube side-arm (Krumpenwasser) (Photos: Nina Mosor).*

The mean groundwater level fluctuates between 2 and 5 metres below ground level (www.noe.gv.at/wasserstand) with an interpolated mean fluctuation of the groundwater table by 0.5 to 1 m (eHAÖ). The entire area is part of a porous aquifer composed of gravel and sand, forming a single porous groundwater body.
Groundwater level trends over the last decades show a stable to slightly rising groundwater table from 1961 until the year 2000 in Oberzögersdorf – the closest recording point but outside of the forest. (eHAÖ, www.noe.gv.at/wasserstand)
The Stockerauer Au functions as a drinking water reserve for the municipality of Stockerau which raises their aim to secure the forest fnctionality and therefore their water reserves (Barbl 2020).
Floodings occour more rarely since the regulation of the Danube and the building of the hydropowerplant Greifenstein. From time to time the area is still flooded. Big floodings happened for example in 2002, 2013, 2016 or 2024.

2.2 Nature protection regulations and aims

Protection of the study site

In 1999, 346 hectares of the Stockerau Forest's total area of 445 hectares have been nominated as a federal nature protection area (www.stockerau.at/system). About one third of the nature protection site is declared as core zone where access of the public is prohibited (Municipality of Stockerau 2023). The other two thirds are management zone. In 2004, the "Bird Protection Area Tullnerfelder Donauauen" was designated by ordinance as the first European protected area in Lower Austria (Straka 1995). Additionally to the Bird Protection Area, the area is under further protection as a Flora-and-Fauna-Habitat (Natura 2000 site) since the year 2011 (www.naturland-noe.at).

Numerous international frameworks and legal foundations are relevant for nature conservation in Austria and are influencing the management of the study site. These can be distinguished in international or national agreements, EU directives, regulations, strategies, guidelines, incentives and funding programs. In the following the most important are shortly outlined:

Flora and Fauna Habitat and Birds Directive

The Habitats Directive (92/43/EEC) aims to contribute to the conservation of biodiversity in the European territory of the Member States (Art. 2 Habitats Directive). For this purpose, a coherent European network of special areas of conservation, designated as "Natura 2000", is to be established to ensure the maintenance or, where appropriate, the restoration of a favorable conservation status of natural habitat types (Annex I) and the habitats of species (Annex II) within their natural range (Art. 3 Habitats Directive) (European Parliament and Council 1992, 2009; Ellmauer et al. 2005).

In the implementation of the obligations arising from the Habitats Directive and the Birds Directive, the concept of "favorable conservation status" plays a central role:

- Sites of Community Importance must ensure the continued existence or the maintenance of a favorable conservation status of the protected features.
- Any significant contribution a site can make to the conservation of the favorable status of the protected features must be considered a conservation objective.
- Conservation measures must correspond to the ecological requirements of the protected features and must therefore target those factors of the protected features that are not in favourable state
- Assessment of deteriorations and disturbances
- Assessment of plans and projects for compatibility
- Monitoring of the sites: Through monitoring, indicators of conservation status are observed to act if a threshold value is exceeded
- Preparation of reports on the implementation of measures and the maintenance or restoration of a favorable conservation status
- the favorable conservation status must be ensured for the following protected assets:
    - Bird species listed in Annex I of the Birds Directive
    - Migratory bird species regularly occurring in Austria, particularly with respect to internationally significant wetlands
    - Habitat types listed in Annex I and species listed in Annex II of the Habitats Directive (*Managementplan für das Europaschutzgebiet Tullnerfelder Donau-Auen* 2023)

EU Water Framework Directive

The EU Water Framework Directive aims the restoration of natural or at least near-natural floodplain ecosystems (Directive 2000/60/EC), through various measures like the creation of new floodplain areas through dike relocation and the re-dynamization of floodplains (Reif et al. 2024).
The renaturation of floodplains has become an increasingly important concern for both politics and administration. This approach is reinforced by efforts to restore through nature-friendly measures the floodplain’s retention functions, as it has been largely lost in many areas (Schneider et al. 2019). Concerning this study the Water Framework Directive plays a role in the quality measurements of the streams within the site as well as the European union-wide aim to increase or maintain the natural state of floodplains like the Stockerauer Au (Directive 2000/60/EC).

EU Biodiversity strategy

As part of the EU Biodiversity Strategy for 2030, which forms part of the Green Deal, the improvement and expansion of protected areas is a key objective. By 2030, the restoration of natural habitats is to be achieved, which includes, among other things, agricultural and forestry-used areas as well as running waters and the management of invasive alien species (Amt der NÖ Landesregierung 2022).

IAS Regulation

Since 2015 this EU Regulation (1143/2014) aims to prevent and manage the spread of invasive alien species by, among others, control measures to limit the further dissemination and associated ecological damage of invasive species (European Union 2014; Amt der NÖ Landesregierung 2022).

Floodplain Strategy for Austria 2020+

The "Floodplain Strategy for Austria 2020+" provides a national framework for the long-term conservation and sustainable development of Austria’s floodplains and river landscapes. It focusses on safeguarding existing valuable floodplain habitats, restoration and extension of degraded floodplains, enhancing public wawreness as well as cross-border cooperation (Amt der NÖ Landesregierung 2022).

National nature protection law

The Lower Austrian Nature Conservation Act 2000 (NÖ Naturschutzgesetz 2000, LGBl. 5500) regulates the designation, use, and protection of nature conservation areas. The Stockerauer Au is designated as a nature reserve under Annex 8 of the corresponding ordinance as well as §2 (45) and § 3 (23) (Amt der NÖ Landesregierung 2022).

Exceptions to the prohibition of intervention § 3 (23) are distinguished in three areas:

A1 areas - one-time management areas:

- the felling of non-site-native tree species and – if this reduces the canopy cover below 3/10 - reforestation with site-native tree species

B areas - forestry management areas:

- the felling of non-site-native tree species
- forestry use in the form of selective single-tree harvesting up to small-group fellings (for firewood use)
- final harvesting in hardwood stands at an average stand age of 80 years and in softwood stands at 50 years, while maintaining 30% canopy cover from overstory trees
- reforestation under the condition that exclusively site-native tree species are used and a mixed culture is established
- the picking of spring flowers and ox-eye daisies up to the maximum of a hand bouquet of each species
- the gathering of wild garlic, mushrooms, and wild fruits

C areas - agricultural management areas:

- a one-time mowing – but not before mid-June

- maintenance of the paths
- access (except in areas A)
- the felling of trees that pose a danger to persons or property, up to a distance equal to tree height along the paths designated in the annex and along the A 22 Danube Bank Motorway
- measures for the drinking water supply of the municipal town of Stockerau (§2 para. 45)

According to the motive report of the ordinance (RU5-NSG-135/014), the following hierarchically organised objectives are identified for the 'Stockerauer Auen' nature reserve:

- Ensuring a secondary natural (succession) development of the sites on the basis of the changed hydrological regime in the course of power plant construction
- Provision of a valuable reference area for assessing the need for action in floodplain areas
- Long-term documentation of the changes in the protected area due to the succession development as part of a multi-year biomonitoring programme
- Conservation and improvement of the typical diversity of sites (forest, meadows) through extensification and careful utilisation of the entire area
- Safeguarding and promoting the current species diversity by establishing large-scale, utilisation- and disturbance-free core zones with a sufficiently high proportion of deadwood (natural forest reserves)
- Establishment and operation of a recreational forest for the local population with educational and information facilities with and without management

  (Amt der Niederösterreichischen Landesregierung 2024)

2.3 Historic developments

Today, Stockerau is a municipal town with approximately 17,000 inhabitants (Statistics Austria) and in roughly 2 km distance of the Danube. Its name reflects a long-standing connection to the adjacent alluvial forest, as "Stocker" refers to "woodcutter" and "Au" to the floodplain. (www.stockerau.at). However, the history of the region dates back considerably further.

The earliest evidence of human settlement in the area dates back to the Neolithic period (Rotter 1940:43). Additional archaeological findings from the Bronze Age and the Roman Imperial period indicate further settlement activity (Zimmermann 2010:320) . The first documented mention of the town occurred in the year 1012 and in 1514, the market town was granted a coat of arms depicting a young tree emerging from a tree stump. The tree stump symbolises the origins of Stockerau, when the dense riparian forest was cleared, while the young tree growing from the stump represents the emergence of a thriving settlement. This serves as another indication that the surrounding forest has been subject to silvicultural use for many centuries—if not millennia (Fetzmann 1963).

<u>Hydromorphologic changes</u>

Throughout centuries, the Danube formed an extensive system of meandering river branches (Holub 2012) (Fig.5). It had the freedom for maintaining a long-term balance between sediment deposition and erosion. The overlay of historical maps from 1775 to 1821 reveals that only about one quarter of the floodplain vegetation was older than 46 years. This is due to the continuous creation of new land and erosion of existing ones by fluvial dynamics (Hohensinner 2010).
Between the 15th and 19th centuries, severe flood events occurred more frequently due to the climatic conditions of a little Ice Age. In particular ice-floods exhibited high erosive force and significantly contributed to the relocation of river channels and the rejuvenation of floodplain

vegetation. These processes not only altered the hydromorphology through the widening and shifting of river channels, but also had substantial socio-economic impacts, as the population frequently endured devastating inundations, in some cases on an annual basis (Hohensinner 2010).

Fig.5: The changes in the course of the Danube in the Tullnerfeld Region (lowland area).
Top: Hydrographic network of the Danube and its tributaries in the "Tullnerfeld" with meanders. In 1781, the Danube consisted of multiple main channels and numerous side arms (Source: 1st Josephinic Mapping 1773-1781)
Bottom: In 2025, the river is straightened with an artificially created side channel ("Gießgang") running parallel within the floodplain, and the natural fluvial dynamics are largely lost (Source: atlas.noe.gv.at).

In 1826, the first channel regulation works of the Danube were implemented near the border of Upper Austria and Lower Austria (Machland), marking the beginning of the channelling of the entire Austrian stretch of the Danube, which continued until 1906. The primary objectives of these engineering measures were not only flood protection, but also expansion of terrestrial surfaces for agriculture and the optimisation of navigational routes (Hohensinner 2010). Between 1870 and 1875, the Danube's present-day riverbed was largely constructed - a course in which it still follows today.
Beginning in 1954, this transformation was further intensified through the development of 10 of hydropower stations. A dense sequence of hydroelectric dams has since converted the river into a chain of reservoirs, within which the natural hydrological processes have almost entirely ceased. During the construction of the "Greifenstein" power plant - located in close proximity to the Stockerau floodplain - the riverbanks were raised and sealed between 1981 and 1985 in order to retain the impounded water within the Danube channel. The remaining oxbow lakes were hydraulically disconnected from the Danube using pumping stations, as the dammed water level in the river now lies higher than that of the adjacent floodplain waters (Straka 1995). Since then, both surface and groundwater levels in the floodplain area have been regulated by human intervention. Some of the former oxbows were linked to form artificial side channels - now referred to as the "Krumpenwasser". Due to its connection to the Danube near Korneuburg and the

installation of fish ladders, this water body is at least partially accessible to fish from the Danube (Straka 1995). However, such artificial channels cannot replace the natural flood dynamics of the Danube (Hödl & Eder 1996).

Usage of wood

Winiwarter & Schmid (2008) were able to show that the Viennese Danube was a socio-natural site, shaped by the practices of humans from the sixteenth century onwards. As the city of Vienna was in need for a lot of wood for builing (Hohensinner et al. 2016), it is possible, that also the Stockerauer Au was influenced by logging since that time.

The black walnut is an example for neophytes that were imported in economic interest centuries ago. It is cultivated in Europe since 1629 (Nicolescu et al. 2020), in Croatia it was introduced in forest management in 1890 (Kremer et al. 2008) and in the Danube Floodplain they may be introduced at the end of the 19th century (www.waldwissen.net).

Usage for hunting

The Stockerau floodplain (Stockerauer Au) was a favoured hunting ground for centuries. As early as the Middle Ages and the early modern period, the region was renowned for its abundance of game. Its proximity to the Danube and the diverse landscape — comprising riparian forests, meadows, and water bodies - provided ideal habitats for wildlife (Mutschlechner n.d.).

Agriculture

Historical maps indicate that agriculture has played a role in this area since at least the 19th century. The meadows were mainly used as grazing areas or herb-picking and later for plant production. After the regulation of the Danube, the floodplain is no longer regularly inundated which on the one hand reduces the natural input of nutrients to the soil. However, on the other hand it has provided greater security and predictability for farming activities (Haidvogl et al. 2018).

2.4 Influences of hunting, forestry and tourism/recreation nowadays

In the eastern, southern, and western directions outside the Stockerauer Au, the forests are predominantly influenced by forestry (often consisting of poplar monocultures) and hunting practices (Knoll 2015). Pursuant to §4 item 6, the exercise of hunting (under the Lower Austrian Hunting Act 1974, LGBl. 6500) and fishing (under the Lower Austrian Fisheries Act 2001, LGBl. 6550) does not fall under the Nature Conservation Act 2000, if it does not conflict with the provisions of §§ 11, 12, 17 paras. 1 to 4 and 6, and § 18 (Amt der Niederösterreichischen Landesregierung 2025).

The density of red deer (*Cervus elaphus*) is much higher than the national average. A hunting management does however only make sense on a big scale as the nature conservation zones serve as refuge areas for deer that is bothered by intensive forestry practices outside Stockerauer Au but within the Natura 2000 area (Barbl 2020).

Outside the core zones, however, forest areas are still significantly shaped by forestry management. In the last four years, 4.85 hectares were clear-cut for reforestation. This practice involves big machineries that remove the upper layer of forest earth and wood chipping for mulching at some parts. The open earth is severely degraded afterwards and easily vegetated by invasive neophytes. Barbl (2020) created a forestry management concept where the aimed forest types are a high softwood forest (*Salix alba, Ulmus minor, Acer pseudoplatanus*) or a mixed forest

(*Tilia cordata, Ulmus, Populus canescens*). *Robinia pseudoacacia, Populus x canadensis* and *Juglas nigra* are said to be unwanted. Also, *Ulmus laevis, Quercus robur, Ulmus glabra, Acer campestris* and *Carpinus betulus* should play a role. The aim is a gradual forest stand transformation aimed at preserving and restoring essential forest functions as well as the suppression and prevention of invasive species and neophytes. Only damaged areas and those necessary for stand transformation and silvicultural improvement shall be treated with small-scale interventions. All reasonably healthy trees that do not pose a hazard within the vicinity of trails should, as far as possible, be retained. The reforestation areas are fenced for at least 10 years. It's also mentioned that standing deadwood doesn't have to be cut totally and lying deadwood can be left if the crown doesn't hinder natural regeneration too much. Natural regeneration should be prioritized wherever possible as "nature is best suited to determine which seedlings establish successfully at a given site". Artificial regeneration is stated to be needed where the loss of *Fraxinus excelsior* requires the complementary introduction of substitute tree species. The reforested species are not local but autochtonous (Barbl 2020).

The forest serves as an important recreational area for the local population of Stockerau (Barbl 2020) and is frequently visited by pedestrians, cyclists, and dog owners. Tourism is also playing an increasingly important role. An Inn located directly by the water attracts many visitors to the nature reserve during fair weather. Signposted trails aim to guide visitors through the area and encourage cyclists to remain on designated paths, as cycling is generally prohibited. An educational nature trail and numerous additional signs help raise awareness about the natural environment, and several signs mark the core areas as nature reserve.

2.5. Potential natural vegetation and its genesis

As aforementioned in the introduction, alluvial forest ecosystems are dependant on hydrological dynamics to retain their natural processes such as channel migration, erosion, and sedimentation. Depending on site-specific conditions, typical successional patterns can be observed in vegetational change (Egger et al. 2009). In general, it is characterised by a spatial mosaic of pioneer communities, riparian reed beds, shrublands, and floodplain forests (Michiels et al. 2007). These communities emerge in a successional dynamic and are repeatedly shaped, modified, or destroyed by the erosive force of flooding events, which in turn alter or reset succession, allowing it to restart elsewhere (Fig.6) (Reif et al. 2024).

Succession and the process of sediment deposition

Shugart (2001) defined ecological succession as an ordered progression of structural and compositional changes in ecosystems toward an eventual stable condition (climax). Whereas primary successions are initiated on new substrates such as gravel banks, secondary successions involve the recovery of vegetation on established soils from disturbances.

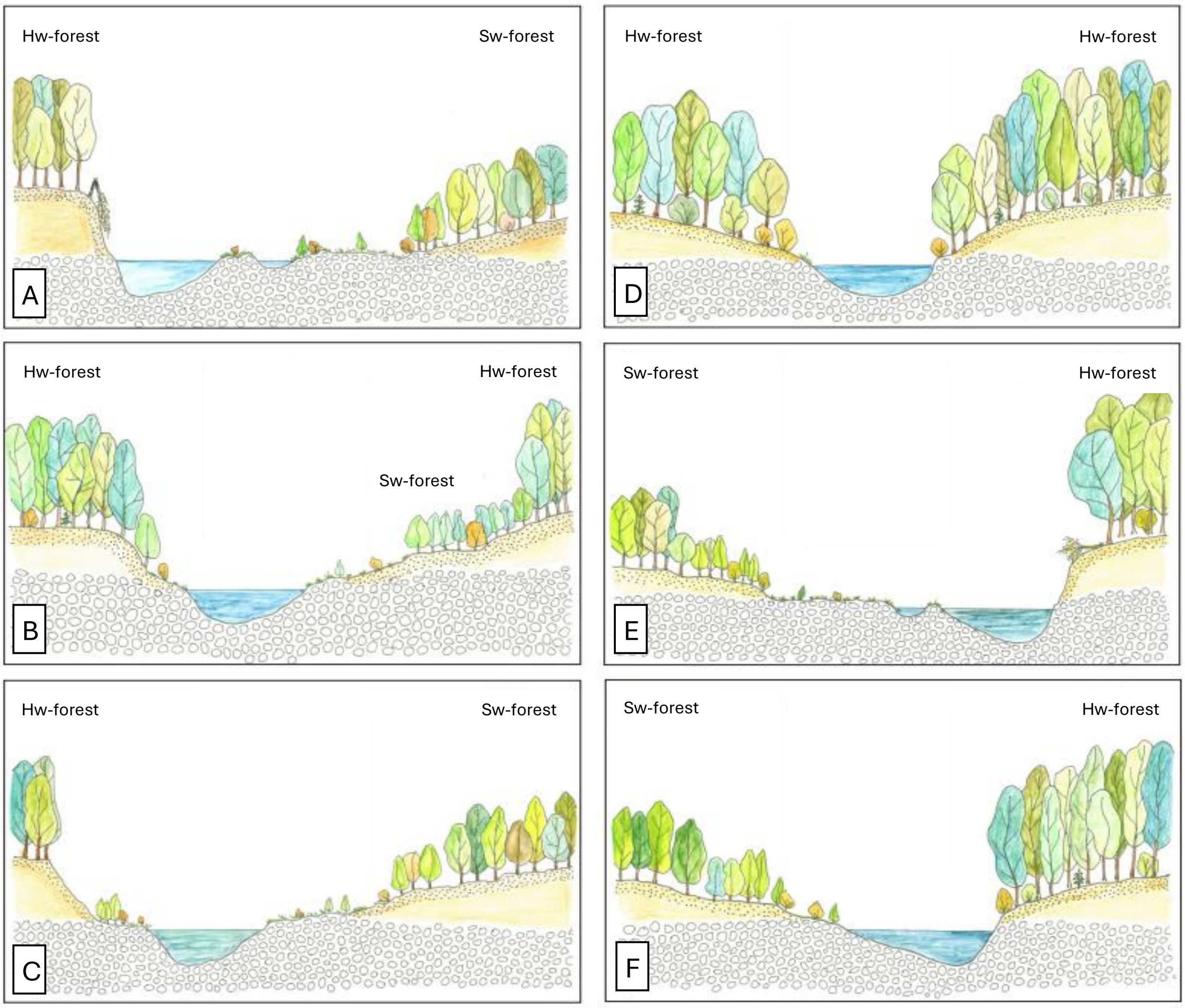


Fig.6: Fluvial dynamics shape the existence of successional patterns. *(Source: Reif et al. 2024, drawings from S. Hagenguth; with permission, modified) (Hw.-forest = hardwood forest; Sw-forest = softwood forest)*

A: *Right: Sediment deposition at the slip-off bank with pioneer willow species. left: channel-side erosion of hardwood floodplain forest at the cut bank.*

B: *Right: Progressive succession at the slip-off bank with the growing softwood forest, sediment deposition.*

C: *Right: Beginning shift of the main channel to the right. Integrating species such as elms, ashes, and oaks transform the softwood floodplain forest into a hardwood floodplain forest. Left: The hardwood floodplain forest reaches its optimal development, and individual willows settle near the channel.*

D: *The main channel has shifted to the centre. Near the channel, willow scrubs and small forests can be found.*

E: *Right: The main channel forms the 'new cut bank' and erodes the hardwood floodplain forest. Left: The slip-off bank has developed by sedimentation, and a new softwood floodplain forest is forming, adjacent to the remaining hardwood floodplain forest.*

F: *Right: The main channel has shifted and erodes the hardwood floodplain forest at the cut bank. Left: On the slip-off bank, succession leads to the development of a softwood floodplain forest.*

Grain size as key for vegetation structures

The development of vegetation succession series is strongly influenced by soil type. This, in turn, is closely related to the river's course, as variations in flow velocity and meandering lead to the deposition of sediments with differing particle sizes at specific locations. Gravel allows water to infiltrate easily, whereas silt, due to its higher water-holding capacity, retains moisture closer to the surface and thus makes it more available for plants (Margl 1973).

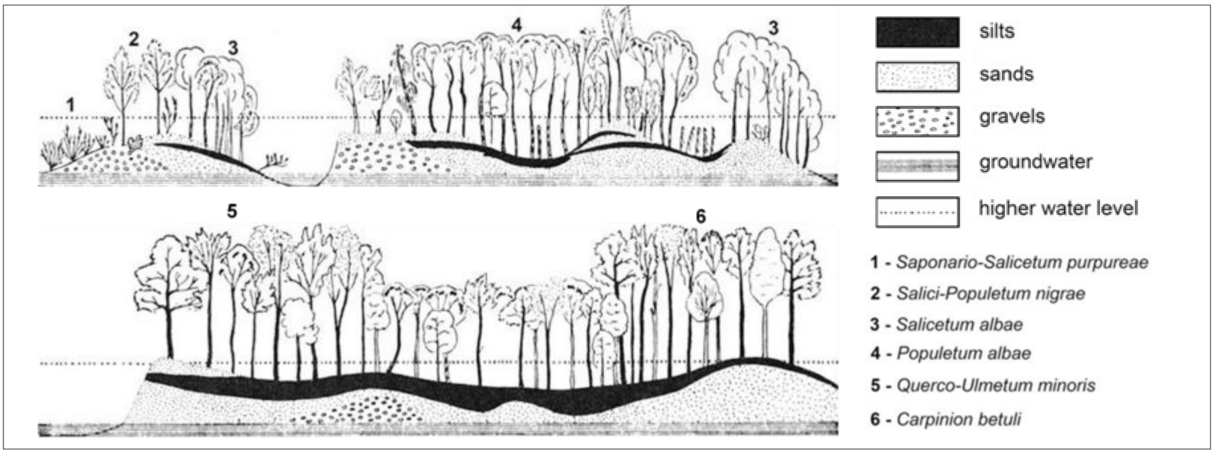


Fig.7: A schematic profile of a naturally created intact vegetation structure of the Danube floodplain.
(*Source:* Margl 1971*, modified)*

The cross-section through the different stages of floodplain vegetation (Fig.7) shows the natural development stages depending on their age, elevation and flooding frequency (Reif et al. 2024). The vegetation stages occur naturally more or less after one another and approximately follow this profile if there was no hydrological dynamic. Such schematic representations help to understand the habitat conditions, however, plant community series do not always follow clear or stable patterns (Sitzia et al. 2023).

Predominantely inundated low areas keep free of vegetation whereas pioneer annuals (e.g., *Chenopodium, Polygonum*) are found when frequenly inundated. Areas with infrequent flooding are colonised by perennial tall grasses and reeds. Narrow strips of willow scrub (*Salix purpurea*, *S. triandra*) develop on gravel or sand banks and transition into flood-tolerant woodlands dominated willow forests (*S. alba* and *Alnus incana*). Hardwood forests composed of ash, elm, and oak occur on higher, fertile soils that flood only within high water events (Sitzia et al. 2023; Reif et al. 2024).

Potential Natural Vegetation

In 1956 the concept of potential natural vegetation (PNV) was introduced by Reinhold Tüxen and until today it serves as an important tool in the field of nature conservation and landscape management (Kowarik 2016). It provides a methodological approach to determine how the natural vegetation of an area would develop if only natural processes (eg. geology, climate, morphology, flood inundation) influenced the land but not human impacts (eg. agriculture, forestry, recreation) (Tüxen 1956). In this study the concept of PNV helps to investigate how natural vegetation could have looked like in the Stockerauer Au if no significant human influences would have degraded its state within the last centuries.

Floodplain vegetation has adapted to the fast-changing and often unpredictable conditions. Ephemeral mudflat communities ("Schlammlingsfluren") as pioneers, for instance, can overdure for many years until water levels recede to then develop very quickly before being submerged or overgrown again. Willows growing have flexible branches and narrow leaves close to a stream to resist high flow velocities and mechanical stress. Branches of some Willow and Poplar species develop root shoot if covered by substrate and *Salix alba* (white willow) can even grow roots into the water. *Populus alba* (white poplar) can develop root shoots after the destruction of its trunk and *Cornus sanguinea* (dogwood) is spreading by runners. Due to the "fertilisation" via floodings, this ecosystem is home to some of the quickest growing trees and many ruderal plants. Furthermore, the seed dispersal of the trees is adjusted: *Salix* and *Populus* have airworthy seeds and some fruits eg. of sandthorn (*Hippophae rhamnoides*) are floatable (Margl 1973).

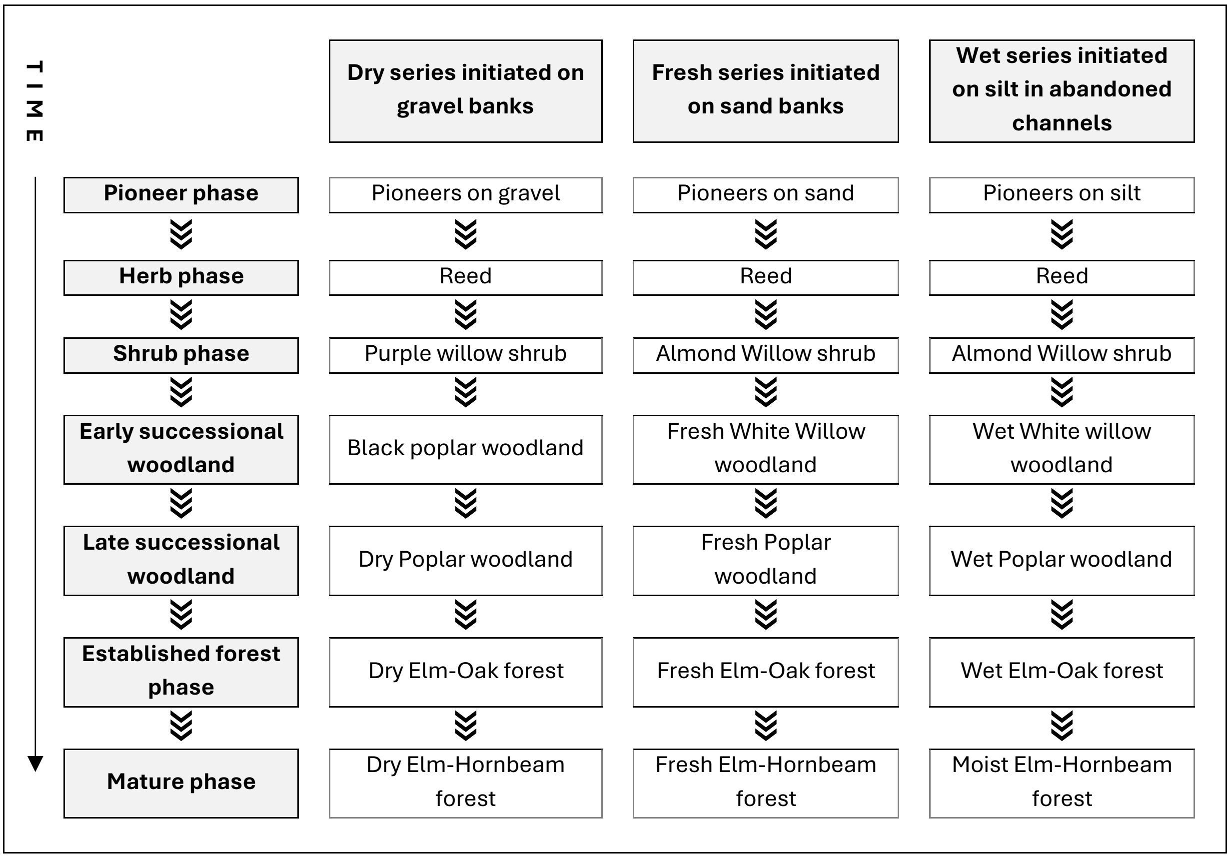


Fig.8: Scheme of ecological succession in the National park "Donau-Auen". *(based on Margl (1973) and Jelem (1974); after (Schöpfer 2016))*

In the following, the typical Potential Natural Vegetation of the Danube floodplain is described and structured according to the phases (pioneer -> mature) outlined in figure 8. There it is also differentiated between dry, fresh, and wet succession series based on the nature of the substrate which Wendelberger-Zelinka described in 1952 (Wendelberger 1952).

2.5.1. Pioneer phase

The early settlements were located along flowing water channels, today mostly along the regulated river. Due to the few new deposits along the river, which has been confined in a stone corset, there are now only very few remaining (Margl 1973).

Dry series develop on gravel banks as it is highly porous and lets water as well as nutrients through. Gravel beds are formed in the active zone of a river and are often inundated by water. Plants colonizing the gravel must be able to endure periods of extreme dryness and must have resilience to recurring mechanical disturbances (Egger et al. 2009). Therefore, only specialists can survive with these conditions. A dominant pioneer in former times was *Myrcaria germanica* but, as soon as other herbs and shrubs overshadow them, they don't receive enough light and disappear (Margl 1972).

Within the pioneer phase on sand typical plants are *Agrostis alba, Phalaris arundinacea, Melilotus albus* and *Euphorbia gerardiana* (Drescher et al. 2014). Sand is an intermittently suspended-load deposit, transported by saltation. Typically, medium-grained and fine-grained sand sediments settle via vertical accretion above bedload deposits during overbank flow (Margl 1971; Schöpfer 2016).

The wet series start with silt settling at low velocities and clay in standing water. Consequently, these fine-grained sediments vertically accrete in the depressions of abandoned channels and flood pools, which remain flooded for longer periods (Schöpfer 2016). Over time their relief rises to the point where it equalizes with its surroundings creating a plain (Margl 1973). Typical pioneer plants in eutrophic standing water bodies of the Danube floodplain are *Nuphar lutea* and *Nymphaea alba*. Schratt-Ehrendorfer (1999) stated that these species are indicators for a development towards terrestralization. Shores of oxbow lakes and ponds silt up and are only intermittently underwater. Typical for these semiaquatic habitats are reeds like *Phragmites australis* and *Phalaris arundinacea*.

2.5.2. Herb phase

With contionuing succession, the pioneer phase is replaced by herbecous cover. This can happen at places where landform rises above the mean summer water level (Egger et al. 2009). Pioneers are contiously displaced with reeds and subsequently shrubs. In the pre-regulated Danube floodplains the now endangered *Typha minima* was colonizing the sandy deposits (Drescher et al. 2014).

2.5.3. Shrub Phase

The shrub section mostly concerns small-scale, hilly sites along streams and Sand as well as silt are the predominant grain sizes. The layer of humic topsoil is well developed and the soil continuous to be porous. Therefore, the soil has high water holding capacity and is classified as moist (Schöpfer 2016).

The Vegetation is represented by *Salix alba, Salix viminalis, Salix triandra* (Jelem 1974) and *Salix purpurea*. Several willow species can germ on the bare sediment banks. *Populus nigra* is occasionally occurring and Alnus incana emerges but is not able to exploit its full growth potential due the limited availability of water (Margl 1973).

Whereas Purple Willow shrub is found on gravel beds inundated 60% of the year, the Fresh Almond Willow shrub phase is often located on the steeper river banks and the Wet Willow shrubs are on plains near the stream, strongly influenced by groundwater (Margl 1973).

2.5.4. Early successional woodland

This is the lowest-lying forest community in the floodplain area and is so strongly influenced by water that, apart from the white willow (*Salix alba*), no other tree species can tolerate the prolonged inundation. Typically, scattered willows grow within a herbaceous or grass-dominated layer that favours moist conditions. In addition to the characteristic white willow, shrub willows can occur if there is enough sunlight for them (Margl 1973).

While the fresh willow woodland grows along flowing waterbodies, the wet willow woodland is generally distinguished by its location along oxbow lakes or isolated channels. In the latter, white poplar (*Populus alba*) and occasionally field elm (*Ulmus minor*) begin to establish. With increasing age and sediment accumulation, both moist and wet willow woodlands gradually transition into fresh poplar forests (Margl 1973).

Within the floodplain, isolated tall-sedge meadows (Großseggenwiesen) can be found. These reproduce vegetatively after flood events, leading to mosaic-like patterns of species assemblages. Diagnostic species of these litter meadows (Streuwiesen) include *Carex gracilis, Poa palustris, Rumex crispus, Agrostis stolonifera* and *Baldingera arundinacea*. Other characteristic species include Forget-me-not (*Myosotis palustris*) and the Creeping buttercup (*Ranunculus repens*) (Margl 1973; Jelem 1974).

On gravel, black poplar woodland increasingly replaces *Salix* species with inundations becoming rarer (in average 2 years). *Salix alba* can still be dominant and is typically found on depressed spots of the surface where the germ buds are able outlast periods where the upper soil layer is dried out. *Cornus sanguinea* as well as *Crategus monogyna* join in the course of time (Margl 1973). Although the water holding capacity of the soil remains limited, the high porosity facilitates good access to the groundwater table. Thus, the soil can be classified as moist (Schöpfer 2016).

2.5.5. Late successional woodland

The dominant tree species is the white willow (*Salix alba*), and, depending on the site, also the black poplar. The softwood floodplain is regularly flooded and is limited to the young, low-lying parts of the floodplain (Wendelberger-Zelinka 1952).

Dry poplar woodland is located a bit higher than fresh poplar woodland and is mainly distinguished by its substrate. Dry poplar woodland grows only on Schlick whereas for the fresh type it's a mixture of Lehm and Schlick. There may be a gravel layer underneath which creates dry conditions. The species that are typical for such conditions are black poplar, liguster (*Ligustrum vulgare*) and Weißdorn (*Crataegus*) which marks the transition to the dry alluvial forest. Heliophilous species such as *Galium mollugo* and *Calamagrostis epigeios* also can exhibit increased abundance (Margl 1973).

Typical for Fresh poplar woodland are *Ulmus minor, Quercus robur* and *Fraxinus excelsior* in the first tree layer and *Acer campestre* in the second tree layer. The fresh poplar forest differs from the more moist type by the presence of the following species: *Sambucus nigra, Clematis vitalba, Stachys sylvatica, Aegopodium podagraria, Brachypodium sylvaticum, Carduus crispus, Galium aparine,* and *Humulus lupulus* (Margl 1973).

Wet poplar woodland is heavily influenced by groundwater and not broader than 2 meters. This forest community lacks clear diagnostic species, as it is too dry for the characteristic flora of the wet willow woodlands, yet still too frequently inundated, excessively moist, and poorly aerated to support species indicative of higher and drier sites. Populus alba often becomes dominant.

The tree layer also includes *Prunus padus, Fraxinus excelsior,* and *Alnus incana* (Margl 1973). The soil is classified as moist, compact brown earth, exhibiting rust-colored mottling due to periodic water saturation (Jelem 1974). Species indicative of moderate moisture conditions that tend to proliferate massively within this mesic poplar forest include *Carex acutiformis, Rubus caesius,* and *Baldingera arundinacea* (Margl 1973).

2.5.6. Established forest phase

In hardwood floodplain forests, species characteristic of drier and less frequently inundated areas become dominant. Typical species that mark the development of such habitats include pedunculate oak (*Quercus robur*), field elm (*Ulmus campestris*), European hazel (*Corylus avellana*), European ash (*Fraxinus excelsior*), and field maple (*Acer campestre*). Accompanying the woody vegetation are a variety of shrubs and climbing plants such as the wild grapevine (Vitis sylvestris), common pear (*Pyrus communis*), and common privet (*Ligustrum vulgare*), which add to the vertical layering and biodiversity of the habitat. The herbaceous layer is similarly diverse and includes notable indicator species like the hedge violet (*Viola beraudii*), wood violet (*Viola sylvestris*), herb bennet (*Geum urbanum*), lungwort (*Pulmonaria officinalis*), and wood sedge (*Carex sylvatica*). These species are well adapted to the comparatively stable and nutrient-rich conditions found in hardwood floodplains (Margl 1973).

The Wet Elm-Oak Forest moist hardwood floodplain lies at the same elevation as the moist poplar floodplain, but it is less frequently flooded due to upstream riverbanks. In case of flooding, the water seeps away only slowly because of a thick layer of silt and clay. It is characterized by the absence of the numerous elevation indicators of the fresh hardwood floodplain, while good moisture indicators are mostly missing or only sparsely present due to good shading (Margl 1973). The soils of the Fresh Elm-Oak Forest have a well-developed, approximately 0.5 meter pure alluvial loam cover. The topsoil consists of a 10-20 cm thick dark gray mull humus horizon, which gradually transitions into the brown-colored subsoil. Due to the favorable soil conditions, plants can grow very well. Therefore, these areas are often used as meadows or arable land. The potential natural vegetation of the fresh hardwood floodplain includes, among others, *Juglans regia, Salvia glutinosa, Origanum vulgare,* and *Eupatorium cannabinum* (Margl 1973).

The Dry Elm-Oak Forest contains gravel in the substrate and shows signs of drought stress in the floodplain vegetation. Ulmus minor and Quercus robur are the dominating trees. Further *Populus nigra* and *Populus alba* might remain scatteredly (Jelem 1974; Schöpfer 2016).

2.5.7. Mature phase

The succession reaches its terminal stage (climax) as a mature forest characteristically featuring *Ulmus minor, Acer campestre, Quercus robur, Carpinus betulus, Fraxinus excelsior* and *Tilia cordata* (Drescher et al. 2014).

The Fresh Lime Forest is only affected by flood events that occur less frequently than once every ten years. Over time, this has allowed flood-avoiding plant species to establish themselves, most notably the Small-leaved Lime (*Tilia cordata*). In contrast, typical floodplain forest species have declined significantly or have disappeared entirely. Many species, especially those with a preference for light, are found along the edges of forest which makes this part the richest in terms of species composition. The following species are indicative of the linden-floodplain: Grey Poplar (*Populus × canescens*), Cornelian Cherry (*Cornus mas*), Dog Rose (*Rosa canina*), White Sedge

(*Carex alba*), Common Ivy (Hedera helix), Wayfaring Tree (Viburnum lantana) and Lily of the Valley (*Convallaria majalis*). These species are characteristic of a forest ecosystem that has shifted from a dynamic floodplain to a more stabilized, less frequently inundated environment, leading to significant ecological succession and structural change in vegetation composition (Margl 1973).

Succession reaches its terminal stage with Caprinus betulus being increasilgl present. The <u>Fresh Elm-Hornbeam Forest</u> has a different substrate than the linden-floodplain but many similar species that are characteristic. The hornbeam requires a denser seedbed than the lime tree, which is why it begins to spread in the dammed floodplain. The transition to hornbeam floodplain takes several decades, even if all site conditions are already met. The biggest difference is the existence of hornbeam which needs a denser ground for seedlings to germinate. Other trees of typical for the mature forest are *Populus x canescens, Acer pseudoplatanus, Prunus avium, Quercus robur, Ulmus minor* and *Fraxinus excelsior* (Margl 1973). *Tilia cordata* is often found on high ridges (Jelem 1974).

2.5.8. Specialised community: Aquatic plants

Wendelberger-Zelinka (1952) differentiatet between side arms, oxbow lakes (Altwässer), floodplain lakes, and floodplain ponds. Floodplain lakes (Auweiher) depend on groundwater but have greater depth, allowing them to retain water throughout the entire year and floodplain ponds (Autümpel) periodically drying (ephemeral), usually shallow waterbodies of small surface area. They typically originate from deeper parts of already silted-up side arms or from detached offshoots of oxbow waters. For the various water types there are typical plant communities described below:

Aquatic plants of *Potametalia* that occur independently of the water type include for example *Potamogeton natans, Ranunculus circinatus, Potamogeton pectinatus* and *Alisma Plantago-aquatica*. Only in oxbow lakes *Elodea canadensis, Callitriche verna* or *Myriophyllum spicatum* can be found.

Deep floodplain lakes are home to species like Hottonia palustris, Nuphar luteum or Ceratophyllum demersum and in shallow waters Hippuris vulgaris and Stratiotes aloides can be observed.

Within the group of reeds (Röhrichte und Groß-seggenwiesen) Sagittaria sagittifolia, Agrostis alba, Utricularia vulgaris and Sparganium erectum are worth mentioning.

In ponds or lakes the communities *Baldingera arundinacea and Scirpeto-Phragmitetum* include species like *Typha latifolia, Schoenoplectus lacustris, Rumex Hydrolapathum* and *Iris Pseudacorus* (Wendelberger-Zelinka 1952).

2.5.9. Specialised community: Xeric habitats

Xeric habitats (Heißländen) are dry habitats within alluvial areas that support rare and endangered species. The occuring vegetation is structured in a mosaic-like patterns and exhibits considerable small-scale variability, making precise assignment to a specific plant community difficult. The most dominant phytosociological orders present on these sites are *Brometalia erecti* and *Festucetalia valesiacae*. In addition to small, ecologically valuable arid grassland (Steppe) relics featuring *Stipa joannis*, there are also areas undergoing shrub encroachment or abandonment (Kurmann et al. 2017).

2.6. Protected objects by FFH

The Stockerauer Au is home to a variety of protected plant as well as animal species that are dependent on such habitats seasonally or the whole year around. Floristic specialties are primarily found in the numerous floodplain meadows and along the floodplain waters. Rare and threatened species that were recorded in these meadows are Perennial Flax (*Linum perenne*), Austrian Speedwell (*Veronica austriaca*) and Siberian Iris (*Iris sibirica*). Among the backwaters endangered species like the Yellow Waterlily (Nuphar lutea), Creeping Celery (*Apium repens*) and Arrowhead (*Sagittaria sagittifolia*) or Water Soldier (*Hydrocharis morsus-ranae*) are some of many that'd be noteworthy.

Protected bird species like the Kingfisher (*Alcedo atthis*) which can often be observed along "Krumpenwasser" or the Sea Eagle (Haliaeetus albicilla) which uses the Danube floodplains as wintering grounds, find their required habitat conditions there (Straka 1995) as well as swarms of Bee-eaters (*Merops apiaster*) which gather there after breeding especially near the meadows.

Other flagship species include the European Beaver (*Castor fiber*) that can be found in the backwaters or the Danube Crested Newt (*Triturus dobrogicus*) as well as the European Fire-bellied Toad (*Bombina bombina*) find habitats with suitable breeding waters. In near-natural floodplain forests, xylobiontic beetle species such as the Stag Beetle (*Lucanus cervus*) finds favourable habitats like the beautifully coloured Blue-tailed Emerald Dragonfly (*Somatochlora metallica*) (Straka 1995; *Managementplan für das Europaschutzgebiet Tullnerfelder Donau-Auen* 2023).

3. Material and Methods

The research questions require two types of data collection. To assess the ecological state of the vegetation (primarily forests) (Part A), a vegetation mapping focussing on the tree inventory was conducted in July and August 2024. For the historical analysis (Part B), a vegetation map from 1990 (Straka 1990) was digitised and compared, alongside a literature review.

3.1. Current ecological status

Prior to the data collection diverse preprations were made. A Q-Field query in Q-GIS was created, permission for field work was obtained, mapping methods were developed, and literature was read to know how to determinate the most important species.

3.1.1. GIS-Preparation for field-work

Prior to mapping, the entire nature reserve was divided into 209 polygons so that the defined parameters could be collected for each polygon. The polygons were divided based on similar vegetation patterns (tree species composition) evident in the orthophotos as well as borders of the core-areas and the road and path network, extracted from the cadastral map (Fig.9). The subdivision was performed in Q-GIS using an orthophoto (20 cm, 2019), a cadastral map, digital elevation model and surface model (source: Geoshop, Federal municipality of Lower Austria). The core areas were manually extracted from a printed map (Municipality of Stockerau 2023). The polygons encompass an area of 0.01 to 10 ha however most of the polygons are between 1 and 4 ha large. The projected coordinate system used in this study's GIS work is MGI Austria GK M34.

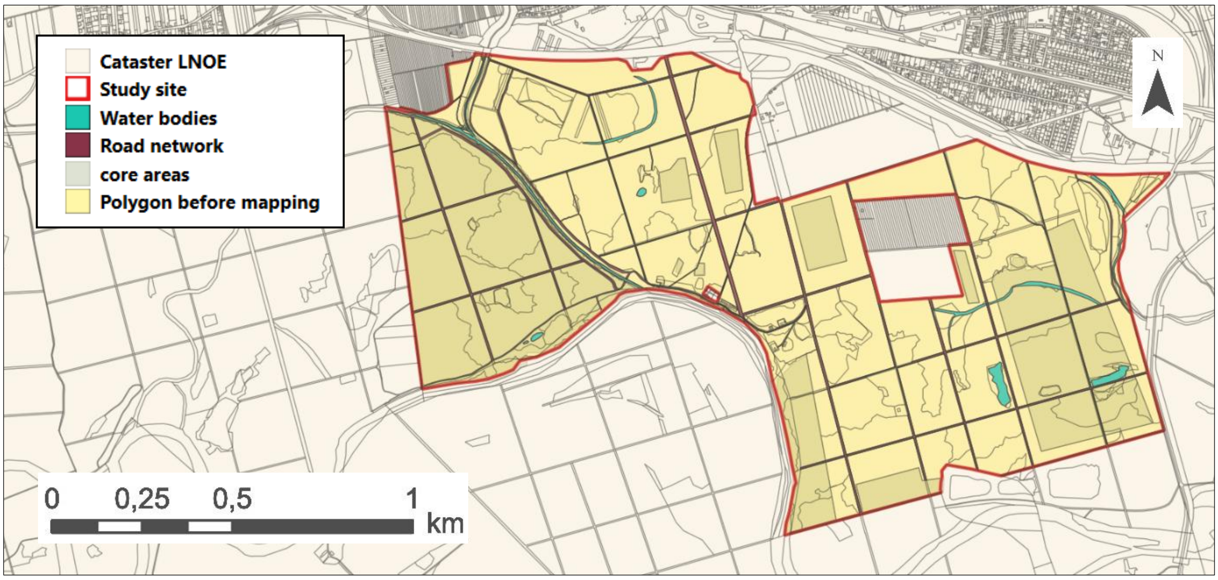


Fig.9: Map of the polygons, road network and water bodies used for field work. *(data source: Geoshop, Federal municipality of Lower Austria)*

It was discussed with the Nature Conservation Department of the County of Lower Austria which data would be useful beyond determining habitat types + conservation status, biotope types, and vegetation types. The following categories were agreed upon: proportions of the tree/shrub and herb layer, tree age classes, proportion and condition of existing ash trees, neophyte occurrence and species of invasive neophytes, as well as total deadwood proportion and proportion of standing deadwood. Furthermore, it was agreed upon which tree species occur in the respective polygons and with what frequency. Moreover, the locations of particularly old trees or trees with valuable hollows can be found. It was also planned to record protected animal and plant species when they were found.

3.1.2. Methods of assessment and classification

For every category that was assessed, parameters were created to then effectively assess each polygon. For a better overview all parameters are listed in the following table with a short decription (Tab.2).

Tab.2: Parameters of the attribute table for Q-Field Query.

Every Parameter was carried out for each polygon.

(HT ... habitat type; BT ... biotope type; VT ... vegetation type; struct ... structure; dis.ind ... disturbance indicators; d ... dominant; s ... subdominant; m ... moderately abundant mixed in; r ... rare/ sporadically scattered; prop ... proportion; dw ... dead wood)

Parameter	Description	*notes*
ID MAP	Identification number	*ID of polygon in map*
Area	Area in m^2	*in m^2, (minimum $100m^2$)*
domType	dominant structure types	*forest/reforestation/shrubland/meadow/water body/tall herbs/ river bank/ fallow/infrastructure*
corezone	in corezone	*yes/ no*
HT-code	habitat type - code	*from Ellmauer 2005*
HT-area	habitat type - area	*Indikatoren A/B/C; from Ellmauer 2005*
HT-spCompo	habitat type - species composition (trees)	*Indikatoren A/B/C; from Ellmauer 2005*
HT-struct	habitat type - structure	*Indikatoren A/B/C; from Ellmauer 2005*
HT-usage	habitat type - intensity of usage	*Indikatoren A/B/C; from Ellmauer 2005*
HT-deadw	habitat type - dead wood	*Indikatoren A/B/C; from Ellmauer 2005*
HT-hydro	habitat type - hydrology	*Indikatoren A/B/C; from Ellmauer 2005*
HT-dis.ind	habitat type - indicators of disturbances	*Indikatoren A/B/C; from Ellmauer 2005*
HT-deerinf	habitat type - influence of deer browsing	*Indikatoren A/B/C; from Ellmauer 2005*
HT-state	state of whole polygon	(calculation afterwards)
HT-notes	habitat type - notes	*text*
BT-code	biotope type - code	*from Red List Austria*
BT-name	biotope type - name	*from Red List Austria*
VT-code	vegetation type - code	*self-made VT list*
VT-name	vegetation type - name	*self-made VT list*
dSpecies1	dominant tree species	*list to choose, + abundance class 1-5*
dSpecies2	dominant tree species	*list to choose, + abundance class 1-5*
dSpecies3	dominant tree species	*list to choose, + abundance class 1-5*
sSpecies1	subdominant tree species	*list to choose, + abundance class 1-5*
sSpecies2	subdominant tree species	*list to choose, + abundance class 1-5*
mSpecies1	interspersed tree species	*list to choose, + abundance class 1-5*
mSpecies2	interspersed tree species	*list to choose, + abundance class 1-5*
rSpecies1	admixed tree species	*list to choose, + abundance class 1-5*
rSpecies2	admixed tree species	*list to choose, + abundance class 1-5*
+Species	more/ other/ rare tree species	*text*
%treecover	cover ratio of trees in %	*0-100 in % (all 3 groups make up 100%)*
%bushcover	cover ratio of bushes in %	*0-100 in % (all 3 groups make up 100%)*
%herbcover	cover ratio of herb layer in %	*0-100 in % (all 3 groups make up 100%)*
% <10y	tree age group 1 from 0-10 y	*0-100 in % (all 5 groups make up 100%)*
% 10-30y	tree age group 2 from 10-30 y	*0-100 in % (all 5 groups make up 100%)*
% 30-60y	tree age group 3 from 30-60 y	*0-100 in % (all 5 groups make up 100%)*
% 60-120y	tree age group 4 from 60-120 y	*0-100 in % (all 5 groups make up 100%)*

% >120y	tree age group 5 from 120-... y	*0-100 in % (all 5 groups make up 100%)*
%ashprop	% of ash tree amount of all trees	*0-100 in % (100% = only ash trees grow there)*
%ashclass1	health status of ash trees; (nearly) fully vital	*0-100 in % (100% = all ash trees are in that state)*
%ashclass2	health status of ash trees; predom. vital	*0-100 in % (100% = all ash trees are in that state)*
%ashclass3	health status of ash trees; predom.died off	*0-100 in % (100% = all ash trees are in that state)*
%ashclass4	health status of ash trees; (nearly) fully dead	*0-100 in % (100% = all ash trees are in that state)*
%dw-total	% of total deadwood	*0-100 in % (100% = same vol. as living biomass)*
%dw-lying	% of lying dw as proportion of total dw	*0-100 in % (100% = all dw trees are lying)*
N-class Inv+NInv	class of all invasive and not invasive neophytes according to their cover of whole polygon	*1...<5 % cover* *2...5-20 % cover* *3...>21% cover*
Np-class Inv. Excl RoJu	class of all invasive neophytes including *Robinia pseudoacacia* and *Juglans nigra* according to their cover of whole polygon	*1...<5 % cover* *2...5-20 % cover* *3...>21% cover*
Np-class Inv. incl RoJu	class of all invasive neophytes excluding *Robinia pseudoacacia* and *Juglans nigra* according to their cover of whole polygon	*1...<5 % cover* *2...5-20 % cover* *3...>21% cover*
NpSpecies1	invasive neophyte species	*list to choose, + abundance class 1-5*
NpSpecies2	invasive neophyte species	*list to choose, + abundance class 1-5*
NpSpecies3	invasive neophyte species	*list to choose, + abundance class 1-5*
NpSpecies4	invasive neophyte species	*list to choose, + abundance class 1-5*
Np_notes	other invasive neophyte species and notes	*text*
FFH-flora	FFH-protected plants if discovered	*from FFH list*
FFH-fauna	FFH-protected animals if discovered	*from FFH list*
notes	other notes	*text*
Photo	photo + GPS location of typical structure evtl. special features	*jpg with coordinates*
specPoints	*special points + GPS location*	*ancient/veteran/notable trees, nests, tree hollows (nice to have but not obligatory)*

In the following sections the methods and attributes listed in table 2 will be defined and explained.

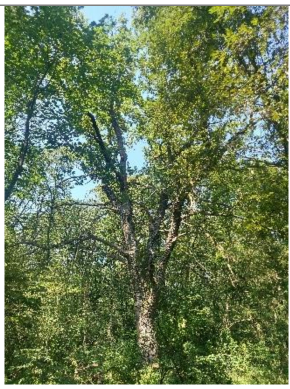
3.1.2.1. Habitat types and degree of conservation

Annex I of the Habitats Directive (92/43/EEC) on the conservation of natural habitats and of wild fauna and flora, lists 198 natural habitat types, 65 of which are designated as priority habitats. Priority status indicates that these habitat types are at risk of disappearing. In Austria, 65 of these habitat types are represented and roughly one third of those listed in Annex I (Habitats Directive, Annex I).

The determination of the predominant habitat types and their conservation grade for each polygon was conducted following the methodology and mapping guidelines outlined by Ellmauer (2005). In accordance with this framework, specific criteria are evaluated for each habitat type, with each criterion assigned to a conservation grade of A, B, or C. A refers to (near)-natural conditions and C for degraded conditions. Only the habitat types for the forests were assessed.

Table 3 shows the two habitat types recorded, their phytocoenses (forest types) and the respective obligate and facultative tree species through which the forest types were identified with an example photo. If other tree specias had a cover over 5%, the forest was classified only as “Softwood” or “Hardwood” forest.

Tab.3: Phytocoenosen of the allovial forest habitat types and their obligate or factultative abundances. *(5...dominant, 4...subdominant, 3...interspersed (eingesprengt), 2 admixed (beigemischt), 1...once) (/ ... and/or; *... Other native broadleaved tree species are not classified as non-native (Fremdholz) if their canopy cover does not exceed 5% in the final stand.) (Photos: Nina Mosor; after Ellmauer et al. 2005)*

Habitat type	Phyto-coenoses	Obligate trees	Facultative trees	Photo
91E0 **Softwood alluvial forest with Alnus glutinosa and Fraxinus excelsior**	Willow alluvial forest	*Salix alba/ S. fragilis/ S. purpurea/ S. rubens/ S. triandra/ S. viminalis 4-5*	*Fraxinus excelsior 2-4 Populus alba 2-4 P. canescens 2-4 P. nigra 2-4 Prunus padus 2-4 **	
	Poplar forest	*Fraxinus excelsior 4-5 Populus alba/ P. canescens/ P. nigra 4-5*	*Alnus incana 2-4 Prunus padus 2-4 Salix alba 2-4 Ulmus laevis 2-4 U. minor 2-4 **	
91F0 **Hardwood Riparian mixed forests of Quercus robur, Ulmus laevis, Ulmus minor, Fraxinus excelsior/ angustifolia**	Fresh hardwood forest	*Fraxinus excelsior/ F. angustifolia 4-5 Quercus robur 2-3 Ulmus minor 2-3*	*Acer pseudoplatanus 2-3 Alnus incana 3 Juglans regia 2-3 Populus alba 3-4 P. canescens 3-4 P. nigra 3 Prunus padus 3-4 Ulmus glabra 3 U. laevis 3*	
	Dry hardwood forest	*Fraxinus excelsior/ F. angustifolia 2-5 Quercus robur 2-3 Ulmus minor 2-3*	*Acer campestre 2-3 A. pseudoplatanus 2-3 Carpinus betulus 2-3 Malus sylvestris 3 Populus alba 2-3 P. canescens 3-4 P. nigra 3 Pyrus pyraster 3 Tilia cordata 2-3*	

3.1.2.2. Biotope types

In this study, a biotope type is defined as by ecological conditions that are largely uniform and distinct from those of other types, thereby offering specific conditions for biological communities. The classification includes both abiotic factors (e.g. moisture, nutrient availability) and biotic characteristics (such as the presence of specific vegetation types and structures, plant communities, and animal species) (Essl et al. 2002a).
The biototope types were taken from the "reference list of biotope types in Austria 2015" from Umweltbundesamt (Essl 2002).

3.1.2.3. Vegetation types

As some areas within the study site can't be assigned to a habitat- or biotope type, the vegetation types were created so every polygon can be labelled. This refers for instance to gardens, buildings or areas that don't meet the requirement for a habitat type (Tab.4). Additionally, there is no exclusive ash-poplar forest habitat- or biotope type and within the vegetation type classes it is possible to classify those in one category.
For most visualisations a simplified version of vegetation types was used as background.

Tab.4: Vegetation types.

Code	*Vegetation type*
1	**FOREST**
10	HARDWOOD forest
11	Oak-Elm-Ash forest (91F0)
12	Maple-Ash forest
13	Ash-Poplar forest (91E0 or 91F0)
14	SOFTWOOD forest
15	Alder-Ash-Willow forest (91E0)
16	White Willow forest (91E0)
17	Poplar forest
18	Silver Poplar forest
2	**FORESTRY**
20	Deciduous tree reforestation predominantly native species over 10 years
21	Deciduous tree reforestation predominantly non-native species over 10 years
22	Deciduous tree reforestation predominantly native species under 10 years
23	Deciduous tree reforestation predominantly non-native species under 10 years
3	**SHRUB, PERENNIAL MEADOW, REED and REEDBED**
31	Deciduous shrubs
32	Tall herbaceous meadows
33	Wet tall herbaceous meadows including reedbeds, (tall) sedge sedges, and riparian willow scrub
34	Tall reedbeds (including common reed sedges) / (tall) sedge sedges
35	Neophyte meadows
4	**MEADOW**
40	Wet alluvial meadows
41	Fresh to moderately dry oat grass meadows
42	Dry and semi-dry grassland

43	Intensive meadows
44	Fallow/deforested
5	**WATER**
51	Flowing water
52	Standing water (partly 3150)
53	Wetland or temperate water
6	**INFRASTRUCTURE**
61	Road and path network
62	Urban: houses, gardens, parking lots

3.1.2.4. Proportions of the tree, shrub and herb layer

When estimating the tree layer, the canopy cover from 6 meters height was considered. The bush layer refers to the canopy cover from 1 to 6 meters and the herb layer to below 1m meter height. The herb layer also includes bare soil which is not often occurring but within inundation zones.

3.1.2.5. Tree age classes

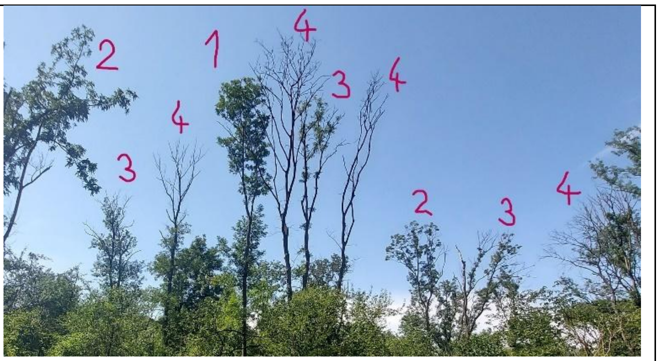
To categorise the trees, 5 age classes were created: 1:0-10y, 2:10-30y, 3:30-60y, 4:60-120y and 5: >120 years. For every class the percentage of the respectively occuring trees were estimated. All groups together make up 100% which is the total tree population in the polygon. The percentage states the proportion of the total tree amount, not the coverage of the age groups. The tree age was calculated by estimating the diameter at breast hight (DBH) and, if unsure of the age class, it was determined by using the website „Baumportal“ (www.baumportal.de/baum-alter-bestimmen). The DBH is determined at 1.30m above the ground. The estimated ages of tree species given from the platform were sometimes also compared with the age rings of cut down trees, which fit well in almost all cases.

3.1.2.6. Proportion and condition of existing ash trees

To get an insight of how much the ash tree dieback has decreased the population the ash tree proportion was estimated as the number of trees of the total amount of trees within the tree layer. The tree cover hasn’t been used because some ash trees have very small crowns (due to the dieback) and they wouldn’t be counted in if only the crown cover is considered. The crown cover is therefore included in the second evaluation: the health state of ash trees was explored by categorising them in four different classes and stating the respective proportions (tab.5).

Tab.5: Ash tree classes stated as the proportion of the total amount of ash trees in the polygon and examples for the classifications. *The numbers refer to the tree underneath them. (Photo: Nina Mosor)*

ash tree class	health status
1	(nearly) fully vital
2	predominantly vital
3	predominantly died off
4	(nearly) fully dead
Examples of classification →	



3.1.2.7. Total (invasive) neophyte occurrence and list of species

Definition of neobiota and invasive species:
Neobiota in Austria are species that were not occurring here until the year 1492. To distinguish neobiota based on their degree of impact on native flora and fauna, various definitions are used (Richardson et al. 2000). In the taxonomic tables, neobiota are classified into three categories: invasive neobiota, potentially invasive neobiota, and neobiota with no known impact to date (Essl et al. 2002b).
In German-speaking countries, neobiota are considered invasive if they occur so frequently in at least one biotope type in Austria that a) either displacement of native animal or plant species is documented or suspected, or b) the structure of the biotope type is significantly altered, or c) the site conditions or ecosystem processes are persistently modified (Essl et al. 2002b).

Before the mapping, it was studied which species are not native in Austria and which are possibly appearing in Lower Austria (Tab.6). Moreover, it was investigated which of those are classified as invasive and how to identify them. Only the neophytes from the list were mapped! There could be many more possible, especially aquatic plants.
The calculation was carried out for the whole study site excluding infrastructure and water bodies. The following species selection in table 6 was integrated in the query to choose from:

Tab.6: Neophytes given in the attribute table to choose from. *(Species marked with a * refer to invasive species in Austria* (Essl & Rabitsch 2002).

Ash-leaved maple (Acer negundo)*
Black locust (Robinia pseudacacia)
Tree of heaven (Ailanthus altissima)*
Hybrid poplar (Populus x canadensis)
Pennsylvanian ash (Fraxinus pennsylvanica)
Canadian goldenrod (Solidago canadensis)
Giant goldenrod (Solidago gigantea)*
Himalayan balsam (Impatiens glandulifera)*
Hypericum mellifera (Impatiens parviflora)
Japanese knotweed (Fallopia japonica)*
Giant hogweed (Heracleum mantegazzianum)
American fireweed (Epilobium ciliatum)
Ragweed (Ambrosia artemisiifolia)*
Milkweed (Asclepias syriaca)
Smooth-leaf aster (Aster novi-belgii)
Canadian waterweed (Elodea canadensis)*
Lanceolate aster (Aster lanceolatus)
Slit-leaf coneflower (Rudbeckia laciniata)
Bidens frondosa (Bidens frondosa)
Jerusalem artichoke (Helianthus tuberosus)
Small Balsam (Impatiens parviflora)
Annual fleabane (Erigeron annuus)

For every polygon three different neophyte categories were mapped:

1) Cover of all neophytes (invasive + not invasive)
2) Cover of all invasive neophytes including *Robinia pseudoacacia* and *Juglans nigra*
3) Cover of all invasive neophytes excluding *Robinia pseudoacacia* and *Juglans nigra*

The cover was stated by the numbers 1-3 according to their abundances in the respective polygon (Tab. 7).

Tab.7: Definition of the neophyte classes.

Nr. of class	Occurrence	Proportion within herb / bush / tree cover
1	low	<5%
2	moderate	6-20%
3	high	>21%

It was also noted how much a type of species is taking from the one cover type it occurs. For instance, Solidago gigantea was found in 6% of the herb cover it is assigned class 2, even if the herb cover only makes up 10% of the total vegetation cover. If additionally, Acer negundo occurred with 2% of the tree cover, an average (mean) of the two values was noted. This calculation makes a comparison between the different vegetation types easier, because, if wanted, only the herb layer of a forest patch can be compared to the herb layer of a meadow or fallow, independently how much herb cover the two patches possess.

3.1.2.8. Total deadwood proportion and proportion of standing deadwood

The amount of dead wood in managed forest is an important indicator for sustainability and biodiversity conservation and dead wood is one of nine pan-European biodiversity indicators for sustainable forest management (Humphrey et al. 2012). It can also be called biotope-wood as it plays an essential role for many species - especially deadwood with a larger diameter than 20 cm (Essl & Rabitsch 2002). There are many different methods how to define and classify deadwood (Merganičová et al. 2012).
This study only distinguishes between standing and lying deadwood and only takes coarse woody debris (CWD) larger than 20cm in diameter and a length of at least 2 meters into account.
The classification follows deadwood category 3 as defined by Erdmann and Wilke (1997) and corresponds to the same survey class used for assessing deadwood in the evaluation of habitat condition according to Ellmauer (2005).
The total deadwood proportion was calculated as percentage of the whole tree biomass within the polygon (=100%). As a second category the proportion of lying deadwood over 20cm of diameter was noted with the proportion of the total deadwood amount.

3.1.2.9. Tree species and their proportion

During the mapping via Q-Field, some of the tree species could be chosen from the prepared selection within the query. 3 species could be selected for every proportion class (Tab.4) and additional (also non-tree species) were written down in a separate field with their respective amount.
The abundance classes (1-5) were copied from the mapping instruction of Ellmauer (2005). The only difference is the class 1, which is used in this study if only one individual or a few but very young ones (not higher than 2m) were found within a polygon (Tab.8).

Tab.8: Abundance classes for tree species. *The numbers in the left column were used after fieldwork for the data visualisation in GIS.(Ellmauer et al. 2005)*

Number	Symbol	Proportion description	Proportion of crown cover
5	d	dominant	>51%
4	s	subdominant	26-50%
3	m	interspersed (medium)	6-25%
2	r	admixed (rare)	<5% but at least 2 species
1	rr	only 1 individual	<5% and only one species or few trees not higher than 2m

Within the data processing it was clear, that it's not possible to effectively visualise the tree species as recorded. Therefore, the data was transferred into a format where the 25 most abundant or habitat-defining tree species (Tab.9) are separately stated with a number according to their abundance (Tab.8). This made it then possible to visualize the occurrence for every of the following tree species seperately.

Tab.9: Tree species that were separately recorded and visualised. *Species marked with a * refer to trees not native in Austria.*

Common Ash (*Fraxinus excelsior*)
Pedunculate Oak (*Quercus robur*)
Field Elm (*Ulmus minor*)
European White Elm (*Ulmus laevis*)
White Poplar (*Populus alba*)
Grey Poplar (*Populus x canescens*)
Quaking Aspen (*Populus tremula*)
Black Poplar (*Populus nigra*)
White Willow (*Salix alba*)
Crack Willow (*Salix fragilis*) or Almond Willow (*Salix triandra*) or Osier (*Salix viminalis*)
Crab Apple (*Malus sylvestris*)
Small-Leaved Lime (*Tilia cordata*)
Grey Alder (*Alnus incana*) or Black Alder (*Alnus glutinosa*)
Black Cherry (*Prunus padus*)
Sycamore Maple (*Acer pseudoplatanus*)
Field maple (*Acer campestre*)
Walnut (*Juglans regia*)
Horse chestnut (Aesculus hippocastanum L.)
Hybrid poplar (*Populus x canadensis*)*
Balsam poplar (*Populus balsamifera*)*
Eastern black walnut (*Juglans nigra*)*
Black locust tree (*Robinia pseudoacacia*)*
Plane tree (*Platanus*)*
Ash-leaved maple (*Acer negundo*)*

3.1.2.10. Locations of keystone trees or tree features

This study differentiates between ancient trees, tree veterans and notable trees.

Ancient describes a tree which passed beyond maturity and is old (aged) in comparison with other trees of the same species (Fay & de Berker 2018). It presumably has a wide, likely hollow, trunk and its canopy may be small. These features don*t need to be a sign that the tree is about to die. In fact, even in this ancient stage the tree may stay alive for many decades or centuries (woodlandtrust).

Veteran is a descriptive term that refers to the tree's condition rather than its age and draws attention to exceptional qualities associated with particular saproxylic habitats in trees (Fay et al. 2018). It shows evidence of wounds or decay processes and significant amounts of dead wood. A veteran tree is a survivor that has developed some of the features found in an ancient tree, not necessarily because of time, but because of its life/ environment (woodlandtrust).

While ancient trees have habitat features sufficient to qualify them as veteran, not all veteran trees will automatically have entered the ancient age class. However, both are hotspots for biodiversity, hosts to colonising organisms above and below the earth and function as an integral living entity (Fay et al. 2018).

Notable trees are usually impressive mature trees that stand out in their local environment because they are large by comparison with other trees around them (woodlandtrust).

The trees were noted down in the query and, if especially noteworthy, a photo with GPS location was taken or only the location was recorded.

3.1.2.11. Protected animal and plant species

This category isn't a focus of this study, but if a protected exemplar was found and identified, it was recorded. To count as protected, it has to be listed in the IUCN Red List as "near threatened", "vulnerable", "endangered", critically endangered", "extinct in the wild" or "extinct" (Spitzenberger 2005).

3.1.2.11. Photos and GPS data

From every polygon and special place (eg. ancient tree) at least one photo was taken. The photos contain the GPS location and were numbered after the polygon they were occurring in.

3.1.3. Permission prior field-work

Prior to field mapping, official permission was obtained from the Federal Government, the Province of Lower Austria, and the municipality of Stockerau. It was confirmed that no destructive interference with flora, fauna, or habitat structures would occur. No plants or habitat elements would be removed, and special care would be taken to avoid disturbing sensitive wildlife. After the consultation of BirdLife Austria it was confirmed that no current nesting of highly disturbance-sensitive species is known of.

Key conditions included:

- Avoidance of disturbance to breeding birds and valuable vegetation
- Prohibition of any alteration to vegetation, soil, or rock formations
- Foot traffic limited to one person off designated paths to minimise impact
- In case of encountering nests, wide detours are required
- Fieldwork only within 8 am until 6 pm and not during strong winds or rainfall

3.1.4. Field-work

Material during field-work

During the field-work each area was visually assesed and classifyied on the site over a preset number af parameters (Tab.4). Localisation and registration were made using a handheld online GIS-applikation (Q-Field).

A binocular was used to distinguish tree species (eg. Populus *alba* vs. *canescens*) and a magnifier (eg. to detect glands on leaves). Books for identification and lists of the prepared categories (eg. biotope types, class definition for ash trees and neophytes) were used for consistency and a phone for the Q-Field application (Fig.10) as well as for identification apps (Plantnet, birdnet, iGräser) and for taking photos.

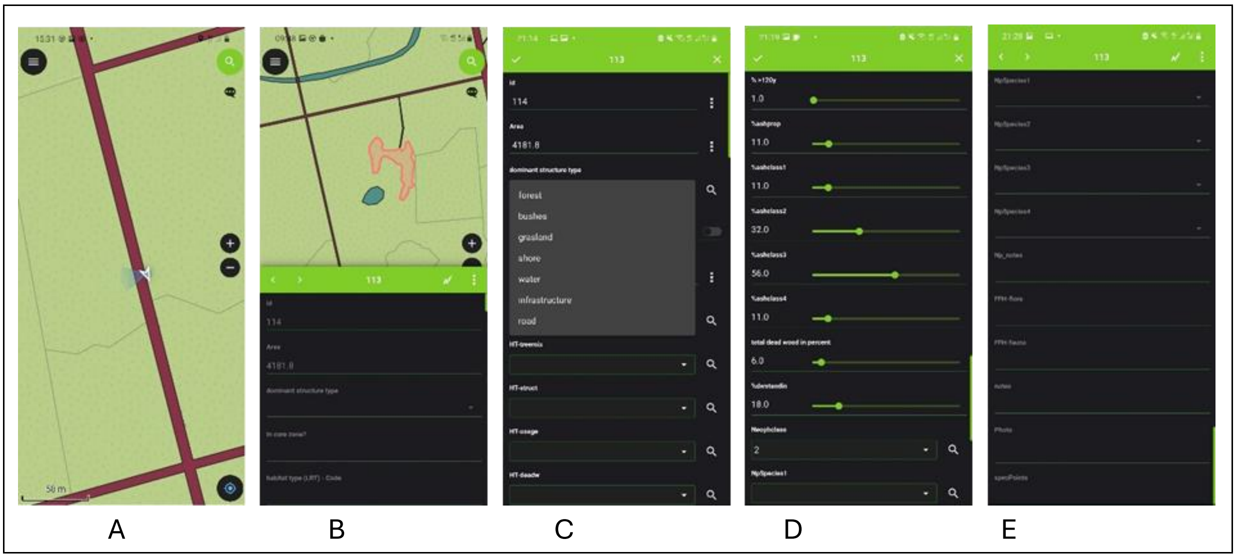


Fig.10: Q-Field Query. *A: GPS location, B: Visualisation of a polygon, C: Example for selections, D: different ways of data input, E: Other categories and photo upload.*

Mapping approach

Each of the polygons was visited once and categories were recorded. Each polygon was surrounded, as well as traversed (except some narrow ones which were only traversed), until the impression was gained, that all trees in the tree layer have been viewed.

Modifications in the mapping procedure

As the polygons were created with the orthophoto of 2019 (source: Geoshop, Federal municipality of Lower Austria), many changes happened to the vegetation cover. The planned method which was filling out the prepared Q-Field query in the field, was more complicated or even insufficient. Due to time constraints, the mapping data was recorded as audio-files, so changes in the polygon sizes and the data for the additional polygons were carried out in a practical way. Moreover, it was possible to record species that were not determined for certain and with more literature at home it was.

The corners of additional polygons were marked in the map or saved as GPS locations.

3.1.5. Post-field-work analysis and further processing using GIS

The recordings were digitalised in form of an excel sheet and compared to the newly accessible orthophoto data of 2024 as well as the relief and surface raster from 2019. The 3000 photos were

named after the respective polygons and a selection with one to three photos per polygon was created for further use.
Subsequent data processing was transferred from Q-GIS to Arc-GIS Pro. 67 Polygons had to be added and all the polygons were adjusted to the newly created path- and road network. The network was divided into 4 sizes based on the path or road width: 1.5 m for footpaths, 3.5 m for less busy forest paths (some meadow paths), 5 m for normal roads and 6 m wide for the largest road. In the field-work it was noted which paths have to be rearranged, deleted or added. Footpaths were rarely included and forest roads that are not used as such at the moment (several trees have fallen over and were not taken away for at least a year) were mainly excluded in the road network. The water bodies were updated with new information of the mapping if they were ephemeral/ periodically dry or mostly not. These changes result in the final 276 polygons shown in Figure 11. (In the Annex you find a version in higher quality with labelled polygons.)

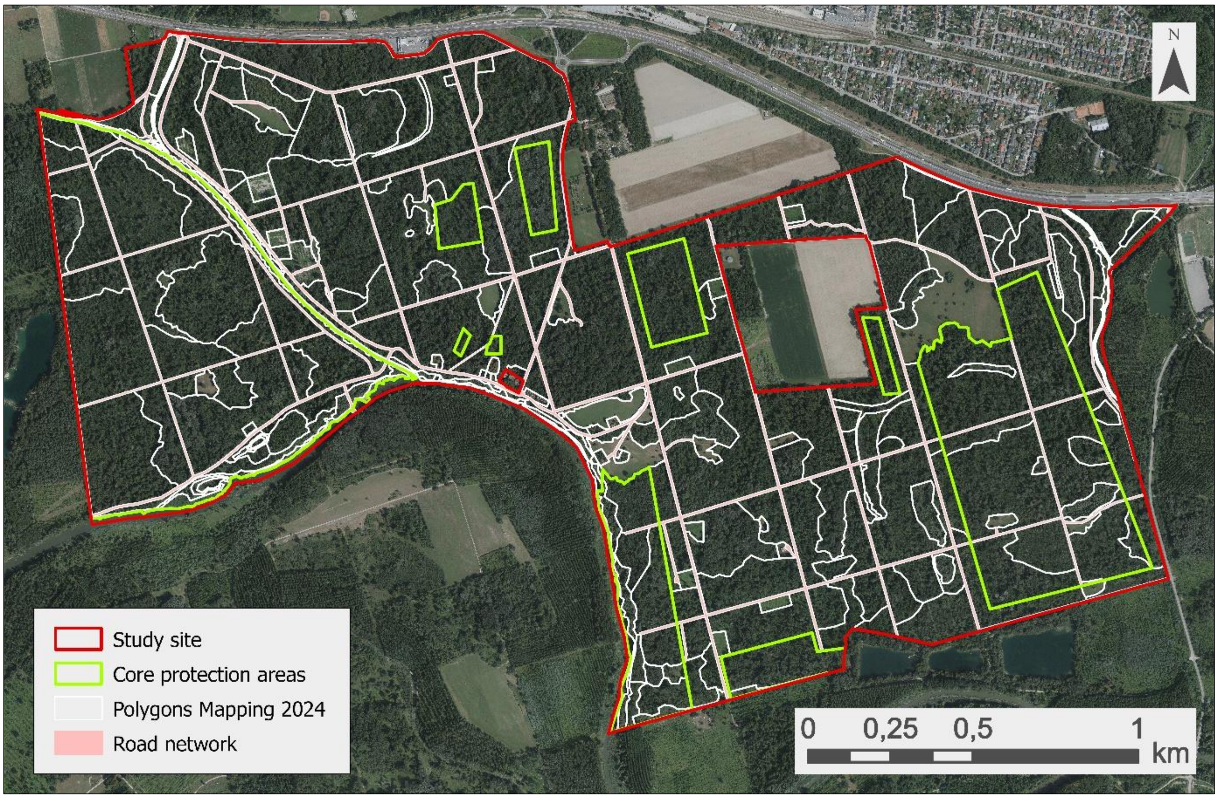


Fig.11: Post field work map: Polygons, Road network, Core zones and study site border after processing. *(Source of the orthofoto (2019): Geoshop, Federal municipality of Lower Austria) This map can be found in higher quality in the appendix.*

The conservation grade of the habitat types was calculated for each polygon as well as the grade for the whole area (Ellmauer 2005).
As the way of recording tree species originally wasn't useful for data comparisons or visualisations it was manually converted to single columns per tree species with numbers from 1 to 5 showing the respective abundance for each polygon.
The numbers in the tables created are rounded to two integers.

3.2. Historical Development

To investigate how vegetation has changed over recent decades and centuries, historical cartographic records were digitized and compared with this study`s vegetation survey conducted in 2024.

Most of the maps found, only distinguished between forests, meadows and waters when it comes to vegetation types. Solely two maps but from the same time (1990,1992) depicting vegetation types were identified. The map from 1990 was chosen for historical analysis and is described in the following chapter.

3.2.1. Historical data GIS analysis

The historical map used for this analysis was created as part of a vegetation survey conducted by Andreas Straka (1990). It distinguishes between ten vegetation types, four of which are forest types (Fig.12).

The vegetation types used for this analysis are waters (Gewässer), meadows (Wiesen), reeds (Röhrricht und Uferstauden), white willow forests (Silber-Weidenauwald), ash-poplar forests (Eschen-Pappelauwald), and oak-elm forests (Eichen-Ulmenauwald frisch/trocken). From this study's mapping carried out in 2024, the correlating vegetation types were used for the comparison. As within this study not all Soft- or hardwood alluvial forest types fit into those categories due to an alterated species composition, the vegetation types "softwood forest" and "hardwood forest" were separately considered (Fig.12).

With the software ESRI ArcGIS Pro the historical map was first georeferenced to the appropriate location scale and subsequently digitised manually. Figure 12 shows on the left side how much it aligns to the polygons from this study's mapping in 2024. On the right side the alignment of the digitised polygons is visible.

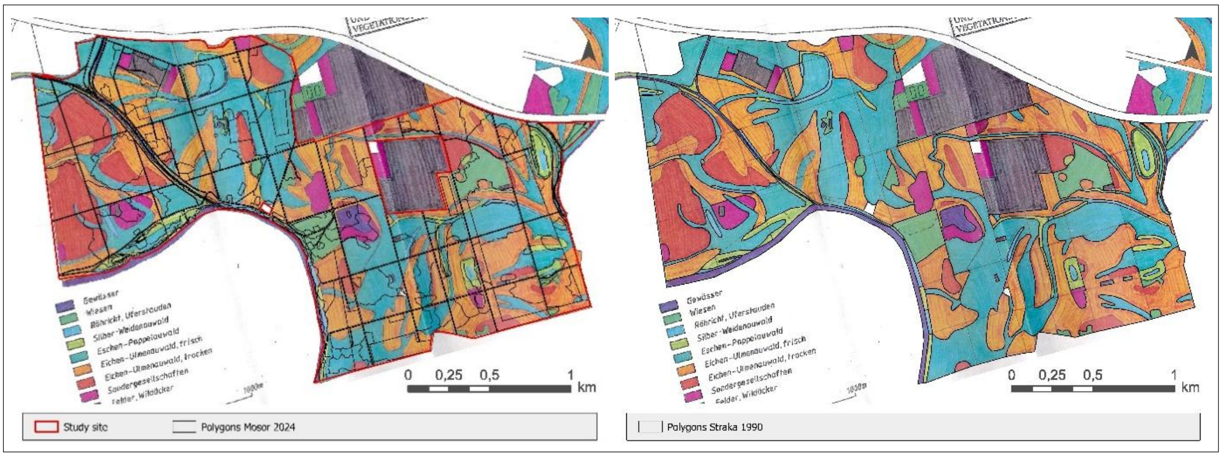


Fig.12: Alignment of the map of Straka 1990 after processing. A: Geo-referenced and the polygons of the mapping of 2024 on top to see how well it fits; B: Digitised Polygons of Straka 1990 as black lines. (Straka 1990, modified)

The differentiation between moist and dry ash-oak forest was disregarded, as this distinction was also not made within this study in 2024. The category 'atypical vegetation units' was left out because no definition was available. The category 'fields/ agriculture and wildlife plots' were ignored because most of it is located out of the nature protection area.

In the next step, overlapping areas of corresponding vegetation types were extracted and their spatial extent before and after was recorded. Every vegetation type's overlapping area with any other vegetation type was the other mapping was calculated.
Within the mapping of 2024, some polygons couldn't be associated with a specific type of forest (eg. ash-poplar forest, black locust forest) and so they were only assigned the category hardwood or softwood forest. The vegetation type softwood forest describes polygons where the abundance of neither willow nor poplar trees is high enough or the abundance of neophytes is too high to classify them as such. Hardwood forests that neither have oaks nor poplar trees or that have a high abundance of neophytes (but not as high to classify them as such) are put in the vegetation type hardwood forest. This refers to 32 ha regarding hardwood forest and 2.6 ha of softwood forest.

3.2.1. Historical data GIS analysis

Additionally, to the inspection of other historical maps, literature references were looked through to find notes of vegetation occurrences of former times. Partly the TurboVeg database of Straka 1990 was also taken into account but it mostly contains information of herbal flora and not as much of tree species.

3.3. Recommendations for future Management

During this study I learned a lot about the site on many levels which lead me to formulate recommendations for a future management. Over one year I studied by many others the following topics (with a selection of the studied publications):

- <u>the history of the region</u>
  (Wendelberger 1975; Straka 1995; Holub 2012; Hohensinner et al. 2013; Haidvogl et al. 2018)
- <u>the current management and management plans/ concepts</u>
  (Bezirksforstinspektion Korneuburg 2010; Barbl 2020; *Managementplan für das Europaschutzgebiet Tullnerfelder Donau-Auen* 2023)
- <u>characteristics of the vegetation (also herbaceous and aquatic plants)</u>
  (Margl 1973; Lazowski 1997b; Schratt-Ehrendorfer 1999; Hübl 2020)
- <u>Protected fauna as well as game</u>
  (Spitzenberger 2005; Gollmann 2007; Ettwein 2015; Barbl 2020)
- <u>similar sites and their development</u>
  (Knoll 2015; Schöpfer 2016; Schneider et al. 2017; Berner et al. 2022; Reif et al. 2024)

Moreover, I was in the field for two months where I could observe a lot. I met with locals and experts in the field of managing protection areas and profit from the expertise of my supervisors. Additionally, I know this site since I was a child which also helps to put the learnings into perspective.

4. Results

Results regarding the field mapping in summer 2024 are stated in chapter 4.1 whereas those of the historical analysis can be found in chapter 4.2.

4.1. CURRENT ECOLOGICAL STATUS

The studied site encompasses approximately 395 ha. 13 hectares are attributed to the road and pathway network. An additional 1 hectare, categorised under buildings, parking lots, and gardens, were not included in the mapping. The water surface area totals 5 hectares, of which 1 hectare accounts to standing waters. Other small ephemeral water bodies, which were (nearly) dry at the time of mapping, were included in the class ’reeds’, as they were too small to be assigned their own polygon in this study.

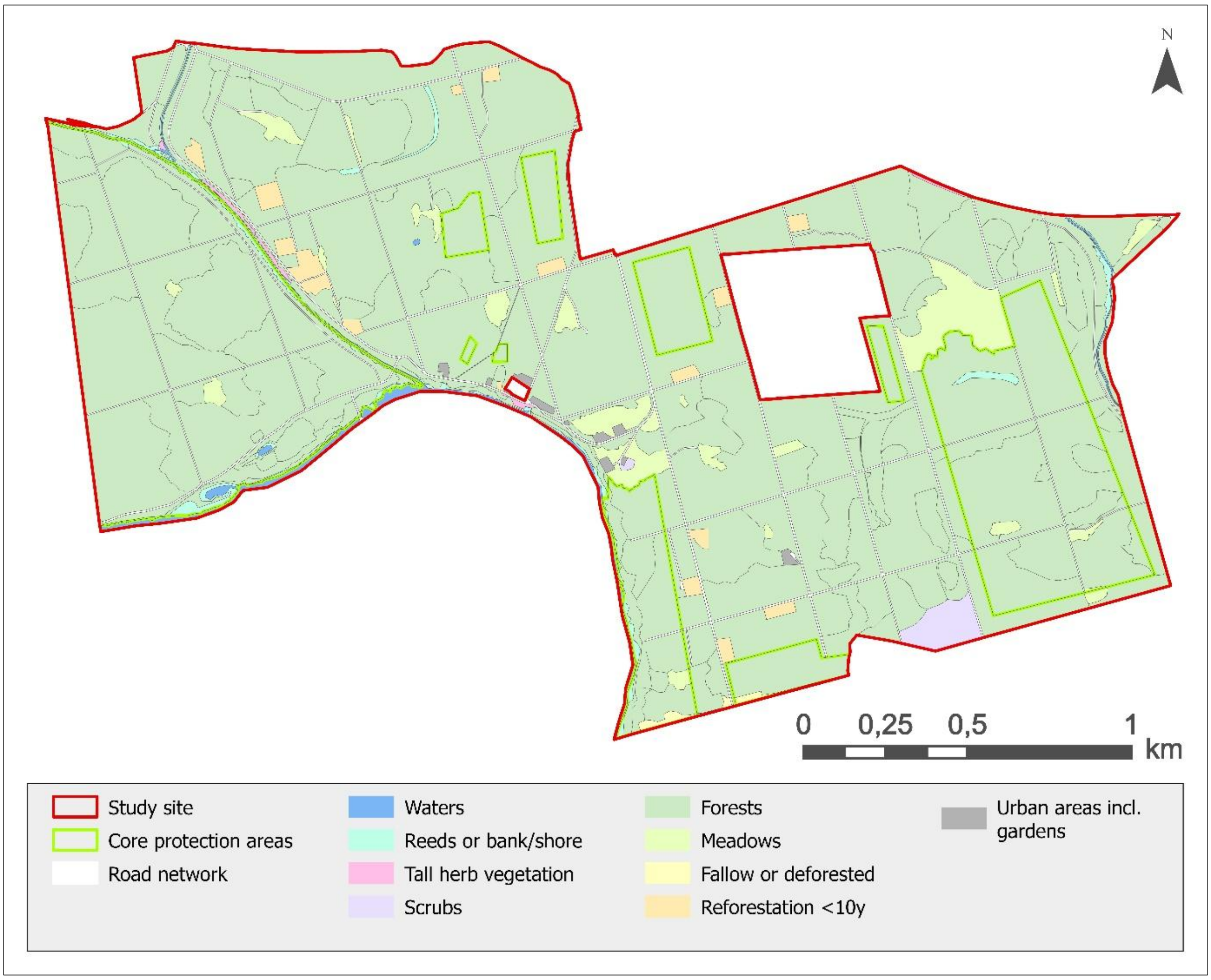


Fig.13: Dominant types (broad classification).

Figure 13 shows a broad classification of all polygons into 9 domminant types: water body, reed, meadow, tall herbaceous community, forest, reforestation, fallow, shrubland and infrastructure. All in all, 276 polygons were mapped, altough 11 of them are gardens, houses and parking lots that are allocated to the dominant type ”infrastructure” and excluded from the mapping (~1 ha). 192 polygons (~346 ha) are assigned to the dominant type ”forest” which is separated from the dominant type ”reforestation”. When it is referred to ”forest” whithin the result section, it is referred to the 192 polygons.

4.1.1. Habitat types

All forest habitat types occuring in the study site were either Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (91E0; SWF) or Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior/ Fraxinus angustifolia* (91F0; HWF).

Table 10 shows that approximately 62% of the study site is covered by one of the two forest habitat types, whereas ~48% of the area is allocated to 91F0. This habitat type also makes up ~78% of the recorded HT but only half of the polygons. This means, that polygons of 91E0 are smaller in average. Approximately 71% of HT 91F0 is within a corezone and ~35% of HT 91E0. These results can also be seen in Figure 14.

Tab.10: Habitat types, their respective areas and shares within core zones.

HT[1]	Properties				Share within core zones		
Code[3]	**Area**	**% of all HT-area[1]**	**% of total SS[2] area**	**Nr. of polygons**	**Area**	**% of the respective HT[1]**	**Nr. of polygons**
91F0	189 ha	77%	48	74	72 ha	38%	25
91E0	56 ha	22%	14	42	40 ha	70%	24
total	245 ha	100%	62	116	112 ha		49

[1]: Habitat type; [2]: SS: Study site; [3]: 91E0: Softwood alluvial forest with Alnus glutinosa and Fraxinus excelsior, 91F0: Hardwood Riparian mixed forests of Quercus robur, Ulmus laevis, Ulmus minor, Fraxinus excelsior/ angustifolia

Fig.14: Forest habitat types within the Stockerauer Au incl. core zones.

Assessing the state of total forest area

Ellmauer (2005) states that an individual plot must be assessed with a conservation status of "C" if either its species composition or hydrology is rated as "C". The entire area was classified as "C" in terms of hydrology due to its lack of dynamics, and the species composition of just over half of the habitat-type-designated area was also assessed as condition "C" (Tab.11).

If the hydrological aspect were to be disregarded, nearly half of the total forest area would still be graded as ”C”. Given that, the reason why many forest areas could not be assigned to any habitat type was due to their inadequate species composition, it can be concluded that ~44% of the total forest area either has a species composition corresponding to condition ”C” (~52 ha (of which ~9 ha in CZ)), or could not be assigned to any habitat type due to insufficient species composition (~101 ha).

Table 11 shows, especially the categories ’hydrology’, ’species composition’, ’deer influence’ and ’dead wood proportion’ the polygons were graded with a C. The categories ’disturbances’ and ’area’ were more easily graded with an A.

Tab.11: The distribution of grade of conservation for the two habitat types. The conservation state is classified in decreasing conservation quality, A, B and C, according to Ellmauer (2005).

Habitat type	**91F0[1]**			**91E0[1]**		
Conservation grade	**A**	**B**	**C**	**A**	**B**	**C**
Sub critera[2]:						
Area	10%	0%	90%	0%	0%	100%
Species comp.	4%	71%	24%	21%	68%	11%
Structure	9%	79%	11%	-	-	-
Usage	38%	61%	1%	83%	17%	0%
Deadwood	47%	42%	10%	77%	22%	1%
Hydrology	0%	0%	100%	0%	0%	100%
Disturbances	0%	86%	14%	0%	98%	2%
Deer influence	0%	33%	67%	0%	19%	81%

[1]*: 91E0: Softwood alluvial forest with Alnus glutinosa and Fraxinus excelsior*
91F0: Hardwood Riparian mixed forests of Quercus robur, Ulmus laevis, Ulmus minor, Fraxinus excelsior/ angustifolia
[2]*: Conservation state sub criteria according to Ellmauer (2005)*

4.1.2. Biotope types

Table 12 shows the 30 different biotope types found within the study site. 14 of those describe forest habitats but most of it accounts to one type: oak-elm-ash alluvial forest. 63 polygons could not be classified as a biotope type. These are either softwood forests (~22 ha), hardwood forests (~85 ha), or forests that have been cleared and not reforested (~0.7 ha). Besides, oak-elm-ash alluvial forests, willow alluvial forest, decideous forest out of not native tree species, hybrid poplar forest, white poplar forest, and reforestations under 5 years account for at least 4 hectares each.

Tab.12: Biotope types, their number of polygons and area in hectares.

Biotope types	**Biotoptypen (German)**	**Nr. of polygons**	**Area (ha)**
Ash-maple forest	Ahorn-Eschenauwald	3	2.6
Maple forest	Ahornforst	1	0.6
Tree backdrop	Baumkulisse	2	0.8
Oak-elm-ash alluvial forest	Eichen-Ulmen-Eschen-Auwald	71	194.7
Hybrid poplar forest	Hybridpappelforst	10	6.9
Decideous forest out of not native tree species	Laubbaumforst aus sonstigen nichtheimischen Arten	14	8.2
Decideous forest out of native tree species	Laubbaummischforst aus einheimischen Baumarten	1	<0.1
Linden forest	Lindenreicher Edellaubwald	1	0.3
Black locust forest	Robinienforst	2	2.6
Black poplar forest	Schwarzpappelauwald	1	0.2
White poplar forest	Silberpappelauwald	6	6.7
Pioneer forest	Vorwald	3	1.4
Willow alluvial forest	Weidenauwald	16	11.1
Tree hedgerow	Baumhecke	2	2.8
Dogwood shrubs	Hartriegelgebüsch	1	0.1
Ash forest	Eschenforst	2	0.6
Reforestation under 5 years	Junge Laubbaumaufforstung	14	4.5
Neophyte vegetation	Neophytenflur	3	0.2
Nettle-dominated vegetation	Brennesselflur	2	0.4
Tall reed vegetation along flowing waters over fine sediment	Großröhricht an Fließgewässer über Feinsubstrat	11	4.3
Freshwater tall-reed vegetation of still waters and terrestrial reedbeds	Süßwasser-Großröhricht an Stillgewässer und Landröhricht	4	0.8
Channelised lowland stream	Begradigter Tieflandbach	2	1.1
Impounded lowland river	Gestauter Tieflandfluss	2	3.4
Near-natural pond	Naturnaher Tümpel	2	0.1
Fresh, base-rich lowland grassland on nutrient-poor soils	Frische basenreiche Magerwiese der Tieflagen	23	7.6
Central European mown semi-dry calcareous grassland	Mitteleuropäischer basenreicher Mäh-Halbtrockenrasen	3	1.7
Mature tree stands in parks and gardens	Altbaumbestand in Park und Garten	8	0.9
Small buildings or sheds	Kleingebäude und Schuppen	1	<0.1
Barn and storage building	Scheune und Speichergebäude	1	<0.1
Power/water purification plant and substation	Kraftwerk und Umspannwerk	1	0.2
No biotope types:			
SOFTWOOD FOREST	WEICHHOLZAUWALD	15	21.6
HARDWOOD FOREST	HARTHOLZAUWALD	46	85.3
Cleared area	Gerodete Fläche	2	0.7

The following map (Fig.15) shows the biotope types of each polygon and depicts that also most of the area is classified as oak-elm-ash alluvial forest. Quite a large amount is either softwood or hardwood forest which is in brackets and in very light colours as it actually is not a real biotope type but a supercategory.

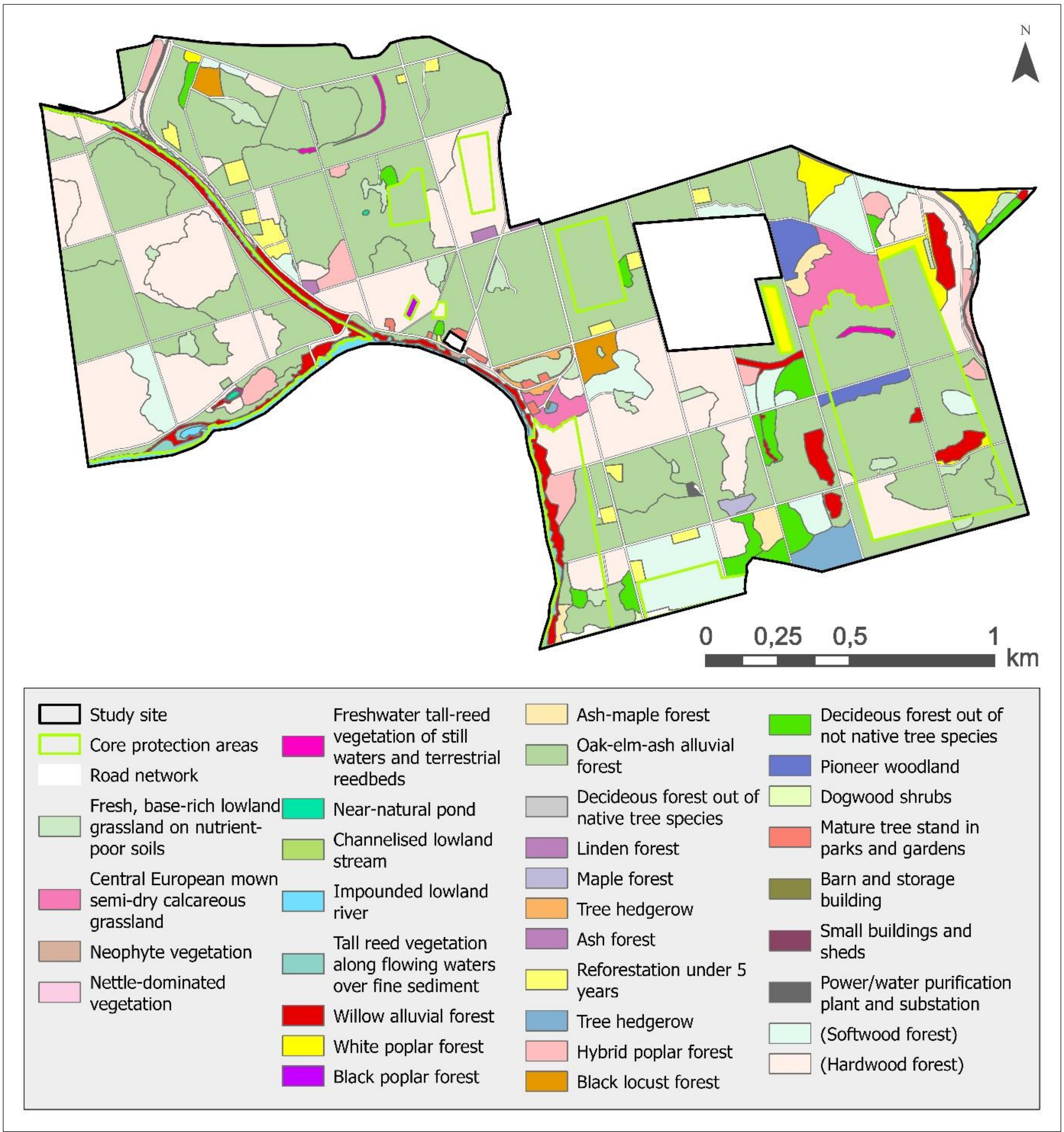


Fig.15: Biotope types within and out of core zones.

4.1.3. Vegetation types

It was differentiated into 20 vegetation types (Fig.16) of which 7 are forest types. Due to their species composition, some polygons could only be assigned to one of the two general categories ”softwood” or ”hardwood”. This happened for example, if not native trees covered more than 15% of the crown cover.

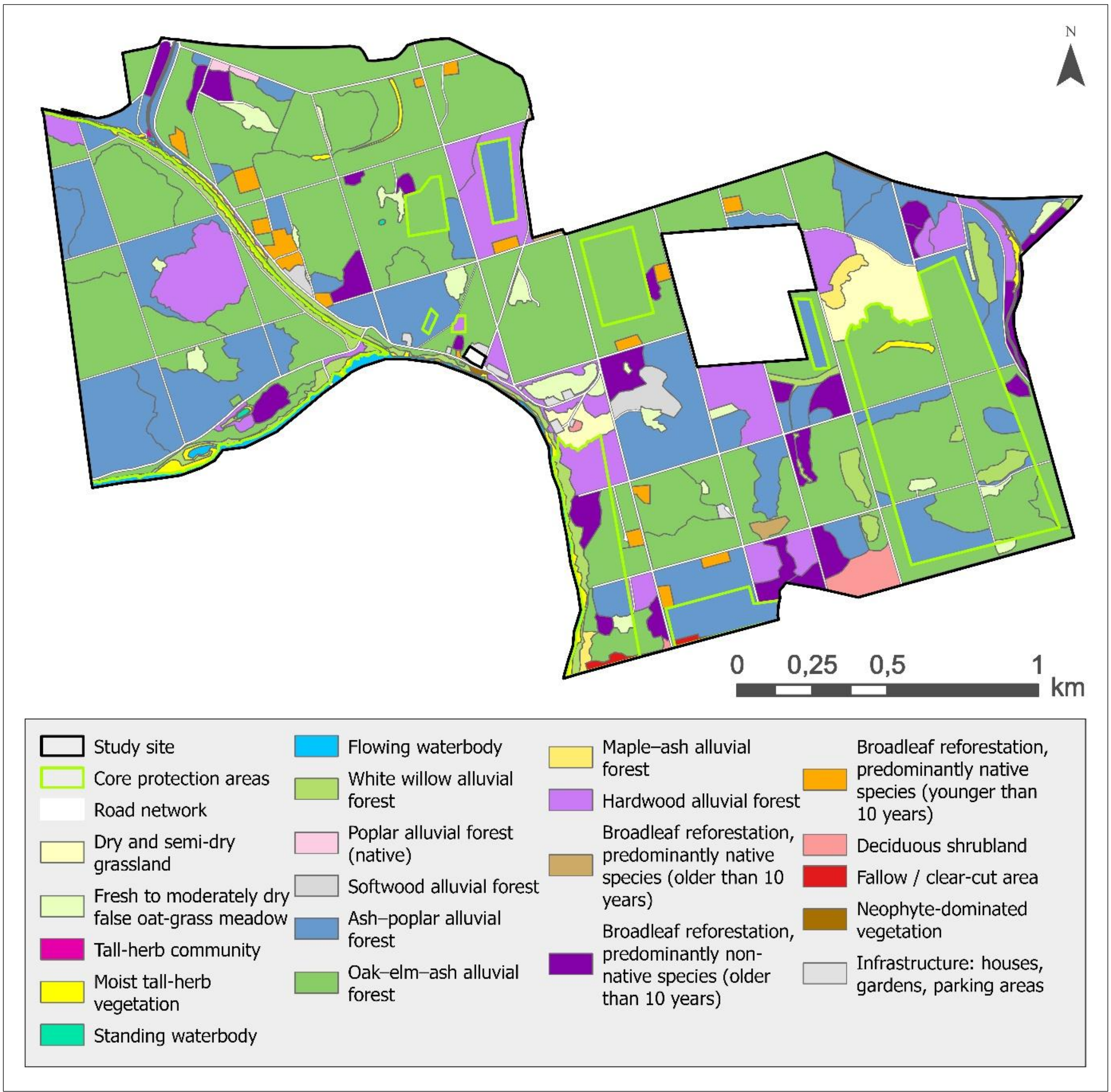


Fig.16: Vegetation types mapped in 2024 including the road network and the core areas of the nature protection area.

The largest vegetation types are the oak-elm-ash alluvial forest with ~195 hectares and the ash-poplar alluvial forest with ~84 hectares. Together they make up ~71% of the whole study site. The smallest proportions of native forests are assigned to poplar alluvial forest, marple-ash alluvial forest and softwood alluvial forest, together making up ~1%. Plantation of non-native broadleaf trees, older than 10 years cover ~4% of the study site, whereas native plantations above 10 years are rare (~1%). Reforestations younger than 10 years cover about 5 hectares and species planted are predominantely native (Tab.13).

Tab.13: Vegetation types and their respective amount, area and proportion of the study site.

Code	***Vegetation Type***	***count***	***Area (ha)***	***%***
1	**FOREST**			
10	Hardwood alluvial forest	24	32.8	8%
11	Oak–elm–ash alluvial forest	71	194.8	49%
12	Maple–ash alluvial forest	2	1.5	0.4%
13	Ash–poplar alluvial forest	45	83.8	21%
14	Softwood alluvial forest	3	2.6	1%
15	Alder–ash–willow alluvial forest	0	0	0%
16	White willow alluvial forest	16	11.1	3%
17	Poplar alluvial forest (native)	2	0.5	0.1%
2	**PLANTATION FOREST**			
20	Broadleaf reforestation, predominantly native species (> than 10 years)	3	0.9	0.2%
21	Broadleaf reforestation, predominantly non-native species (> than 10 years)	25	16.3	41%
22	Broadleaf reforestation, predominantly native species (< than 10 years)	16	5.1	1%
23	Broadleaf reforestation, predominantly non-native species (< than 10 years)	0	0	0%
3	**SHRUB, HERBACEOUS VEGETATION, REED AND FEN**			
31	Deciduous shrubland	3	2.9	0.7%
32	Tall-herb community	1	<0.1	<0.1%
33	Moist tall-herb vegetation including large reed beds, (tall-) sedge fen, and riparian willow thickets	16	5.5	1%
34	Extensive reed bed (including common reed stands) / (tall-) sedge fen	0	0	0%
35	Neophyte-dominated vegetation	3	0.3	<0.1%
4	**MEADOW**			
40	Moist alluvial meadow	0	0	0%
41	Fresh to moderately dry false oat-grass meadow	23	7.6	2%
42	Dry and semi-dry grassland	2	7.6	2%
43	Intensively managed meadow	0	0	0%
44	Fallow / clear-cut area	2	0.7	0.2%
5	**WATERBODIES**			
51	Flowing waterbody	4	4.5	1%
52	Standing waterbody	2	0.1	<0.1%
53	Moist zone or temporary waterbody	0	0	0%
6	**INFRASTRUCTURE**			
61	Road and path network	0	13.1	3%
62	Infrastructure: houses, gardens, parking areas	11	1.1	0.3%
	SUM TOTAL		**395.4**	

About half of the meadow area was classified as “fresh to moderately dry false oat-grass meadow" and the other half, but only 2 meadows, was mapped as “dry and semi-dry grassland”.

The waterbodies were differentiated in flowing, standing and temporal/ephemeral, whereas the emphemeral waterbodies were not recorded separately as they were too small. Next to waterbodies the succession series were best observed (Fig.17).

Fig.17: Succession states close to a water body.

Left: detailed map of the succession series next to water bodies. Right: photo of the succession series (at Krumpenwasser). (photo: Nina Mosor)

4.1.4. Cover of trees, bushes, meadows

The vegetation cover across the total area (excluding water bodies and infrastructure) can be summarised on average with 43% of tree cover, 24% of shrub cover, and 33% of herbaceous cover. Within the core zones, the proportion of herb cover is approximately 3% less and therefore bushcover is higher.

When comparing the forest area (without reforestation areas) to the study area (excluding water bodies and infrastructure) it is notable that the forest area has a higher tree and shrubcover and half of the general averary in herb cover. Within the core zones, tree cover is slightly less and herbcover is slightly more. When reforestation areas are included in the analysis, a slight decrease in tree cover is observed, accompanied by a substantial increase in herbaceous cover, which rises to an average of 21% of the total forest (+reforestation) area (Tab.14).

Tab.14: Tree, bush and the herb cover proportions of the forest area distinguished between core zones and the total forest area.

	treecover		bushcover		herbcover	
in Study Site[1]/ Core Zone[2]	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**
Total site (except waters and Infra)	43%	42%	24%	28%	33%	31%
Total forest	54%	50%	30%	32%	15%	18%
Total forest +reforestation	51%	50%	28%	32%	21%	18%

The total area of polygons with less than 50% tree cover is approximately 14 hectares smaller than that of polygons with more than 50% tree cover. Core zones account for an 8% higher proportion of area within the category of tree cover below 50% (Tab.15).

Tab.15: Treecover proportions of the total forest area above 50%, below 50% and below 30% in hectares and percent of the area within the respective treecover class. *It is distinguished between the total forest area including reforestation areas and their core protection area shares.*

	treecover > 50		treecover < 50		treecover < 30	
in Study Site[1]/ Core Zone[2]	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**
forest + reforestation area	166 ha	55 ha 16%	180 ha	82 ha 24%	48 ha	19 ha 5%

Meadows, reeds or tall herbaceous communities as well as reforestation areas are shown to have a high herb cover (Fig. 19). Bush cover occurs in large amount within about half oft he oak-elm-ash forests and plantations over 5 years often have more herb cover than in naturally grown forests, therefore very little bush cover.

4.1.5. Age distribution within forest areas

The trees were classified in 5 different age classes measured in the proportion an age group has within a polygon. In most polygons all age classes are present exept the last concerning trees older than 120 years.

To see in numbers how the age class proportion is split between the forest types, Table 17 shows the differences between 3 natural forest types in total and of their core zone areas. Regarding the forest areas in total, ~33% of trees had the age of 30-60 years and ~27% were between 11 and 30 years. Within the corezones, the average proportion of trees between 31-60 years and 61-120 years is higher.

Oak-elm-ash forests as well as ash-poplar forests show quite similar proportions to the total area, exept that more trees were between 0-10 years and and a bit less in the older age classes. White willow forests, on the contrary, had very few individuals until the age of 10 (~4-5%) and therefore the highest proportion of trees over 60 years. In all white willow forests the average proportion of trees older than 120 years reached nearly 9% - within core zones only half of it, but this is still double as much as within the other forest types (Tab.16).

Tab.16: Age classes average proportion (rounded, in %) of polygons within different scenarios. *(Reforestation areas are not included)*

Age	**0-10 y**		**11-30 y**		**31-60 y**		**61-120 y**		**>120 y**	
in Study Site[1]/ Core Zone[2]	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**	**SS[1]**	**CZ[2]**
Total forest	17%	15%	28%	24%	33%	35%	20%	25%	2%	2%
Oak-elm-ash forest	22%	19%	26%	23%	32%	37%	18%	19%	2%	2%
Ash-poplar forest	19%	14%	23%	24%	34%	34%	22%	27%	2%	1%
White willow forest	5%	4%	24%	11%	34%	38%	29%	42%	9%	4%

4.1.6. Abundance and state of *Fraxinus excelsior*

The ash trees recorded were all European ashes (*Fraxinus excelsior*) and despite their decline they are still an important and spread part of the forests. In 82% of the study area (~93% of forest area), ash trees were found regardless of their abundance.

Fraxinus excelsior was found being dominant in 4 Polygons (~10 ha) and mostly it was occuring mixed with a crown cover between 6 and 29 percent (~121 ha). Within an area of ~90 ha the species was occuring sub-dominantely and within approximately 105 hectares it was found admixed (Tab.17). Most ashes were recorded in oak–elm–ash alluvial forest (~195 ha) and in ash–poplar alluvial forests (~84%). In core zones they mostly occur subdominantely or dispersed (6-50% abundance) whereas in the total forest area they also occur often under 5%.

Tab.17: Ash tree abundances within the varios vegetation types in hectares.
("Natural" refers in this case to the first 5 rows without the category hard- or softwood forest as those were often described as such due to their high abundance of neophytes.)*

Forest + reforestation VT types	**5**	**4**	**3**	**2**	**1**	**total**
Abundance (% of crown cover)	**>50**	**26-50**	**6-25**	**<5**	**once**	
Oak–elm–ash alluvial forest	5.2 ha	51 ha	80 ha	58 ha	-	**195 ha**
Maple–ash alluvial forest	-	-	1.1 ha	-	-	**1.1 ha**
Ash–poplar alluvial forest	4.9 ha	39 ha	19 ha	21 ha	-	**84 ha**
White willow alluvial forest	-	-	0.2 ha	3.4 ha	-	**3.5 ha**
Poplar alluvial forest (native)	-	-	-	0.5 ha	-	**0.5 ha**
Hardwood alluvial forest	-	0.4 ha	18 ha	9.5 ha	-	**28 ha**
Softwood alluvial forest	-	-	0.02 ha	2.6 ha	-	**2.6 ha**
Broadleaf reforestation, predominantly native species (older than 10 years)	-	-	-	-	-	**-**
Broadleaf reforestation, predominantly non-native species (older than 10 years)	-	-	2.7 ha	9.3 ha	0.9 ha	**13 ha**
Broadleaf reforestation, predominantly native species (younger than 10 years)	0.3 ha	-	-	0.4 ha	0.5 ha	**1.2 ha**
Broadleaf reforestation, predominantly non-native species (younger than 10 years)	-	-	-	-	-	**-**
Total forest + reforestation	**11 ha**	**91 ha**	**121 ha**	**105 ha**	**1.5 ha**	**328 ha**
Total natural* forest	10 ha	90 ha	100 ha	83 ha	-	**283** ha
Total natural forest incl Soft + Hardwood forest	10 ha	90 ha	118 ha	95 ha	-	314 ha
Total reforestation	0.3 ha		2.7 ha	9.7 ha	1.5 ha	14 ha
Total forest + reforestation within core zone in ha	**1.3 ha**	**58 ha**	**64 ha**	**10 ha**	**-**	**133 ha**
Total forest + reforestation within core zone in %	**12 ha**	**64 ha**	**53 ha**	**0.1 ha**	**0 ha**	**41 ha**

Regarding the whole study area, an ash tree crown cover of more than 75% of a polygon can be found in ~10 ha. However, within ~140 ha no tree was found and within ~123 ha the ash tree proportion is between 9% and 1% (Tab.18).

Tab.18: Ash proportion of whole study area in hectares.

Ash prop (crown cover)	>75	51-74	26-50	25-10	9-1	0
Area of polygons in ha	9.6 ha	8.4 ha	69 ha	103 ha	123 ha	140 ha

Figure 18 shows the distribution of ash tree proportions within polygons and ash tree classes on a map. Areas with a low ash tree proportion are found in the northern as well as central parts of the study area. Along rivers the ash tree proportion is also low, whereas in some core areas it’s visible, that a high proportion of ash trees are occuring.

Fig.18: Ash tree and ash class proportions of the forest area in hectares.
(This map can be found in higher quality in the appendix.)

Along Göllersbach, more ash trees were found in class 1 than anywhere else. In the central parts with low abundance, a lot of trees were found in class 4 and little or none in some polygons in class 1. Nearly every polygon where at least one ash is occuring, has a proportion of class 3, mostly it’s the largest class.

The condition of the ash trees is shown in 4 classes whereas 1 indicates a healthy and 4 an (almost) dead tree. Within core zones, ash trees take up double the crown cover proportionally but their state is slightly worse. Albeit there is no significant difference in the classes 1 and 4, more ash trees of class 2 (very few dead branches) were found outside of core zones. Therefore, within core zones, more ash trees were found in class 3 (Tab.19).

Tab.19: Ash class proportions of the forest area in hectares. *(% of tree species refers to the proportion of ash tree species in each polygon.)*

Forest + reforestation VT types	**% of tree species**		**Class 1**		**Class 2**		**Class 3**		**Class 4**	
in Core Zone (CZ) / total Study Site (SS)	**CZ**	**SS**	**CZ**	**SS**	**CZ**	**SS**	**CZ**	**SS**	**CZ**	**SS**
Oak–elm–ash alluvial forest	22	13	7	10	32	34	43	43	17	12
Maple–ash alluvial forest	70	4	5	10	15	40	75	30	5	20
Ash–poplar alluvial forest	23	16	10	8	30	35	43	44	18	13
White willow alluvial forest	4	6	5	8	15	35	70	45	10	13
Poplar alluvial forest (native)	0	1	0	0	0	30	0	70	0	0
Hardwood alluvial forest	8	6	4	8	28	31	41	33	28	9
Softwood alluvial forest	0	25	0	1	0	13	0	30	0	23
Broadleaf reforestation, predominantly native species (older than 10 years)	0	0	0	0	0	0	0	0	0	0
Broadleaf reforestation, predominantly non-native species (older than 10 years)	1	6	0	5	25	35	75	41	0	5
Broadleaf reforestation, predominantly native species (younger than 10 years)	0	0	0	0	0	0	0	0	0	0
Broadleaf reforestation, predominantly non-native species (younger than 10 years)	0	0	0	0	0	0	0	0	0	0
Total average (without null values)	**21**	**10**	**6**	**7**	**24**	**32**	**58**	**42**	**16**	**14**

4.1.7. Dead wood

The total dead wood proportion of the whole study site (excl. urban areas) in the Stockerauer Au makes up ~7.7% on average and ~8.4% of the forest area. Figure 19 shows the different proportions as gradients which makes visible, that especially the corezones evince a higher dead wood proportion (~12%). About 79% of the area with a high total dead wood proportion (15-20%) is located within a core zone.

The proportion of lying dead wood makes up on average ~75% of the whole study site (excl. urban areas) and ~84% of the forest area. The forested core zones account for ~86% lying deadwood proportion of the total forest area. Thus, standing deadwood amounts to a quarter of the total dead wood within the whole study site (excl. urban areas), 16% of the forested area and 14% of the forested area within core zones (Fig. 20).

Fig.19: Total dead wood proportion within and without core protection zones in percent.
(The dark brown shades show a high proportion of dead wood within a polygon.)

Fig.20: Correlation of total deadwood and lying dead wood proportion.

4.1.8. Neophyte occurence

Regarding neophytes it was differentiated between 3 categories: 1. invasive and not invasive neophytes, 2. Invasive neophytes with *Juglans nigra* and *Robinia pseudoacacia*, 3. Invasive neophytes without *Juglans nigra* and *Robinia pseudoacacia*. This differentiation was not planned, however, in the beginning of the fieldwork it became clear that *Juglans nigra* and *Robinia pseudoacacia* are occuring like the definition of invasive species used in this study describes them. Polygons classified with the dominant type infrastructure or water bodies are not included.

Fig.21: Neophyte abundances. *A: Invasive neophyte abundance without Robinia and Schwarznuss; B: Invasive neophyte abundance with Robinia and Schwarznuss; C: Invasive and not invasive neophyte abundance. (Occurrence classes 1-3: 1...<5%, 2...6-20% and 3...>21% of the respective neophytes occurred within the herb/bush/ or tree cover.)*

Figure 21 illustrates clearly that core protection areas are less intensively occupied by invasive species.
Moreover, it is shown that invasive neophytes excl. *Juglans nigra* and *Robinia pseudoacacia* mostly take up class 1 (< 5% cover). If *JuNi* and *RoPs* are included, only half of the study site is in class 1. When including the not invasive neophytes that have been mapped, the amount of polygons in class 1 decreases to one third of the study site. Numers for these differences can be viewed in table 20.

Tab.20: Shares of the neopyte categories and the respective classes of the respective area *(either surveyed area (study area except infrastructure and water bodies = ~376 ha) or forests (= ~346 ha) or of core zones (= ~145 ha).*

		invasive + non-inv. neophytes		invasive neophytes incl. RoPs+JuNi		invasive Neophytes excl. RoPs+JuNi	
		Amount of polygons	% of resp. area	Amount of polygons	% of resp. area	Amount of polygons	% of resp. area
of surveyed area (259 polygons)	Class 1	92	30%	161	53%	237	98%
	Class 2	106	45%	70	38%	16	1%
	Class 3	61	25%	28	8%	6	0.2%
of forests (192 polygons)	Class 1	53	28%	114	51%	187	99%
	Class 2	88	46%	55	40%	4	0.5%
	Class 3	51	27%	23	9%	1	<0.1%
of core zones (79 polygons)	Class 1	37	51%	65	80%	76	99%
	Class 2	36	42%	12	19%	2	0.3%
	Class 3	6	8%	2	1%	1	0.1%

When focusing solely on invasive neophytes excluding black locust (*Robinia pseudoacacia*) and black walnut (*Juglans nigra*), nearly 100% of the area within the core zones falls into class 1. Across the entire study site, class 1 accounts for ~98% of the area. However, when black locust and black walnut are included, the situation changes significantly: only half of the study site or forest area remains in class 1.
Overall, 70% of the study site and approximately half of the core zones are covered by neophytes with a canopy of more than 5%.
9 mapped species are classified as invasive and 4 more as neophytes but not invasive Species that occured dominantely within at least one polygon (Fig.23).

Some invasive neophytes occurred in only a few places. Impatiens *glandilifera* occurred within 6 polygons that amount to 13 hectares and *Ambrosia artemisiifolia* was only found at one freshly disturbed place of forestry work. *Ailanthus altissima* was also found in very few places. On the contrary, *Juglans nigra, Robinia pseudoacacia, Acer negundo, Solidago canadensis* and *Impatiens parviflora* are found common or very common (Fig.22, 23).

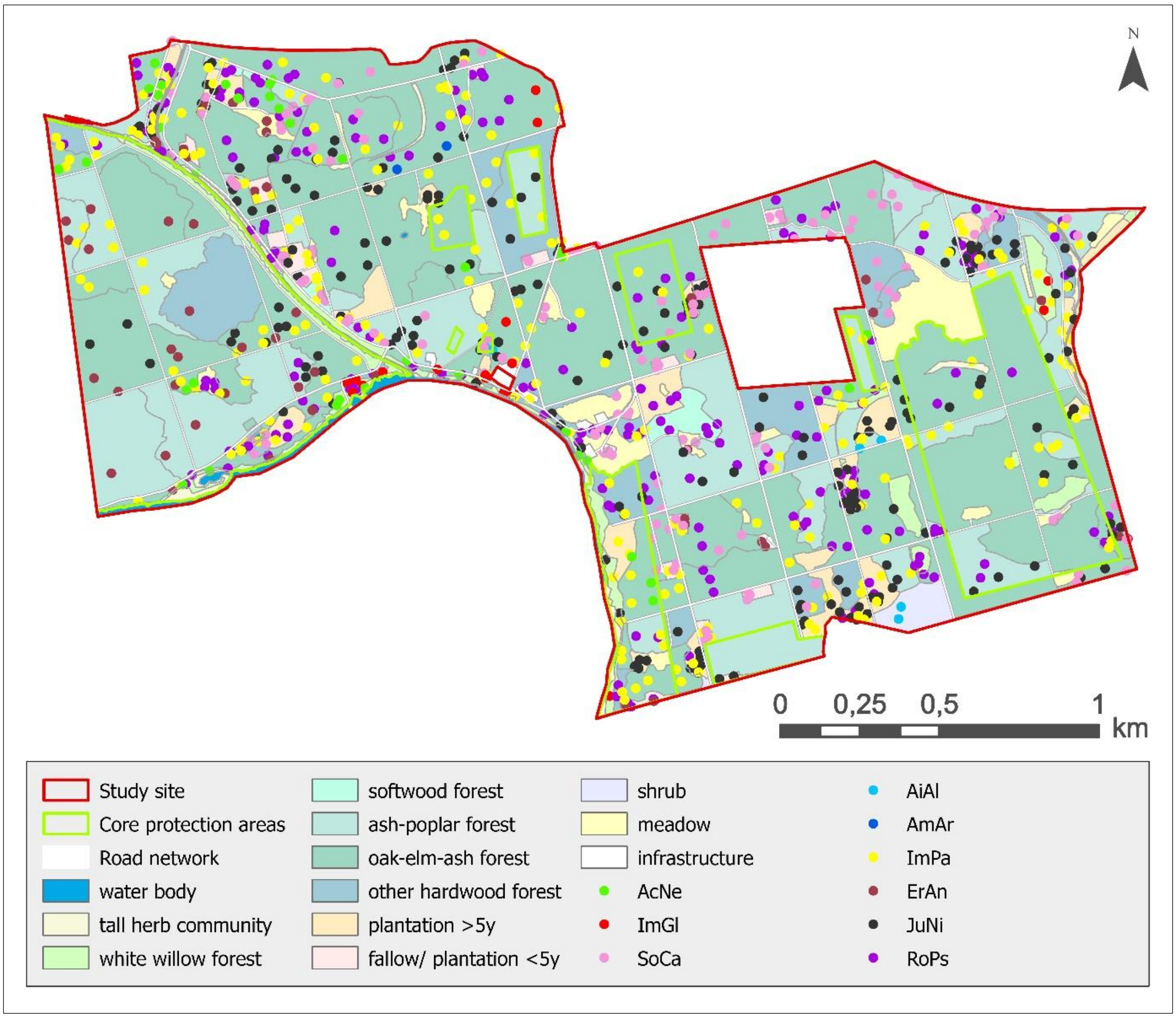


Fig.22: Occurrence of invasive neophytes incl. Juglans nigra and Robinia pseudoacacia. *The respective dots per species show the abundance class (1-5) they were assigned to within each polygon. (AcNe...Acer negundo, ImGl...Impatiens glandilifera, SoCa...Solidago canadensis, AiAl...Ailanthus altissima, AmAr...Ambrosia artemisiifolia, ImPa...Impatiens parviflora, ErAn Erigeron annuus, JuNi... Juglans nigra, RoPs... Robinia pseudoacacia)*

Regarding non-invasive species, Figure 23 shows that *Populus x canadensis* was found within 36 polygons (~75 ha (~20 ha within core zones)). Within ~19 ha it was classified as dominant or sub-dominant in polygons. Especially in areas neighboring those they often occured intersperced. Most occurences were identified through mistletoe (*Viscum album*) on them, or typical growth of mature trees or their occurrence as plantation. Most trees either had a diameter at breat height (DBH) of 50-70 cm, in two polygons they had a DBH of 80 to 110 cm. Some had a DBH of 25-40 which occurred mostly admixed, although it is to mention that the definite identification of young trees is not for sure without genetical tests.

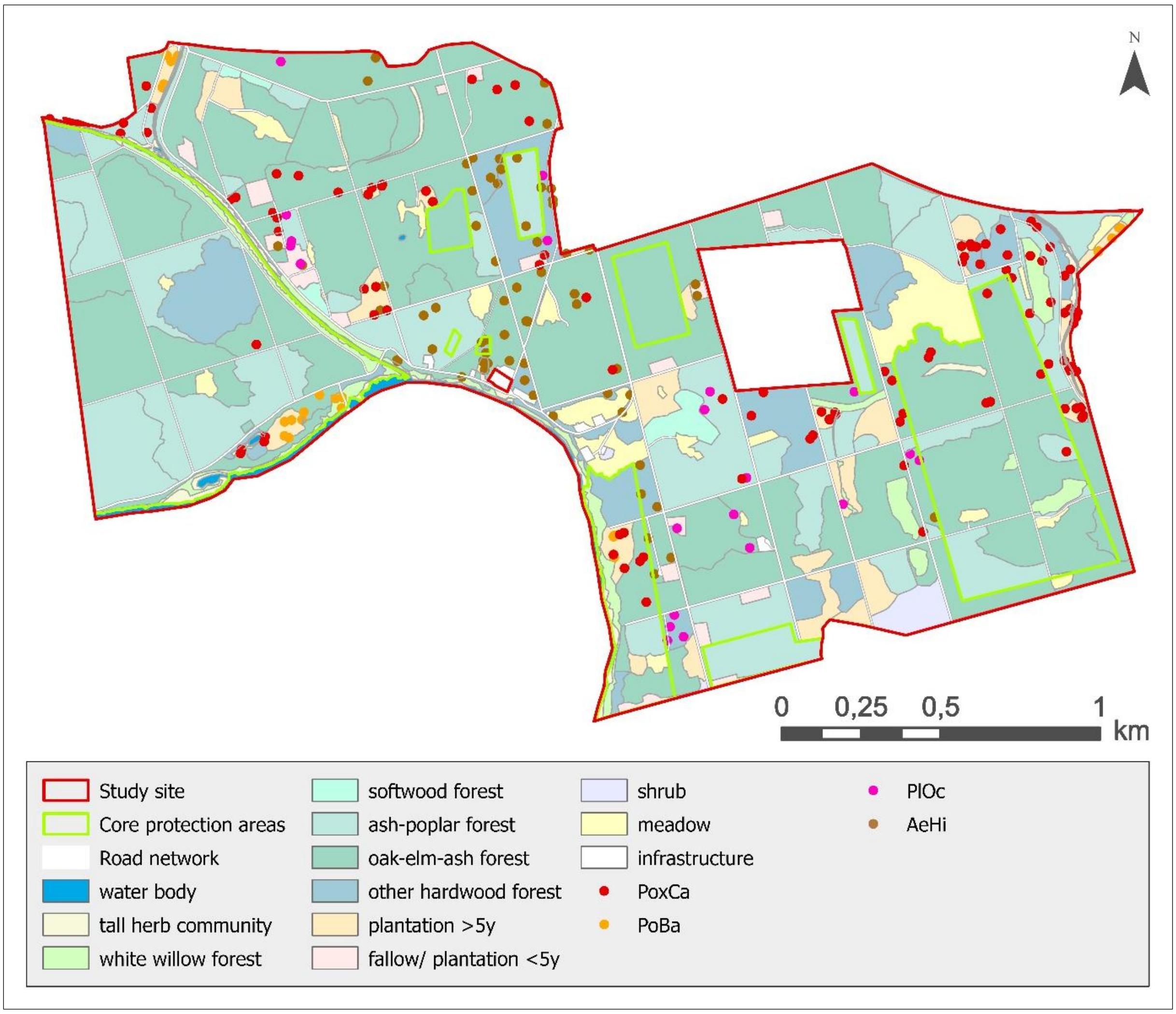


Fig.23: Occurrence of mapped non-invasive neophytes. *The respective dots per species show the abundance class (1-5) they were assigned to within each polygon. (PoxCa...Populus x canadensis, PoBa...Populus balsamifera, PlOc...Platanus occidentalis, AeHi Aesculus hippocastanum)*

Populus balsamifera occurred in 3 polygons dominantely where the trees mostly had a DBH of 40-60 cm and some individuals had 35cm in DBH. All plantations are close to water bodies. Four of the six polygons they grow in are within core zones.

Platanus occidentalis only occurred in 11 polygons but only max. sub-dominantely. None of the occurences is within core zones.

Aesculus hippocastanum, the horse chestnut, is mostly found in the central parts of the study site (Fig.23). As it was used for alleys several decades ago, most trees have a DBH between 40 and 60cm. The majority of the trees showed signs of infestation by the horse-chestnut leaf miner (*Cameraria ohridella*).

Tab.21: Abundance of neophytes in the surveyed area.
Numbers show the area in hectares in which the species occur with the respective abundance. (marks invasive species)*

	once	**admixed**	**inter-spersed**	**sub-dominant**	**dominant**
Cover proportion in polygon	**once or few herbs**	**<5%**	**6-25%**	**26-50%**	**> 51%**
Horse chestnut (Aesculus hippocastanum)	2.0 ha	22 ha	24 ha	3.4 ha	0.4 ha
Hybrid poplar (*Populus x canadensis*)	3.8 ha	36 ha	17 ha	17 ha	2.3 ha
Balsam poplar (*Populus balsamifera*)	0 ha	1.0 ha	1.5 ha	0 ha	2.2 ha
Eastern black walnut (*Juglans nigra*)*	3.3 ha	35 ha	108 ha	11 ha	3.8 ha
Black locust tree (*Robinia pseudoacacia*)*	7.3 ha	51 ha	82 ha	13 ha	2.8 ha
Plane tree (*Platanus occidentalis*)	9.7 ha	11 ha	8.4 ha	0.9 ha	0 ha
Ash-leaved maple* (*Acer negundo*)	11 ha	12 ha	1.5 ha	0 ha	0 ha
Himalayan balsam* (*Impatiens glandulifera*)	1.6 ha	11 ha	0.3 ha	0 ha	0.1 ha
Canadian goldenrod* (*Solidago canadensis*)	0 ha	62 ha	8.9 ha	5.0 ha	0.1 ha
Tree of heaven* (*Ailanthus altissima*)	0 ha	3.2 ha	0 ha	0 ha	0 ha
Ragweed* (*Ambrosia artemisiifolia*)	0 ha	6.3 ha	0 ha	0 ha	0 ha
Small Balsam* (*Impatiens parviflora*)	0 ha	191 ha	0.9 ha	0 ha	<0.1 ha
Annual fleabane* (*Erigeron annuus*)	44 ha	23 ha	0 ha	0 ha	0 ha

Neophytes occurring dominantly or sub-dominantly over extensive areas (greater than 10 ha) include *Populus × canadensis, Juglans nigra,* and *Robinia pseudoacacia (Tab.21)*. Among the tall-herbaceous neophytes, *Solidago canadensis* occurs in sub-dominantely across ~5 hectares. It is most frequently found admixed, occurring in around 62% of the surveyed area. Impatiens parviflora is even more widespread, occurring admixed over an area approximately three times larger than that of Solidago canadensis.

Additionally, some trees of the young reforestations could not be native. As they weren't accessible it's not for sure if some of the young trees are for example *Carpinus orientalis* (Oriental hornbeam).

4.1.9. Tree species insights

Whithin the native tree species, *Fraxinus excelsior* was by far (sub-)dominant within the biggest area. *Acer pseudoplatanus* occurred within 219 hectares with a cover of 6-25%. That is much more than of *Prunus padus, Ulmus leavis, Populus canescens and Fraxinus excelsior* which were als occurring on over 100 ha with a cover od 6-25%. *Quercus robur, Ulmus minor, Salix, Malus sylvestris, Juglans regia, Acer campestre* and *Alnus* were never found (sub-)dominantely.

Tab.22: Abundance of autochtonous tree species in the surveyed area.
Numbers show the area in hectares in which the species occur with the respective abundance.

	once	**admixed**	**inter-spersed**	**sub-dominant**	**dominant**
Tree cover in polygon	**1 tree**	**< 5%**	**6-25%**	**26-50%**	**> 51%**
Common Ash (*Fraxinus excelsior*)	0.9 ha	107 ha	121 ha	90 ha	10 ha
Pedunculate Oak (*Quercus robur*)	<0.1 ha	135 ha	55 ha	0 ha	0 ha
Field Elm (*Ulmus minor*)	1.7 ha	118 ha	30 ha	0 ha	0 ha
European White Elm (*Ulmus laevis*)	0. 9 ha	77 ha	175 ha	11 ha	0 ha
White Poplar (*Populus alba*)	5.6 ha	67 ha	86 ha	9.6 ha	0 ha
Grey Poplar (*Populus canescens*)	3.5 ha	64 ha	125 ha	54 ha	0 ha
Black Poplar (*Populus nigra*)	10 ha	91 ha	76 ha	5.1 ha	0.2 ha
Quaking Aspen (*Populus tremula*)	11 ha	52 ha	6.7 ha	4.7 ha	0 ha
White Willow (*Salix alba*)	17 ha	59 ha	18 ha	6.6 ha	3.90 ha
Other willows (*S. fragilis /triandra/..*)	12 ha	19 ha	2.4 ha	0 ha	0 ha
Crab Apple (*Malus sylvestris*)	2.8 ha	28 ha	0 ha	0 ha	0 ha
Small-Leaved Lime (*Tilia cordata*)	6.3 ha	97 ha	72 ha	11.6 ha	0 ha
Grey or Black Alder (*Alnus incana/ glutin.*)	8.4 ha	3.3 ha	7.4 ha	0 ha	0 ha
Black Cherry (*Prunus padus*)	0.9 ha	73 ha	194 ha	8.9 ha	0 ha
Sycamore Maple (*Acer pseudoplatanus*)	1.6 ha	50 ha	220 ha	14 ha	1.1 ha
Field maple (*Acer campestre*)	4.6 ha	101 ha	39 ha	0 ha	0 ha
Walnut (*Juglans regia*)	6.3 ha	24 ha	10 ha	0 ha	0 ha

The Annex contains a map of the abundances of native poplar species for each polygon.

4.2. Historical development

In this chapter, first the results of the comparison of this studys' vegetation and the historical map are stated. In the second chapter results of the literature study are outlined.

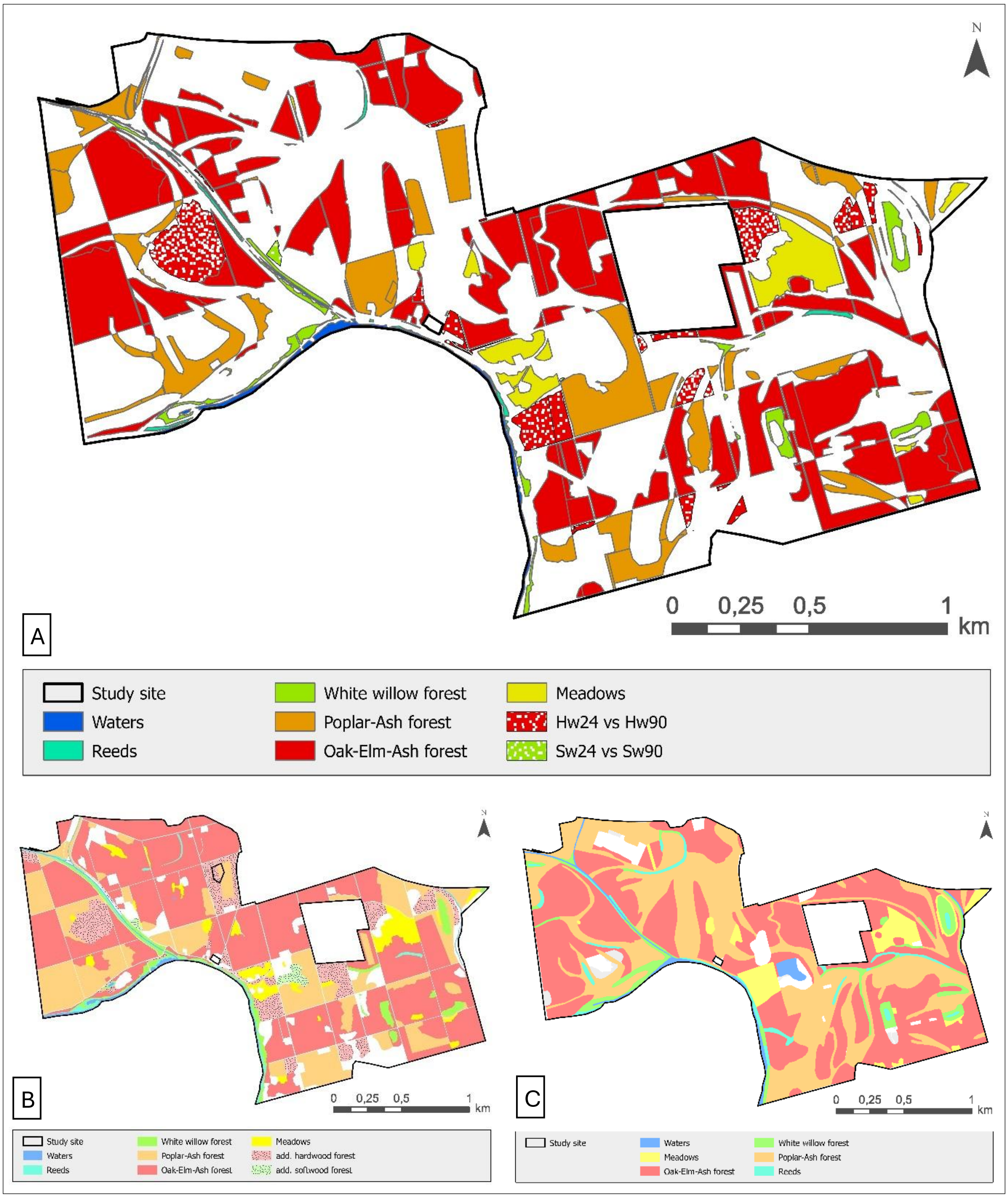


Fig.24: Historical map comparison: *A: Overlay of the same vegetation types from 2024 and 1990; B: used from this paper's maping 2024; C: Vegetation layers used from Straka 1990.*

4.2.1. Changes in vegetation since 1990

The vegetation layers mapped by Andreas Straka 1990 that were included in the comparison encompass ~375 ha and the layers from this study (Mosor 2024) amount to ~135 ha when the layers “hardwood forest” and “softwood forest were not included.

The vegetation type categories for both mappings are waters, reeds, white willow forest (SWF), poplar-ash forest (SWF/HWF), oak-elm forest (HWF) and meadows. Additionally, the vegetation types of the mapping in 2024 include additional hardwood forest (HWF) and softwood forest (SWF) (Fig.24,B).

Tab.23: Compared layers from Straka 1990 and Mosor 2024 with their area and their respective overlapping areas (yellow) in hectares and percentages of their total area in 2024.

	Mosor 2024										
		Total area in ha	**Oak-Elm-Ash forests**	**Hard wood forest**	**Ash-Poplar forests**	**Soft wood forest**	**Willow forests**	**Meadows**	**Reeds**	**Waters**	**Total Overlaps**
	Total area in ha		**152 ha**		**84 ha**		**12 ha**	**15 ha**	**4.2 ha**	**4.4 ha**	**135 ha**
Straka 1990	**Oak-Elm-Ash forests**	**184 ha**	105 ha	30 ha	39 ha		1.7 ha	1.7 ha	0.4 ha	0.4 ha	**148 ha**
	Ash-Poplar forests	**140 ha**	71 ha		81 ha	2.6 ha	1.1 ha	1.4 ha	0.6 ha	0.2 ha	**155 ha**
	Willow forests	**17 ha**	4.7 ha		2.0 ha	0.1 ha	12 ha	0.3 ha	1.3 ha	0.8 ha	**21 ha**
	Meadows	**18 ha**	1.7 ha		0.9 ha		0.3 ha	12 ha	0 ha	0 ha	**15 ha**
	Reeds	**8.9 ha**	2.8 ha		1.2 ha		2.1 ha	<0.1 ha	3.6 ha	0.4 ha	**10 ha**
	Waters	**7.8 ha**	<0.1 ha		0.5 ha		0.6 ha	0.1 ha	1.4 ha	4.3 ha	**6.7 ha**
	Total	**375 ha**	**186 ha**		**124 ha**		**17 ha**	**15 ha**	**7.1 ha**	**6.1 ha**	

The Oak-Elm-Ash forests of 2024 are overlapping in two thirds of their areas with the same vegetation type and most of the other areas were Ash-Poplar forests in 1990. Nearly all Willow forests are overlapping with the same vegetation type in 1990 and meadows to an extend of about three quarters. Water areas are also almost completely overlapping (Tab.23).

The Annex contains the overlapping layers of each vegetation type.

4.2.2. Literature study of other historical recordings

During the research, several historical maps as well as recordings of vegetational mappings were found. It was searched in online archives for historical documents as well as in books.

Historical maps depicting vegetation types

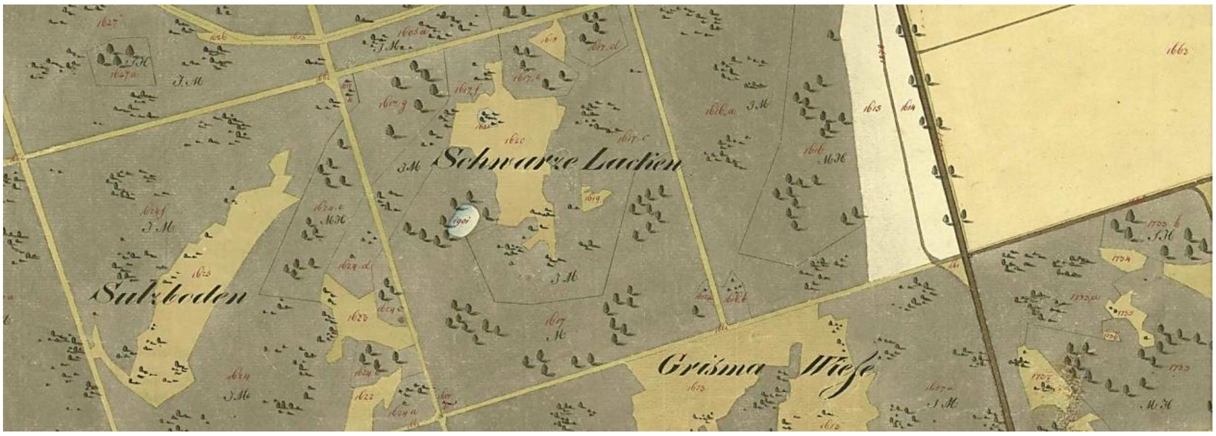


Fig.25: Franciscan Survey 1822. *In the detailed map it is visible that there was a differentiation made between "shrubs" and "forest" as well as "meadows". This is a part of the centrum of the study site and some of the meadows are occurring until now. The small lake is ephemeral nowadays.*

The first comprehensive cartographic map is the Josephinian Survey from 1773–1781, also known as the first military survey of the Habsburg Empire. Hand-drawn and coloured maps depict the floodplain areas in naturalistic manner. About 30 years later the Franciscan Survey (1809–1819) (Franziszeischer Kataster) updated the Josephinian Survey and served as a basis for taxation, with taxes primarily levied on agricultural and forestry yields (Fig. 27). The map sheets have a scale of 1:2880 and depict, with parcel-specific precision, the respective land use type. It can be mentioned that Hohensinner et al. couldn't find any differenciations between the terms "alluvial forest" and "coppice forest" used nowadays that would make sense (Hohensinner et al. 2016).
In 1846 the Perspective Map of Lower Austria was carried out by Franz Xaver Schweickhardt von Sickingen. Pasetti created a map of the Danube between 1859 and 1867 specifically for the planning of the major Danube regulation project and the third Franzisco-Josephinian Survey of the Habsburg Empire was mapped between 1872 and 1875 (infothek.donauauen.at).

Historical analysis of literature about former tree vegetation recordings or management practices

From the 17th century onwards, it is known that floodplains were used for coppice usage (Niederwaldnutzung) (Hohensinner et al. 2016; Berner et al. 2022).
The first floristic recordings are from Johann Haring in 1887 and also depicted in Figure 26. At that time, the floodplain forests covered a large area in the Stockerauer Danube wetlands and were intersected by numerous branches that were semi-dry due to the loss of direct connection to the Danube. 7 frequently and 7 rare occurring Willow species were found. *Populus balsamifera* was frequently planted and *Populus alba* was rare *and P. canescens was frequent*. Wet meadows were abundant (Haring 1887).
In the beginning of the 1990s, Mader (1992) carried out a mapping of "site units" ("Standorteinheiten") – types of vegetation that would be optimal (Fig. 26). In that time, ash trees made up ~42% of tree proportions, white popular trees ~16%, black poplar trees ~3%, oak trees as well as willows accounted for ~5% of the tree proportions. Among neophytes, hybrid poplar

stands accounted for ~12% of the tree proportion, black walnut for ~2% and black locust for ~5%. Sycamore maple made up ~4% of the tree proportion and other smaller proportions of black alder, bird cherry, and various shrubs were mentioned.

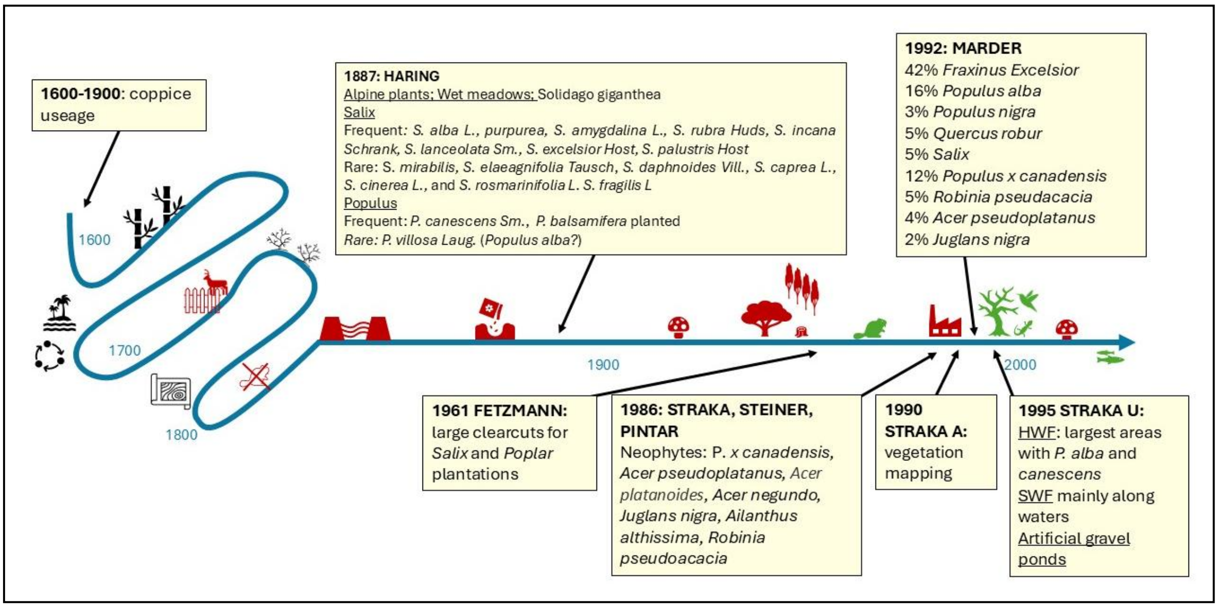


Fig. 26: Timeline of historical events with regard to vegetation analyses.
17th century*: since then, coppice usage as forestry practice (Hohensinner et al. 2016);* ***until middle of 19th century:*** *Danube as a braided river system with islands, equilibrium state (Hohensinner 2020);* ***since at least 18th century:*** *hunting had high importance, numerous game enclosures and non-native deer introduction (Barbl 2020);* ***1791****: first region mapping: Josephinian survey for the Habsbuger monarchy (Hohensinner et al. 2016);* ***1863****: the last beaver was killed* (Seiter 1990)*;* ***middle of 19th century****: Danube channelising and straightening. All other arms and water bodies have been cut off, the groundwater sunk due to the deepening of the river. Fish couldn't migrate; floodplain vegetation started to change drastically. (Straka 1995);* ***1923****: Dutch elm disease started to cause severe damage to Ulmus minor* (Kirisitz & Konrad 2007)*;* ***20th century****: widespread cultivation of hybrid poplars and black walnuts (Nicolescu et al. 2020);* ***1976****: beaver reintroduction* (Seiter 1990)*;* ***1985****: power plant Greifenstein and "Gießgang/ Krumpenwasser" was built (Straka 1995);* ***1999****: Stockerauer Au as nature protection zone;* ***since 2005****: ash dieback is occurring in Austria* (Kowalski et al. 2010)*;* ***2018****: a fish-bypass Greifenstein was built (power.verbund.com).*

Elsalore Fetzmann (1961) statet that in the Stockerauer Au beautiful floodplain forests stretched along old, former branches of the Danube, but large areas were repeatedly clear-cut and reforested with willow and poplar cuttings. The oxbows were no longer directly connected to the river and therefore had a low flow velocity, comparable to the groundwater. One of the largest of these branches is the so-called "Krumpen." A wide stone dam largely sealed it off from the oxbows above - only a few permeable spots in the dam provided a connection (Fetzmann 1963).
In 1986 Straka U., Steiner H.M. und Pintar M. assessed the ecological situation of the alluvial forest right next to Stockerau. Due to various anthropogenic interventions, the vegetation of the alluvial forest was deviating-both in species composition and structure - to varying degrees from the original state. The structure of the floodplain forest was significantly influenced by forestry use. The varying intensity of forestry was reflected in age, species composition, and forest structure. Hunting also played a major role, as the population density of red and roe deer significantly influences vegetation development through browsing pressure. The varying proportion of non-native tree species in the different subareas is noteworthy. These non-native

species include hybrid poplar, sycamore maple, norway maple, box elder, black walnut, tree of heaven, and black locust (Straka et al. 1986).
Ulrich Straka outlined the Situation in the Tullnerfelder Donauauen in 1995 and mentioned a number of artificially created gravel ponds and grasslands that exhibit a wide spectrum of mostly extensively used meadow types as well as shrub formations. Also, the alder forests resulting from coppice forestry are mentioned with hardwood floodplain forests covering the largest areas with ash as well as grey and white poplar as the dominant tree species. Softwood floodplain forests were mainly found near the river and along the floodplain waters (Straka 1995).

4.3. Recommendations for future management

What struck me positively during the mapping process was the commitment to nature education for visitors and the many nature trails and information boards, including the "Shrubtop Trail" and the "Footbridge through the Reedbed," as very nature-friendly attractions for experiencing nature. Maps of the area and flyers are available at different places, providing information about paths, core zones that should not be entered, and the conservation value of the area.
Nature's “quiet zones” appear to be respected by visitors, who generally remain on designated paths. Waste management also seems highly effective: bins were emptied regularly enough and there was no visible litter of visitors. It is also positive that the number of seating and resting places is appropriate - not too many or too few. Furthermore, the absence of large parking areas encourages access without the use of cars.
Along the watercourses, several particularly old willows are protected from beavers by wire mesh. This is an effective measure to divert beavers towards other, more common tree species. There are some more (old) willows, especially in the north-west of the area, where it would also make sense to protect them with mesh.
Besides the reforestation zones, individual trees were planted along paths. Most of them are in a good state and protected with mesh.
However, I also noticed opportunities for improvement which I will outline in the following. It should be mentioned that although I’m trained in this field, I’m not an expert and especially the recommendations regarding hydromorphical changes should be talked through with experts before implementation.

Hydrology

Many former river arms are now disconnected from flowing watercourses, though some end only short distances from active streams. Currently, these old channels are moist ditches, occasionally interrupted by roads. Reconnection to the water system could be possible, at least seasonally. This would benefit moisture-dependent species and enable planting of typical alluvial trees like poplars.
During floods, such forests would fulfil their function as retention areas. Without hydrological restoration, these areas may flood less frequently in the future. Moreover, dried-out ditches accelerating succession toward climax forest and a loss of alluvial character.

Neophyte Management

Assessment reveals a significant presence of neophytes, some of which may still be effectively removed, such as *Ambrosia, Impatiens glandulifera, Acer negundo*, and *Ailanthus altissima* - currently occurring at distinct places but likely to spread rapidly.

Solidago canadensis is extremely dominant in some areas but is rarely found scattered. It can be controlled through repeated mowing at the right times, especially as it is mostly confined to accessible former forest strips along paths.
Erigeron annuus and Impatiens parviflora are widespread and frequent, making management labour-intensive and questionable.
Management of neophytes in core zones is debated and requires further research to assess feasibility and appropriateness.
The aggressive spread of *Juglans nigra* and *Robinia pseudoacacia* warrants intensive management in managed zones. Young trees are easily removed but widespread. Felling adult trees could be combined with targeted planting of native species to outcompete regenerating invasive species. Robinia coppices vigorously, so girdling is preferable to felling.
If time or funding limit neophyte management, volunteer support could be sought. Voluntary assignments under professional supervision could help reduce the amount of neophytes.
In the very north-west of the study area, close to the highway, there is a part of protection area (160m^2) that especially needs neophyte management and a change in land use, as it functions as a reversing place for cars and is in very bad shape.

Reforestation
The reforestation method currently used, involves clear-cutting plots ranging from 0.1 to 0.5 hectares in size. While rarely a few medium-sized trees are left standing, all other vegetation is felled to ground level and completely removed. The upper layers of soil are removed or heavily disturbed and smaller biomass is shredded. This practice results in severe degradation of the upper soil layer, with both the herbaceous layer and root structures failing to survive. The exposed soil surface consequently becomes highly susceptible to colonisation by neophytes (invasive non-native plant species). This method is not compatible with nature conservation principles, particularly with the availability of alternative approaches. This practice cannot be recommended from a nature-conservation perspective under any circumstances and is not in line with the respective ordinance. The proposal of Barbl (2020) to apply this technique to convert 70 hectares over the next 15 years is especially questionable in terms of sustainability. Trees in these areas would be of almost uniform age, standing and fallen deadwood would be extremely scarce, and neophytes would likely become even more dominant. The mechanised logging and associated soil disturbance would not only result in the displacement or mortality of various faunal species, but it would also cause the loss of numerous native ecosystems.
In terms of tree species composition, one must question why native poplars are not more frequently planted. In one location, black poplars were planted using a method that involved clearing a 1–2 m corridor into the forest and fencing the individual trees to prevent browsing. These poplars are in good condition and this approach minimally alters the forest structure, does not hinder animal movement, and reduces neophyte establishment by maintaining existing soil conditions. Leaving adjacent deadwood might also help trees survive dry periods. This method is recommended to be used instead of clear-cutting as it has many ecological advantages, although it might be more costly.
Legal obligations require the paths used by the public to be secured. This has led to forest strips along paths appearing to be "cleared out," especially where ash dieback has significantly affected the area. Over a 30 m width, the tree layer is visibly diminished and not only ash trees were taken away. While it is understandable that dangerous ash trees should be removed for public safety, these strips mostly contain little to no deadwood. Trees are cut low at ground surface and

removed entirely (except for branches), which is an outdated method. More conservation-friendly approaches are already in practice in many protected areas. It is recommended to cut the stems at a height of about 4-7 meters so the tree is much less likely to fall and can stand decades longer. Sick ash trees may even need to be shorter. The thick stems are a valuable habitat for numerous species. The upper part of the tree should also be left at the site. Especially if the cut surface is incised at various angles it facilitates colonisation by organisms. Branches could be retained in 20–50 cm lengths to provide habitat for birds, without posing a hazard to visitors.
Planting individual trees in spaces where trees are missing or instead of an invasive tree are greatly recommended.

Meadow Management
Meadows are also managed in connection with hunting. Many of the meadows within forests lack species richness (at least in summer). A different mowing regime would greatly benefit the reserve. Less frequently mown meadows (e.g. "Stockwiese", "Uferwiese", meadow near the former gravel extraction) demonstrate high biodiversity.
Tracks in hunting meadows show that vehicles often drive to the centre of the meadow for feeding purposes. This results in soil compaction and visible ruts. It should be considered whether hunters could park at the meadow edge and proceed on foot, which would improve meadow quality.

Signage
Altough according to the regulation on the nature reserve, cycling is not permitted, official cycling paths exist, and their signage is clearly understandable. However, as a cyclist, it is not evident that paths, especially those not declared as official cycle paths, are prohibited for cycling. Small signs at junctions indicating which paths are not for biking would help keep cyclists on the official cycling routes.

Path Management
The road network was conservatively assessed in the mapping; for instance, forestry roads were estimated at 3.5 m in width. Some currently disused or rarely used paths were not included. Nevertheless, approximately 13 ha are dedicated to paths, which, combined with buildings and gardens, constitute 3.5% of the protected area. Given that many of these paths in the core zones are no longer necessary, it could be considered whether a significant portion should be reforested - especially those already overgrown with grasses or obstructed by fallen ash trees. Some paths are needed for hunting access, but from the perspective of this study, certain paths could be re-designated.

Private Properties
Litter is occasionally found on private land within the reserve, such as broken asbestos-cement sheets or old metal. Landowners should be held accountable for proper maintenance of their plots.
This includes sustainable neophyte management. For example, Solidago dominates around the “Naturfreunde-Haus”, and many exotic plants were observed on other private properties. Landowners should be educated on the ecological value of native planting. Mandatory removal of invasive species and the exclusive use of native plants would significantly contribute to conservation efforts.

Waste Management

Some reforested trees are marked with plastic tape or are protected by plastic or mesh guards, which sometimes remains in the forest. Ecological alternatives exist nowadays and should replace plastic materials, which should also be removed when on the ground.

Streams transport litter into the reserve, where it accumulates in deadwater zones. Regular clean-up efforts would fulfil our environmental responsibilities.

Possible extensification of core zones

The conversion of additional spaces into low-management areas would reduce the number of paths accessed by the public and therefore in need for securing. Furthermore, it would decrease disturbance for wildlife due to larger "quiet zones".

A few especially valuable forest areas were found out of the core zones. They are typically characterised by the existence willows and the absence of many neophytes. Moreover, the neighboring core zone for most, makes it a perfect place to discuss an expansion of the core area. One of those areas is a 1.5-hectare large willow forest with many young poplar trees surrounding it. A second one could be south of "Stockwiese", and many willows as well as poplar and alder trees grow there due to a transecting ditch of a former oxbow that could be temporally rehydrated in the future.

In the south-west, right after the dam at Krumpenwasser, the only gravel bed can be found. This place is very valuable for many endangered plant- as well as animal species (esp. birds). As it is within the core-zone it shouldn't even be used. A solution should be found to not always proclaim it as a "quiet zone" and eg. birds can rely on not being disturbed by dogs running freely for eg. half the year.

Potential of the Tullnerfelder Danube Floodplains FFH Site

To sustainably and comprehensively improve the overall situation for future generations and secure the function of the alluvial forest, it is recommended to research and discuss possibilities for restoring hydrological dynamics. As the discharge of the Gießgang (Krumpenwasser) and many artificial weirs are regulated by humans, there is a challenging yet feasible opportunity to create more dynamic flows.

This may require a shift in forestry practices and government support as well as, scientific research as a foundation for discussion.

All stakeholders - foresters, hunters, fishers, visitors, conservation experts, tourism stakeholders, and policymakers - should be involved from the beginning in developing a shared vision for the future of the Tullnerfelder Danube floodplain reserve. As a second step it is recommended to jointly develop a new forest management plan that takes the ordinance into account and is oriented towards nature conservation.

5. Discussion

To sum up, 30 biotope types were found within the mapping of the Stockerauer Au. The oak-elm-ash alluvial forest covers ~50%, ash-poplar alluvial forest ~21% and non-native broadleaf reforestation over ten years cover 4%. About 62% the study site area is covered by HT-91F0 or HT-E0, the rest of the forest exhibits a dedraded/ alterated species composition. The habitat type area was assessed with a "C" pointing out that the habitat is in a bad shape. Reasons for this were found manifold within the mapping: Besides the missing hydrodynamic, browsing pressure by deer is significant, the ash and field elm dieback is progressing, and invasive neophytes occur at a substantial level with rising tendacy. *Fraxinus excelsior, Ulmus minor*, *Alnus* and *Salix* species show decreased amount in offspring, whereas *Acer pseudoplatanus*, *Black Cherry, Robinia pseudoacacia* and *Juglans nigra* exhibit an extensive natural regeneration. Core zones show a significantly higher ash tree, dead wood proportion and tree proportions between 30 and 120 years and a significantly lower proportion in (invasive neophytes). And the shrub vegetation cover becomes increasingly dominant in shaping forest structure.
The Analysis of Straka's vegetation mapping data (1990) shows that most categories overlap to a very high extend. This applies to the Ash-Poplar forest, the Willow forest and the water bodies. Meadows and reeds were overlapping with three quarters of their areas. The Oak- Elm-Ash forests of 2024 are only overlapping with two thirds of their area and the other third accounts to Ash-poplar forest. This could show the succession of 70 ha from the transition stage of soft- and hardwood forest to mature hardwood forest in the last 34 years. These findings are fitting to the findings on historic vegetation data (Haring 1887, Fetzmann 1961, Straka 1995).

A) CURRENT ECOLOGICAL STATUS

Habitat assessment

The reason why all forest habitats are currently in poor condition lies in the absence of a largely intact hydrological regime. Due to the regulation of the Danube and the construction of hydropower stations, the hydrological dynamics have been altered to such an extent that the natural function of the floodplain is presently not possible (Lazowski 1997b). Even if the hydrological aspect were to be disregarded, half of the area would still exhibit poor condition due to its species composition.

Forest Types

The small-leaved lime is frequently encountered across half of the forested area and is also accompanied by species typical for lime-woods such as *Populus × canescens*, *Cornus mas*, and *Viburnum lantana*. These areas can therefore be attributed to the "mature phase." The presence of the hornbeam, however, (still) occurs not abundantely, which would otherwise indicate a climax stage. Nonetheless, it is being planted within the scope of reforestation initiatives.
The waterbodies are often surrounded white willow woodland. However, only very few young species can be found – there, most of the Willows are older than 100 years. Within moist habitats, for example close to old oxbows, middle-aged Willows are not rare. The few ephemeral lakes are home to the largest populations of willows and there young individuals can be found. With increasing drying-out of the land, not only due to climate change but also to changing groundwater levels, these habitats are under threat to experience change in their successional state much faster than what would be typical.

Ash tree situation

Ash dieback is a major factor in the alteration of tree species composition - both in softwood and hardwood floodplain forests.

Due to browsing by deer, the number of natural regenerations is significantly reduced. Mature ash trees are increasingly dying and are scarcely replaced by younger individuals. However, it should be mentioned that more natural regeneration of ash than of oak or poplar was observed. During mapping, I repeatedly had the impression that the condition of ash trees in proximity to water bodies was often better (e.g. polygons 193, 195).

Although no strict correlation could be found, it can be assumed that ash may be more susceptible to disease as a consequence of the Danube regulation, due to the absence of flooding and increasing drought. The ecological requirements of Fraxinus excelsior examined support this assumption (GULDER 2001).

Fraxinus angustifolia was not mapped, as its presence was only discovered retrospectively. Since there are populations east of Vienna, it is quite possible that it also occurs in the Stockerau floodplain forest.

Native Natural Regeneration

The greatest proportion of native natural regeneration consisted of bird cherry, European white elm, and sycamore maple (excluding red dogwood, hawthorn, woolly snowball, and privet).

Poplar presence is strong at a few sites. However, scarcely any individuals taller than 40 cm or younger than 5 years were found.

The same applies to oak trees (*Quercus robur*): only very little natural regeneration occurs and, if so, these are mostly browsed. Across the entire area, four oak specimens with a height of about 2 metres were identified. The vast majority of oaks have a DBH (diameter at breast height) of 50-80 cm, some around 110 cm, but no young individuals were found. Some of the oaks were visibly diseased.

Neophytes

Neophytes constitute a significant proportion of the tree population. Many were planted prior to the designation of the nature reserve 30 years ago, yet their effects remain omnipresent.

The black walnut is cultivated in Europe since 1629 (Nicolescu et al. 2020), in Croatia it was introduced in forest management in 1890 (Kremer et al. 2008) and in the Danube Floodplain they may be introduced at the end of the 19th century (www.waldwissen.net).

The black walnut (*Juglans nigra*) is cultivated in Europe since 1629 (Nicolescu et al. 2020), in the Danube Floodplain they may be introduced at the end of the 19th century (www.waldwissen.net). *Juglans nigra* generally has high site requirements and, according to Nicolesu et al. (2020), is rarely common in forests. It occurs dominantly or sub-dominantly on 14 ha and is found on a further 140 ha with a cover of 5-25%. As it is avoided by Austrian deer species (Ehring & Keller 2010), it has more favourable starting conditions. Only for fraying behaviour it appears that game prefers the black walnut (Nicolescu et al. 2020)- four frayed trees were identified. Black walnuts are globally the best known allelopathic species due to the juglone substance present in all parts (Nicolescu et al. 2020). These naphthoquinone dyes (juglone) exert a phytotoxic effect on surrounding vegetation and is also toxic to fish, parasites, and fungi (www.waldwissen.net). Consequently, mature individuals are likely to displace native regeneration and influence native plants negatively in other ways.

The black locust (*Robinia pseudoacacia*) was also introduced by humans, including as monocultures and strongly alters resident species composition, species diversity and nutrient availability (Staska et al. 2014). As a leguminous plant, it enriches the soil with nutrients through nitrogen-fixing bacteria in its roots, thereby altering the floristic composition of the habitat (Haider 2020). It is now present in approximately one third of the area and accounts for a significant portion of natural regeneration. It also appears to be avoided by game.
Due to the widespread presence of *Robinia pseudoacacia* and *Juglans nigra*, and the substantial proportion of their natural regeneration, displacement of native species can be assumed. This qualifies as a criterion for categorisation as invasive species; therefore, *Juglans regia* and *Robinia pseudoacacia* were assessed as invasive.

Other neophytes, such as the American poplars (*Populus x canadensis* and *Populus balsamifera*), were likewise planted as monocultures several decades ago and form species-poor stands that are only gradually being colonised by other species. These poplars exhibited significantly fewer tree cavities than native species or Populus tremula. One reason for that may be that they still haven't reached a certain age where they start to develop hollows but appear to be it the same age group because they grow faster.
In the Danube-Auen National Park, it was observed that hybrid poplar plantations become more species-rich with age and display low cover of (invasive) neophytes. It is recommended that these stands be left to develop naturally, as they are evolving toward semi-natural forests (Knoll 2015). If, however, areas are cleared as part of near-natural forest conversion, it could be discussed whether prioritising areas with high neophyte presence (e.g. black walnut and black locust) could make sense.

Deer browsing
Browsing pressure by game was mostly recorded as high and particularly moderate in the northern parts. Numerous signs of wildlife were observed in the core zones and/or near water bodies. Enclosed comparison plots indicated that wildlife populations are high. As game avoids black walnut and black locust, these species dominate among young trees. I maintain that this is another factor why native species have significantly reduced chances of establishing themselves, since these niches are already occupied. Additionally, I assert that due to the limited establishment opportunities for native species, the browsing pressure on them is further exacerbated.

Deadwood
Deadwood fulfils numerous essential ecological functions in forest ecosystems and should not be underestimated. It provides critical habitat for numerous species of fauna, flora, and fungi. Amphibians and reptiles utilise fallen deadwood for overwintering or basking, and in lakes and flowing waters, deadwood significantly increases biodiversity. Deadwood also plays an important role in forest regeneration. Additionally, tree trunks stabilise the soil and mitigate erosion, e.g., during heavy rainfall events. Furthermore, deadwood stores carbon and acts like a sponge, absorbing large volumes of water and releasing it slowly. This underscores the increasing importance of deadwood in relation to climate change (Schneider & Wermelinger 1999).
However, falling branches pose a risk to forest visitors and may increase fire hazards (Schneider & Wermelinger 1999).

A high proportion of deadwood was recorded in only three polygons, while few forest areas (excluding reforestation sites) exhibited very low amounts. Standing deadwood was particularly common in areas with many dying ash trees. In the management zone, it was clearly observed that ash trees had been completely removed along pathways. Frequently, no or only a few fallen trunks remained from these safety measures. In my view, both total and standing deadwood proportions could easily be increased within management zones, which would positively affect habitat quality.
Frequently, cut wood is piled together and left to decompose. This is a common practice to increase surface area for natural regeneration (Barbl 2020). I could imagine that uncut and piled deadwood might actually enhance regeneration potential. It retains moisture even on dry days which is crucial for young seedlings and creates structural diversity, which may make browsing more difficult for wildlife or require higher energy expenditure. This reasoning needs more research. The structural diversity also benefits many bird species. Additionally, it would offer more protection for animals, which could reduce stress levels caused by disturbance (e.g. by forest visitors).

Hydrodynamics
Throughout the entire area, one gravel patch that was formed in recent years was identified. This covered approximately 40 m^2 in summer, with no pioneer colonisation observed. In summer it is a central bathing spot for people and throughout the years for their dogs. The banks of flowing water bodies have changed only minimally over recent decades, indicating that they are only able to follow their natural flow behaviour to a limited extent.

Limitations, Data Uncertainties, and Potential Inaccuracies in Survey and Processing Methods
First of all, it should be stated that the creation of the polygons prior to the mapping has a significant influence on the entire mapping and analysis process. Although the most recent orthophoto available was used for dividing the polygons based on visible structures, this image dated back to 2019. Given the rapid changes occurring in today's forest ecosystems, considerable discrepancies were observed during fieldwork. To better represent the current situation, 70 additional polygons were created during the survey. At the beginning of data analysis, orthophotos from 2024 were released, which led to a decision to update the boundaries on a small scale. More extensive updates were not possible, as the data for each polygon had been adapted to its specific area during the time of fieldwork.
Another factor to consider is the level of experience: before the mapping process, it was difficult for me to distinguish between tree species and forest types using orthophotos. However, with increasing knowledge with the subject, it became much easier to "read" the forest in this way. This, of course, also influenced the delineation of polygons, although it could be argued that this helped prevent bias resulting from pre-sorting based on tree types. It is possible that some results might vary if the polygons had been created using a different method.
The Stockerauer Au area is often highly fragmented and mosaic-like. Even though an effort was made to divide the polygons sensibly, generalisations were often unavoidable, or certain factors became averaged out. For instance, if a polygon was relatively large and neophytes, willows, or lack of deadwood occurred only in small sections, this was often no longer reflected in the data. To avoid losing such details, field notes were taken, although they are not explicitly addressed in this work.

Sometimes polygons were too large, resulting in much being averaged out (differences no longer clearly visible or generalised in species inventory, age class). Due to the many small-scale habitats, and especially the numerous small areas in poor condition, it was not possible to capture all of them individually and particularly valuable small patches were not always recorded separately due to their size.
Furthermore, although general species knowledge was present and deepened before the mapping, I lacked the expertise to identify certain species and subspecies especially some *Salix* and *Populus* individuals - with 100% certainty, particularly due to their tendency to hybridise. Another limiting factor was the lack of accessible leaves on some trees, and despite using binoculars and a hand lens, some uncertainty remained during identification. Identification of some *Ulmus* specimens was also occasionally uncertain.
As a considerable portion of the assessment relied on estimation, it should be noted that this naturally introduces some degree of fluctuation. Depending on the surveyor, weather conditions, plot size, and experience, deviations up to a certain degree are natural (Traxler 1998; Ellmauer et al. 2005).
For classifying forest habitats, it was possible to only carry out the mapping in summer. Alluvial forests are home to a large number of geophytes, meaning that a phenological assessment would be more suitable for evaluating the area as a whole. This would also allow hydrological changes to be detected.
Particularly during the traversal of core zones, existing wildlife trails were occasionally used. This may have influenced the assessment of browsing pressure, as browsing is likely to be higher near wildlife paths.

B) HISTORICAL DEVELOPMENT

Historical vegetation map analysis

The vegetation development since 1990 shows a progression in succession of nearly half of the Ash-Poplar woodland into Oak-Elm-Ash forest. This concerns many of the forest patches in the north or east which is farest away from Krumpenwasser and the Danube. It would make sense, that the succession is faster in that region due to an increased level of dryness and/or higher elevation of the surface.
Altough these results make sense and can be underlined by the vegetation data found in other mappings (Haring 1887, Fetzmann 1961, Straka 1995), these results should be taken with caution.

Literature analysis

The tree proportions described by Mader (1992) show that the ash tree declined strongly whereas the sycamore maple, black locust and black walnut became significantly more abundant.
Haring (1887) described much more willow species and a higher abundance. Populus balsamifera was frequently planted at that time.
Straka states in 1995 that softwood floodplain forests are mainly found near the river and along the floodplain waters which supports the findings of the historical analysis, that Ash-Popular forests especially further away from water bodies transformed into hardwood floodplain forests.

Limitations, Data Uncertainties, and Potential Inaccuracies in Survey and Processing Methods

Regarding the comparison of the historical map with the results of this study, it must be stated that the findings should not be given excessive weight, as the survey methods used were not

identical. Straka (1990) did not base polygon delineation on the road network and most likely did not use orthophotos either. Furthermore, the precise criteria used for the classification of forest types remain unclear.
It cannot be ruled out that the methodologies and mapping approaches differ significantly between the two datasets. Either due to historical variations in classification systems or simply because the surveys were conducted by two different individuals with differing levels of expertise. In this case, the historical data was collected by an experienced surveyor, whereas I approached the fieldwork as a beginner.
Two additional reasons for potential discrepancies between the datasets lie in the GIS analysis. Although efforts were made to align the historical map as accurately as possible with the 2024 mapping polygons, the georeferencing was not perfectly accurate. This misalignment may be partly due to the original map not being completely flat during the scanning process, which affected its spatial accuracy.
The reason why reeds are not that much overlapping could lie in their form on the map. As they are mostly stretched in length, there is more risk to miss them in the overlay due to georeferencing or mapping inaccuracies.

C) Recommendations for future management

Deductions for the ecological situation in the study site's forests

Based on the findings of this study, it is evident that the Stockerauer Au continues to represent a valuable habitat in 2024, providing refuge to numerous threatened animal species through the preservation of its natural habitats. Despite the absence of hydrodynamic processes, neophytes introduced prior to the designation of the area as a nature reserve pose serious competition to native plant species. The limitation of these invasive species should be more effectively integrated into future management plans.
The restricted natural regeneration of native tree species such as oak (*Quercus robur*), ash (*Fraxinus excelsior*), willow (*Salix spp.*), field elm (*Ulmus minor*), and various poplar species (*Populus spp.*) is largely attributed to browsing pressure from wildlife and lets the shrub cover develop more dominance. In contrast, species such as sycamore maple (*Acer pseudoplatanus*), bird cherry (*Prunus padus*), European white elm (*Ulmus laevis*), and non-native species such as black walnut (*Juglans nigra*) and black locust (*Robinia pseudoacacia*) are likely to become more dominant in shaping future forest composition.

Limitations of Fauna and Flora Assessments under the Habitats Directive

The FFH habitat mapping plays a central role in assessing and monitoring conservation-relevant habitats across Europe. Despite its ecological relevance, the methodology could be critisised in some points.
First of all, the implementation of mapping guidelines can vary between nations or even within. For this study the mapping guidelines of Ellmauer (2005) have been used. The obligate and facultative species for each habitat can vary between different guidelines. Also, the amount and type of deadwood included within the mapping could be stated differently.
The comparison of areas mapped according to the same guideline can varies between different surveyors and could lead to inconsistencies in classification. Also, phaenotypical effects could lead to inconsistensies as habitats undergo seasonal changes and these facilitate or complicate

vegetation characteristics, the obviousness of usage or species identifications. Within this study, for example Populus tremula was much more visible in the forest in late summer than before as their leaves turn yellow.
Another critique lies in the irregularities of mapping updates. Once a site has been surveyed, it may not be reassessed for many years, despite ecological changes such as succession, pest outbreaks, or land use changes. This can lead to outdated or misleading information about a site's current condition.
Furthermore, within the Natura 2000 mapping only the protection assets are in focus and evaluated. Naturally, it would lead tot he ignorance of other valuable areas or species that have not been listed within the protection features of Annex I and II.
As observed within the „Tullnerfelder Donauauen"(not this study's study site), being designated as part of the Natura 2000 network does not, by itself, guarantee a management or enforcement that meets the aims oft he protection site, sometimes maybe not even ecological improvement. Effective conservation depends on regular planning, funding, and stakeholder involvement.
In conclusion, the mapping of the FFH Directive identifies conservation priority areas based on nominated endangered species and habitats but not whole ecosystems or species that are less known. Regional disparities in monitoring efforts and methodologies can occur and the six-year reporting cycles delay the detection and response to ecological changes or short-term fluctuations could average themselves out. This undermines data comparability and complicates national-level assessments of conservation status.

Limitations regarding future management

When considering future management for the Stockerauer Au there are various challenges or potential limits that could arise. Some of the key elements are listed in the following section.
First and foremost, it could be challenging to find compromises in management practices between the various stakeholders (forestry practicalities, nature protection regulations and aims, hunters, recreationists, fisher, landowners, tourism and the local municipality). In many fields there will be overlapping interests but in terms for usage rights ther could appear conflicting interest or responsibilities. As it is a nature protection area the respective laws need to be fulfilled as basis and for the freedom that comes on top it makes sens to formulate an overall aim that every actor can support in their field. Much communication that informes every included actor from the beginning is important so every party feels heard and informed.
Like mostly, financial constraints can also lay a role. Laborious forestry practices, time-consuming invasive species control, costly hydrological restoration, or future monitoring and research can be expensive and, in some cases, dependent on grants, funding or cooperations. Besides, the maintenance of the actual structures, signs and much more needs attention and ressources.
Depending on which changes in the management could be implemented, there is always the risk that users are not willing to change their behavior or follow new guidelines (bike paths, core zone).
In a long-term, consistent monitoring data is needed to evaluate success or adapt strategies based on changing conditions like climate change. Regarding the Lower Austrian Natura 200 areas the last comprehensive data survey dates back more than 20 years. Starting in 2025, the current condition of the existing FFH habitat types will be assessed.
Moreover, it can happen that management practices don't show the aimed effects if they are not performed in the needed timeframe or extent (eg. invasive species management).

The management vision and aims are important to be communicated to the public with information why it is important to do so to create awareness and support (deadwood management, invasive species, “quiet areas” for wildlife, restricted paths, restoration and reforestation projects).
Finally, there could be regulatory restrictions of forestry laws, hunting laws, nature conservation laws or Natura 2000 guidelines that may limit aimed interventions like the establishment of “quiet zones”, path redesignation, logging practices or hydrological alterations.

6. Conclusion

The data carried out in the field work as well as within the historical analysis serves as an updated evaluation of the site’s condition – especially of the forest. The data can be valuable for further research as well as for an update of the existing management plan.

Current ecological status

As the forest habitat is in a poor ecological condition, changes are necessary to again fulfil the objectives of the nature protection site and to act by law. Especially the loss of hydrodynamics, natural regeneration and the species composition need to be in focus to preserve the site as alluvial forest with all its protected assets and valuable functionality.

Historical development

The historical development analysis underlines the findings of the field study: the forest is transforming towards a climax state which would not be an alluvial forest anymore. Primary succession does hardly play a role and if no major changes happen, the historical developments will continue to unfold, leading to a decrease in alluvial forest, endangered species and habitats.

Recommendations for future management

Luckily, there are many possibilities to preserve and restore the protected habitats and species. Some of the described recommendations are easy to implement (eg. leaving lying deadwood and standing stems of 4-7 m instead of removing the whole tree due to security reasons). Other management practices need more planning, good communication and maybe grants (eg. neophyte management). However, these are only the very tip of the iceberg. To preserve the alluvial forest, the hydromorphology needs to be restored.
Hydrological changes that affect only the Stockerauer Au are likely to be implemented more easily than those involving the Krumpenwasser. Altering the Krumpenwasser system would require the inclusion of all relevant stakeholders as well as targeted research to develop viable planning proposals. In particular forestry practices would need to adapt to more natural site conditions.

The management changes will not only determine the prospective ecological functions of the site (eg. as drinking water reserve) but also its existence in the next decades or centuries. Especially regarding climate change and biodiversity loss these decisions will have great effect on future generations.

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Geoshop, Federal municipality of Lower Austria
- Cataster map (2023)
- Borders of Nature protection and Natura 2000 areas
- Digital elevation model (2019)
- Surface model (2019)
- Orthophotos (2019, 2024)

eHAÖ – Hydrological Atlas of Austria (2001)
Pulisher: Bundesministeriums für Land- und Forstwirtschaft, Klima- und Umweltschutz, Regionen und Wasserwirtschaft (BMLUK).
Production: Institut für Hydrologie und Wasserwirtschaft der Universität für Bodenkultur Wien (BOKU).

Popular science summary

Floodplain ecosystems consist of flowing waters that naturally form a diverse and always changing landscape of gravel and sand banks, islands and lakes that once were part of the stream. They are home to many endangeded animals and plants, most of them can only live there. Close to the water, where waterlevels often rise, herbs and willow bushes grow. At places that are less inundated, willow trees develop and at higher elevations ash-poplar woodlands establish. At even higher elevations where floodings are less frequent, hardwood forests establish with elm, ash and oak trees. Functioning floodplain ecosystems need regular floodings, a shallow groundwater table and a river that changes the landscape. Over centuries, the plant species of a place typically change in a certain order (herb -> shrub -> softwood forest -> ash-poplar forest -> hardwood forest).

Within central Europe, truly natural hardwood floodplain forests do not exist along large rivers anymore. Today, fewer than 10% of Germanys floodplains remain ecologically functional, and hardwood floodplain forests, which are particularly ecologically valuable, now cover only about 1% of their former extent. Also, in Austria floodplain forests are heavily degraded by river channelization and hydropower plant constructions. Moreover, forestry, agriculture, fishing, gravel extraction, deer browsing, various tree diseases as well as plant species that originally don't come from Austria threaten their existence. This happens even though we humans need these ecosystems for drinking water, climate regulation, flood retention, recreation, water purification and many more.

This study aims to assess the ecological state and the historical forest development of a floodplain protection site north-west of Vienna in Austria. It's called "Stockerauer Au" and is not directly connected to the River Danube for 150 years. Within a vegetation mapping, 30 different biotope types have been identified of which half was hardwood forest. 4% of forests were dominated by species that originally don't come from Austria like black locust or black walnut. These tree species are strong competitors and even a threat to native trees. Zones of the nature protection area that are not allowed to be managed show higher proportions of ash trees, deadwood, and trees between 30 and 120 years.

As a second part a map showing vegetation types of the year 1990 was compared to the vegetation types found in this study. The results suggest that waters and willow forests didn't change in area but the ash-poplar forest. One third of the hardwood forest nowadays was ash-poplar forest 34 years ago. These findings are also fitting to the findings of a literature analysis concerning historical vegetation records (Haring 1887, Fetzmann 1961, Mader 1992, Straka 1995).

In conclusion, the study site "Stockerauer Au" can develop in two major directions: either hydrological dynamics can be restored, and the objectives of the protection areas will be kept. Or the management will continue more or less as it is and the forest will predominantly develop into a climax state, leading to the loss of many protected habitats and species. All in all, management practices in the Stockerauer Au need to be updated and a broad, inclusive discussion on how to reach the aims of this nature protection site is welcomed. This needs further research on how more hydrological dynamic would affect different actors and how a potential revitalisation could be accomplished.

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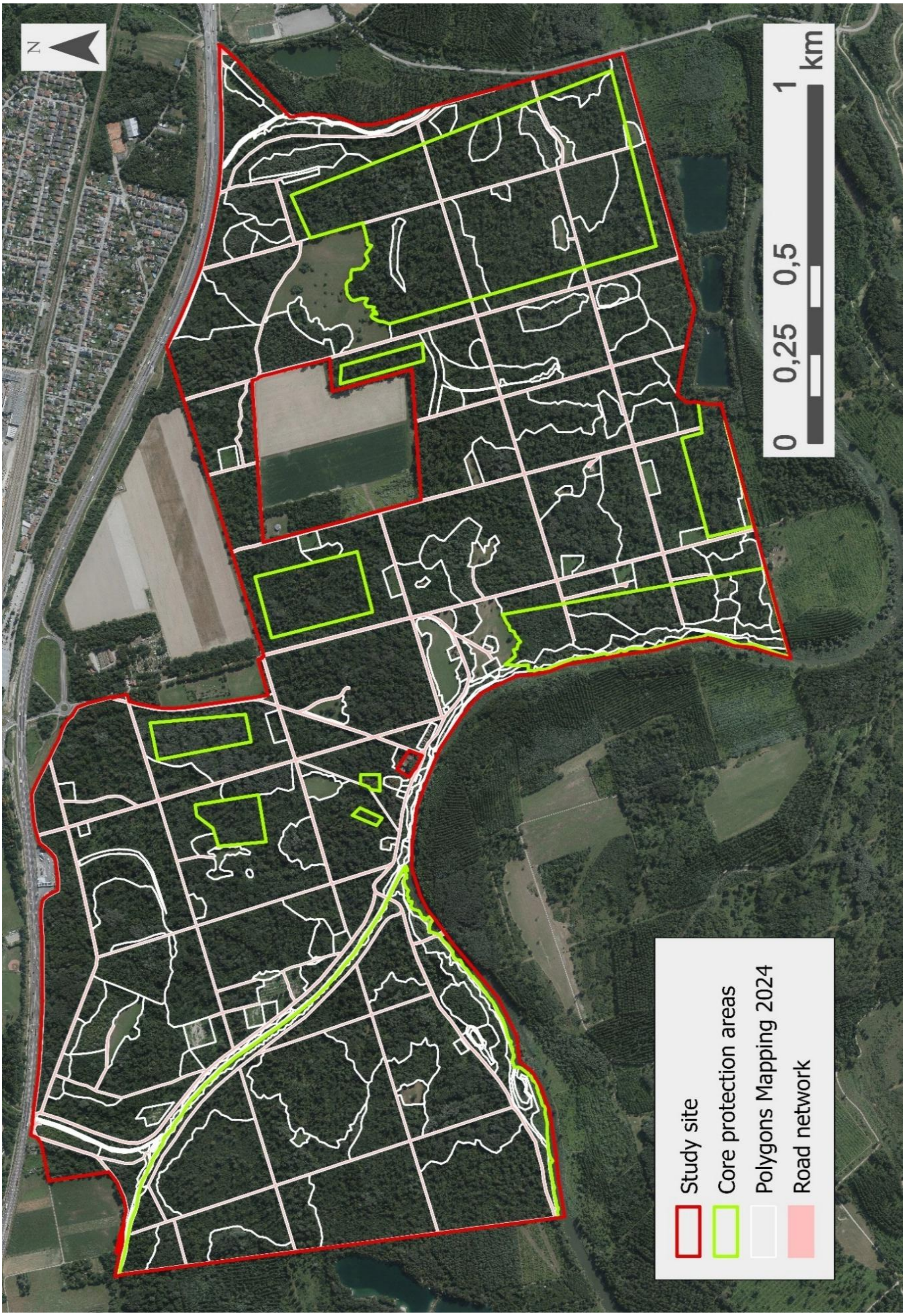


Fig.I: Polygons and road network created within the mapping 2024 in the Stockerauer Au. *(In green the core areas are visible and in red the border of the nature protection area. Source Orthophoto: Geoshop, Federal municipality of Lower Austria)*

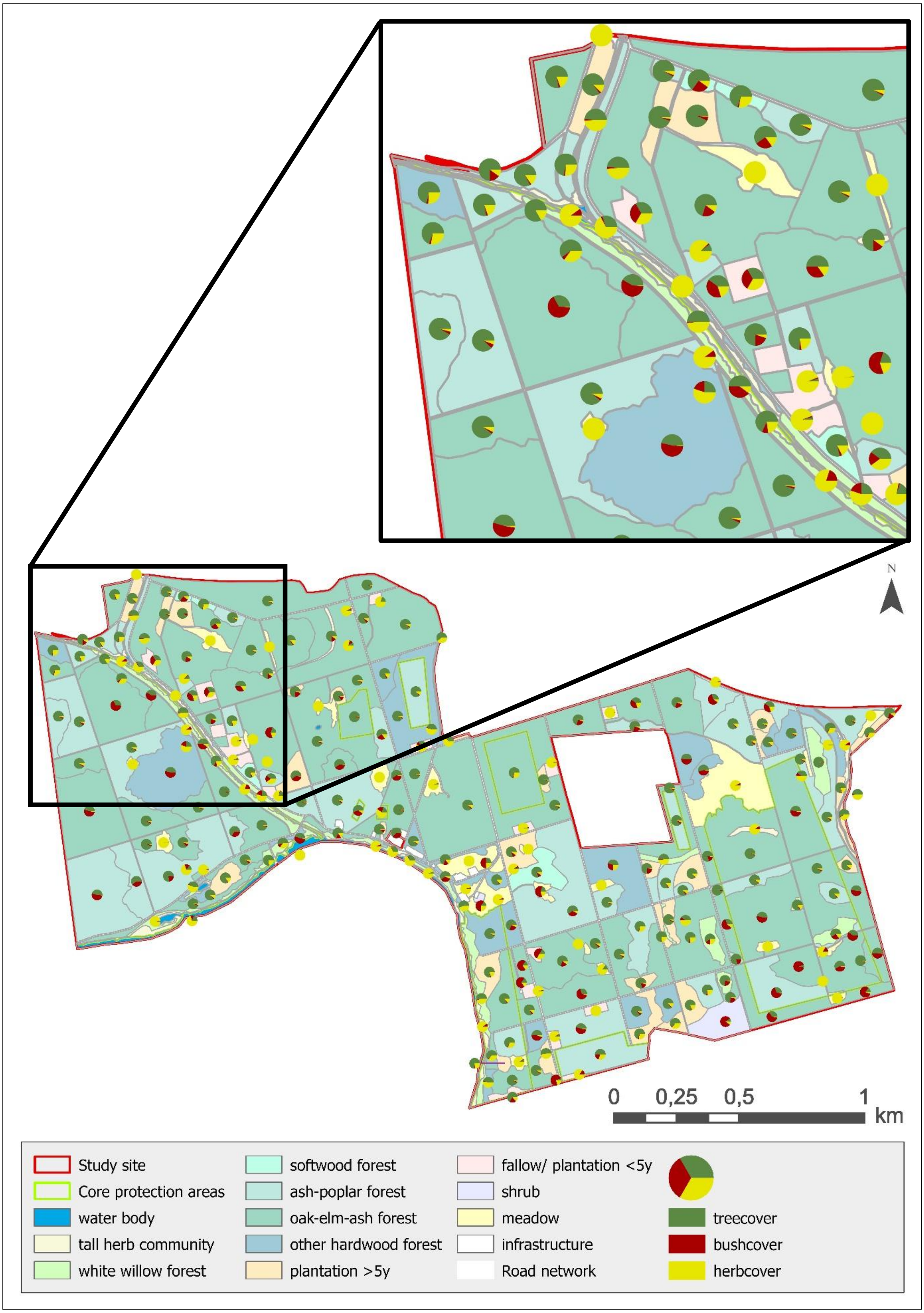


Fig.19: Coverage ratios of tree-, bush and herbcover in comparison with the simplified vegetation types and the core zones.

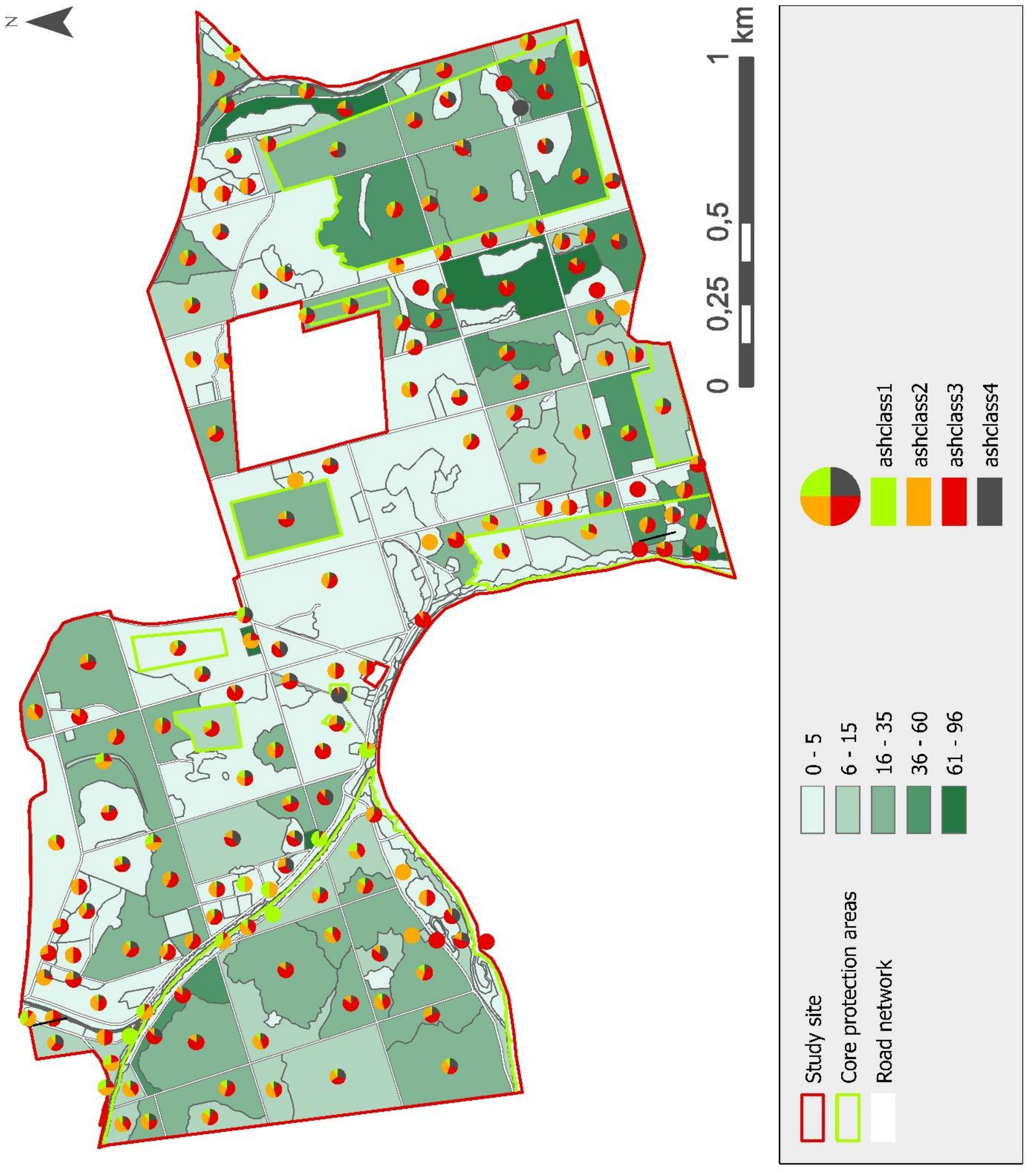


Fig.II: Ash tree proportions for each polygon in green and the respective ash classes as proportions in a chart above.

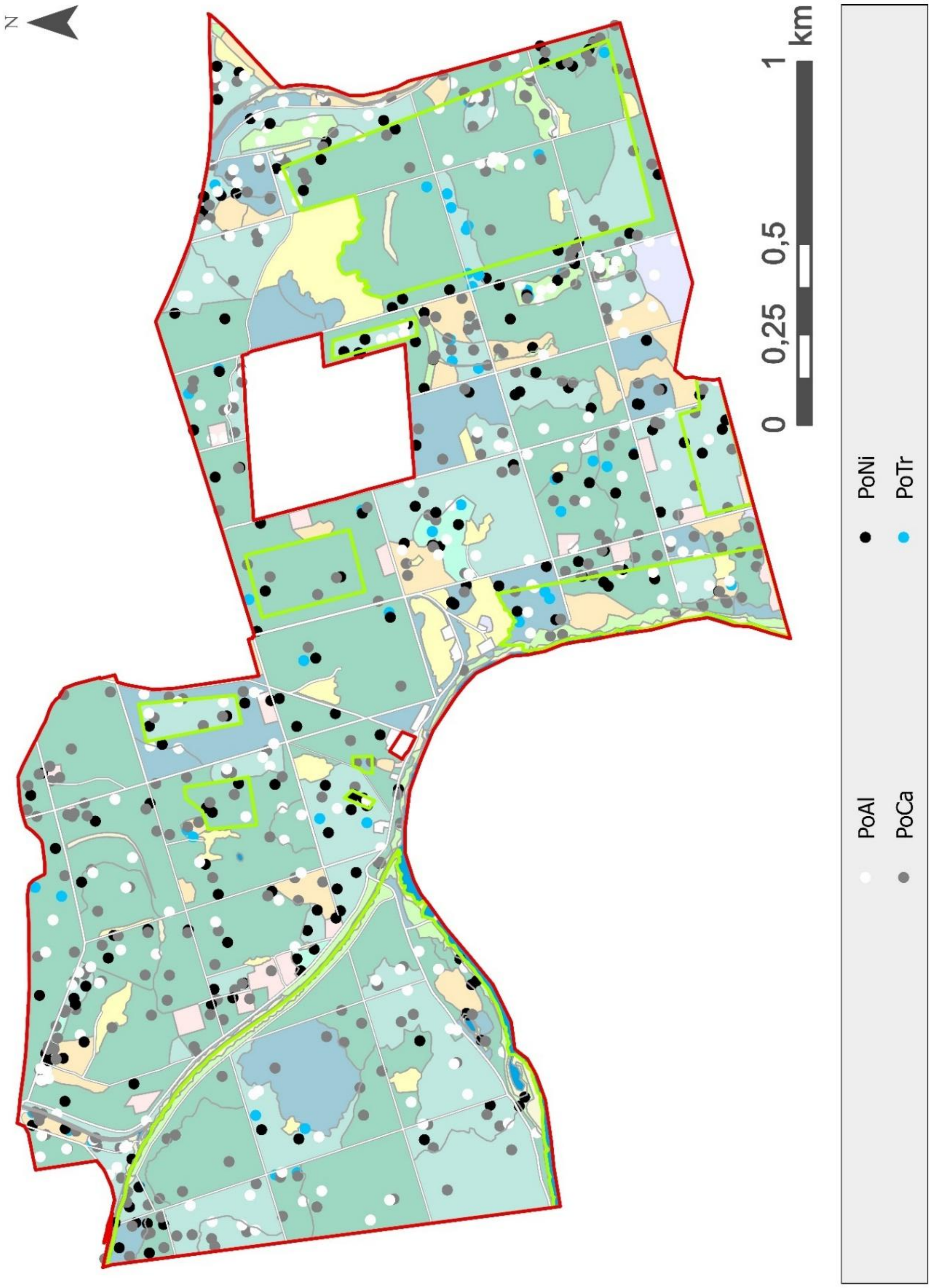
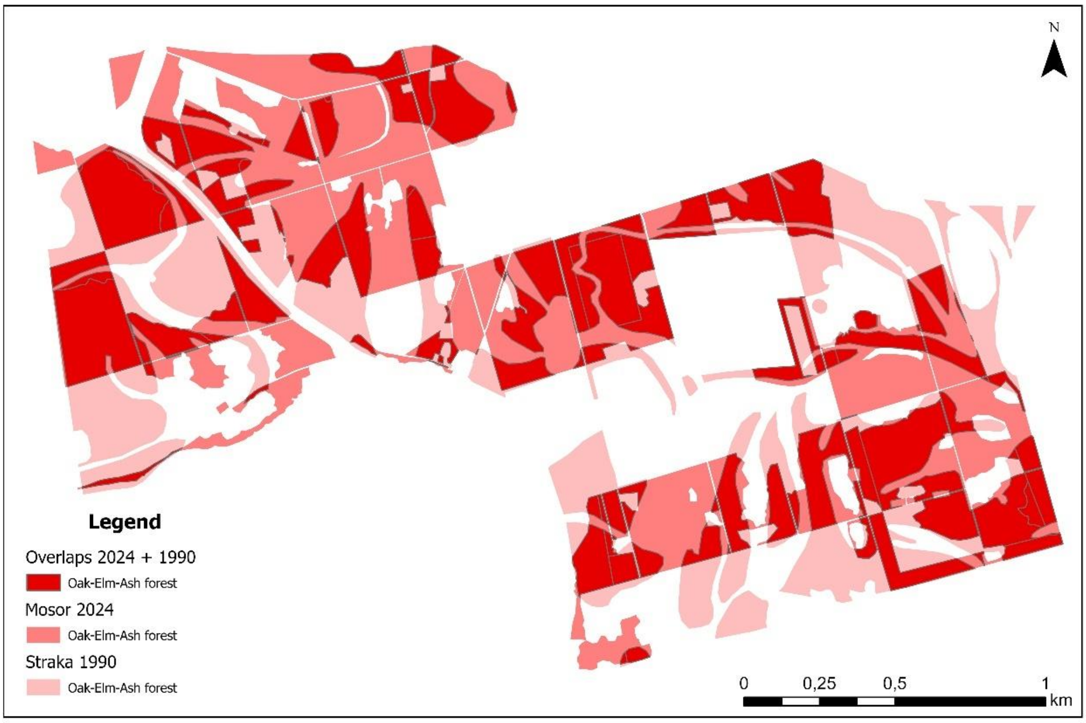
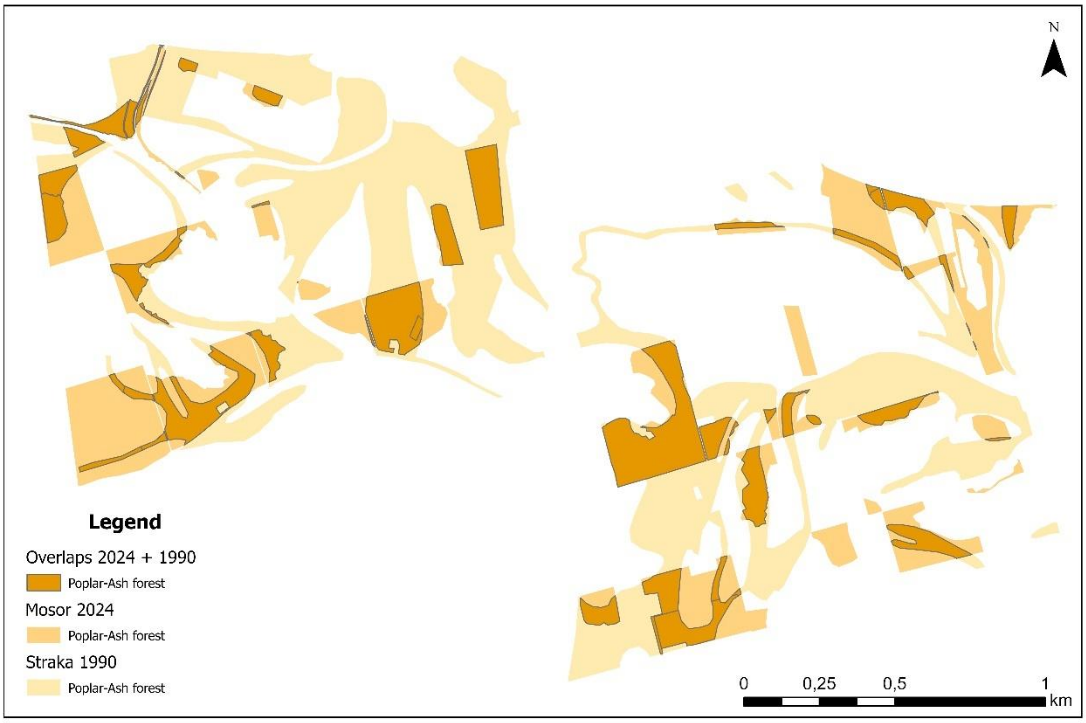
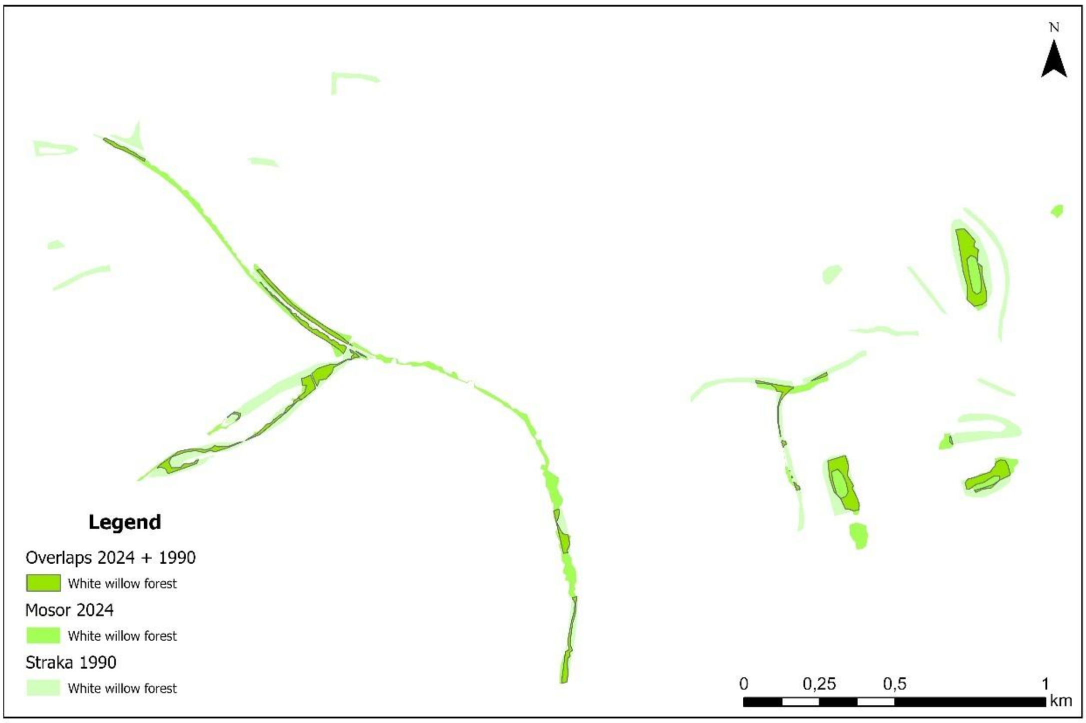


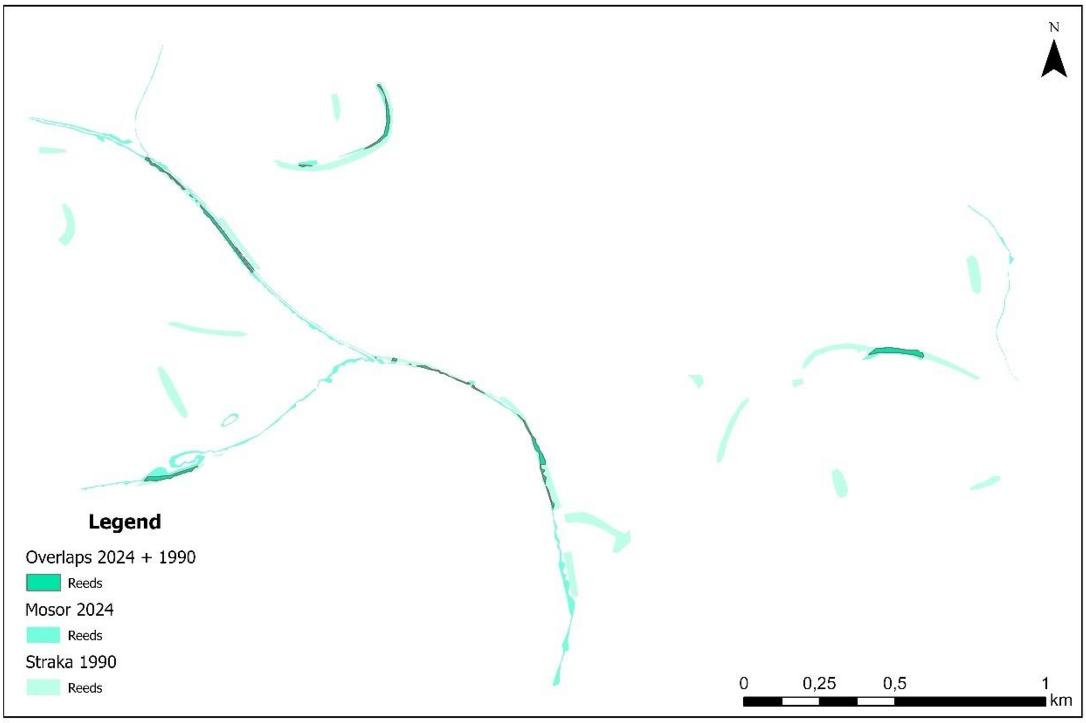
Fig.III: Poplar species and their abundances per polygon. *Each point (1-5 per polygon) represents one abundance class higher (1...once, 5...dominant) (PoAl...Populus alba, PoCa...Populus canadensis, PoNi...Populus nigra, PoTr...Populus tremula)*

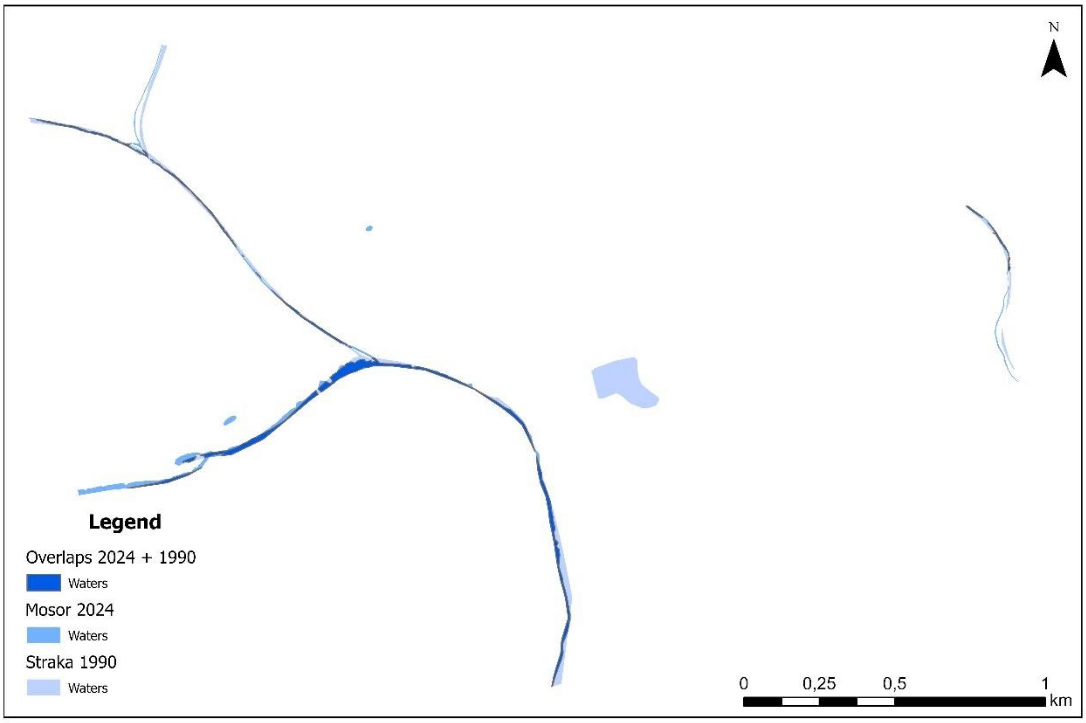
Fig.IV-X: The following 6 maps show overlaps of each vegetation type of Straka 1990 and Mosor 2024.

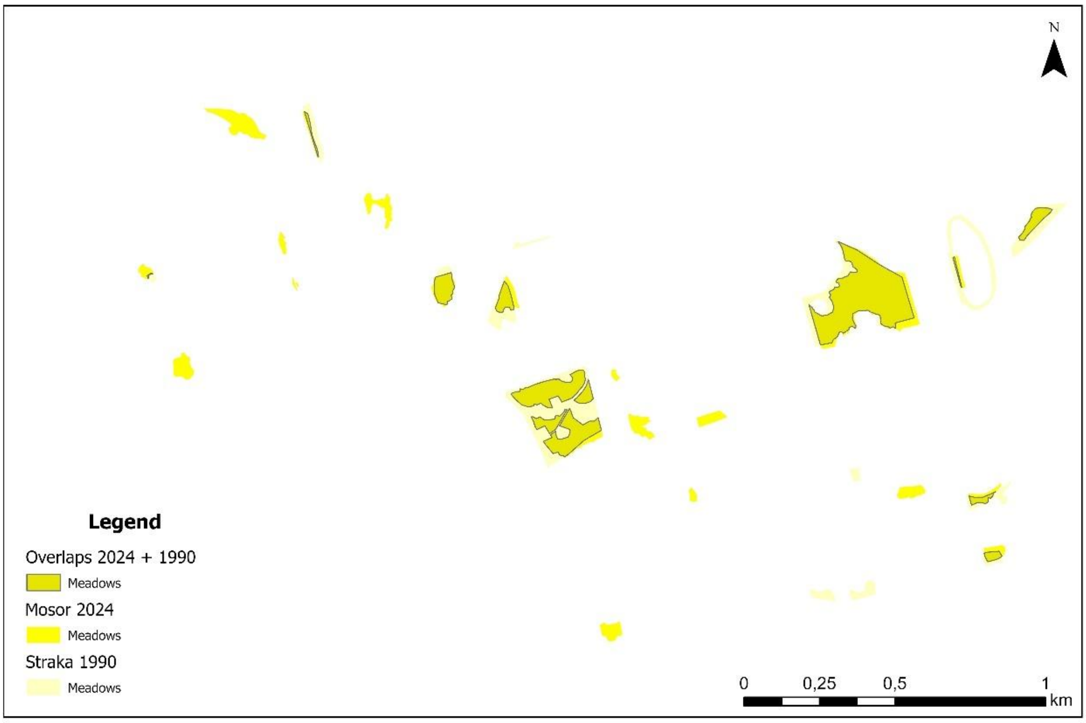





N
Legend
Overlaps 2024 + 1990
White willow forest
Mosor 2024
White willow forest
Straka 1990
White willow forest
0
0,25
0,5
1
km


N
Legend
Overlaps 2024 + 1990
Reeds
Mosor 2024
Reeds
Straka 1990
Reeds
0
0,25
0,5
1
km


N
Legend
Overlaps 2024 + 1990
Waters
Mosor 2024
Waters
Straka 1990
Waters
0
0,25
0,5
1
km


N
Legend
Overlaps 2024 + 1990
Meadows
Mosor 2024
Meadows
Straka 1990
Meadows
0
0,25
0,5
1
km

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