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Human-induced vegetation change in the Turaida vicinity during the Iron Age and the medieval period

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Abstract

A lack of detailed information on pollen from the Gauja River valley potentially limits the strength of various reconstructions (vegetation composition, human impact, dominant agricultural activities) for this territory. This study seeks to examine the human-induced changes on vegetation, in particular with regard to the arrival of the Livs in the Turaida vicinity during the Late Iron Age. Here, we present the first analyses of pollen data, macroscopic plant remains and macroscopic charcoal undertaken in the lower Gauja River valley (territory inhabited by Gauja Livs). The gathered sediment record, or the Roči bog, points to the appearance of the Livs in the territory during the 10th century. Our results show an accelerating shift in the landscape from dense forest coverage to inclusion of more open areas, which would be consistent with the clearing of areas for cultivation.

The human-induced change resulted in a decrease in forest coverage, an increased presence of cultivated plants and an acute intensification of fire-related events. The sediment record shows that oat cultivation was dominant during the Late Iron Age and other crops (barley, wheat, rye) came into sustained use only at the beginning of the medieval period. The sudden decline in all cultivated crops (barley, oats, rye and wheat) in the mid-14th century could be due to sudden environmental changes or to the Black Death, but as this data contradicts research from other parts of Latvia, further study is advisable.

Introduction

Few doubt that the increased urbanisation and intensified agrarian activities of the Late Iron Age and medieval period left a significant impact on the surrounding environment. Within the last two decades, there has been a growing interest in exploring the interplay between nature and the people inhabiting it (Brown and Pluskowski 2013; 2014; Stivrins et al. 2015; 2016; Brown 2019; Laimdota et al. 2019; Izdebski et al. 2022). The variations in the studied regions reveal both similarities and differences in how the local population adapted to or influenced their environment.

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One of the understudied regions in Latvia is the lower part of Gauja River valley near modern-day Turaida. Historical and archaeological findings indicate that during the Late Iron Age, the Finno-Ugric–speaking Livs settled this territory and established new urban centres by constructing fortified wooden castles (known as hillforts) (Graudonis 2003a, pp. 22–24; Zemītis et al. 2024, p. 8). This led to intensified exploitation of natural resources, through both agriculture and the need for craft materials.

This paper examines land-use patterns during the Late Iron Age and medieval period in the vicinity of Turaida hillfort. It aims to set an information baseline concerning the Gauja Liv landscape and its transformation. To answer the scientific questions, this study uses principal palaeoecological research methods, such as pollen, macroscopic plant remains and macroscopic charcoal analysis in conjunction with the historical and archaeological data. The Roči bog was selected as the current study site as it is located near the Gauja Liv population centre — Turaida hillfort — and is surrounded by historically cultivated lands and thus holds relevant information about past people's activities.

1. Material and methods

1.1. Study region

The earliest human presence in the lower Gauja River basin based on archaeological material is considered to be as early as 9000–8300 BC (Ciglis 2015, p. 11). These people were transient hunter-gatherers who did not leave a notable trace in the surrounding environment. During the Middle Neolithic (4100–2900 BC), there was an episodic presence of people of the Corded Ware culture who practised semi-nomadic cattle breeding. Their survival strategy still relied largely on exploiting the existing resources rather than establishing agricultural practices. The earliest known permanent settlement (Krusta kalns) near Turaida is related to the 1st millennium BC (Ciglis 2015, p. 13). How extensively the lower Gauja settlements were used is still under discussion as the known settlements and cemeteries contain little archaeological material and have not been sufficiently dated. Based on the sparsity of the known artefacts, it is assumed that the population density was low (Ciglis 2015, p. 27; Zemītis et al. 2024, p. 12).

The archaeological record shows that the arrival of the Livs was the most notable demographic shift in the region. Historically, the exact time of the appearance of the Livs has been attributed to either the very end of the 10th or the beginning of the 11th century (Graudonis 2003a, p. 23, 31). The latest scientific studies seem to be more in favour of the 10th century. Excavations in Jāņukalns (0.4 km from Turaida hillfort) revealed burials with artefacts typologically attributed to the 10th century (Fig. 1) (Jemeļjanovs 2014, p. 50; Beitiņa 2015, p. 119). Although the site is disturbed, the artefacts are the earliest archaeological material indicating the arrival of Livs in the vicinity (Ciglis 2015, p. 29). Additionally, the charcoal found at Kārļa kalns (approximately 0.2 km from Turaida hillfort) have been dated to the 10th century (Zemītis 2024, p. 12).

The most densely populated centre in the region was Turaida hillfort (Fig. 1). The start of its construction has been dated by archaeologist Jānis Graudonis to the second half of the 11th century (Graudonis 2003b, p. 7, 13; Beitiņa 2015, p. 139). This was done based on the dendrochronological dating of the excavated houses and the typological dating of artefacts. However, in 2015 Jānis Ciglis re-examined the artefacts excavated at Turaida hillfort. He found that some of the originally excavated Turaida hillfort artefacts could be typologically dated to the 10th century (Ciglis 2015, p. 29; Beitiņa 2015, p. 139). This dating is also indirectly supported by the ceramic material, which contains a notable amount of hand-built pottery. Although this type of pottery was used till the beginning of the 12th century, it would have been more common in the 10th century (Dumpe 2019). So far, the matter cannot be considered fully resolved as different authors state different preferred dates for the start of the Turaida hillfort (Graudonis 2003a, p. 23, 31; Graudonis 2003b, p. 7; Ciglis 2015, p. 29; Beitiņa 2015, p. 13; Dumpe 2019, p. 18; Zemītis et al. 2024, p. 12, 15). What is undisputed is that during the 11th to 12th centuries the hillfort was a political and economic centre with a corresponding population density.

During the Baltic crusades, the Turaida hillfort was burned down and in 1214 a stone/brick castle was built in its place (Graudonis 2003a, p. 49; Jansons 2007, p. 11). The later castle functioned as a military and political centre, but around the 16th century it started falling into disrepair (Jansons 2007, p. 146) and in 1776 the last functioning buildings were destroyed in a fire (Ose 2017, p. 10).

The study site is situated within a region predominantly influenced by Quaternary glacial and glaciofluvial processes. The glacigenic sediments, primarily composed of unsorted till material, extend across the northern, western and southern parts of the surrounding area. These sediments, deposited by glacial activity, are characterised by their heterogeneity, containing a mixture of clay, silt sand and gravel. In contrast, the eastern part of the region is dominated by glaciofluvial sediments, which consist mainly of sand. These sediments were deposited by meltwater streams during the retreat of glaciers, forming stratified deposits typical of glaciofluvial environments. The sandy composition of this area influences both the landscape and hydrology, providing a permeable substrate that affects water infiltration and drainage patterns. The lowest elevations within the study area, which are also the

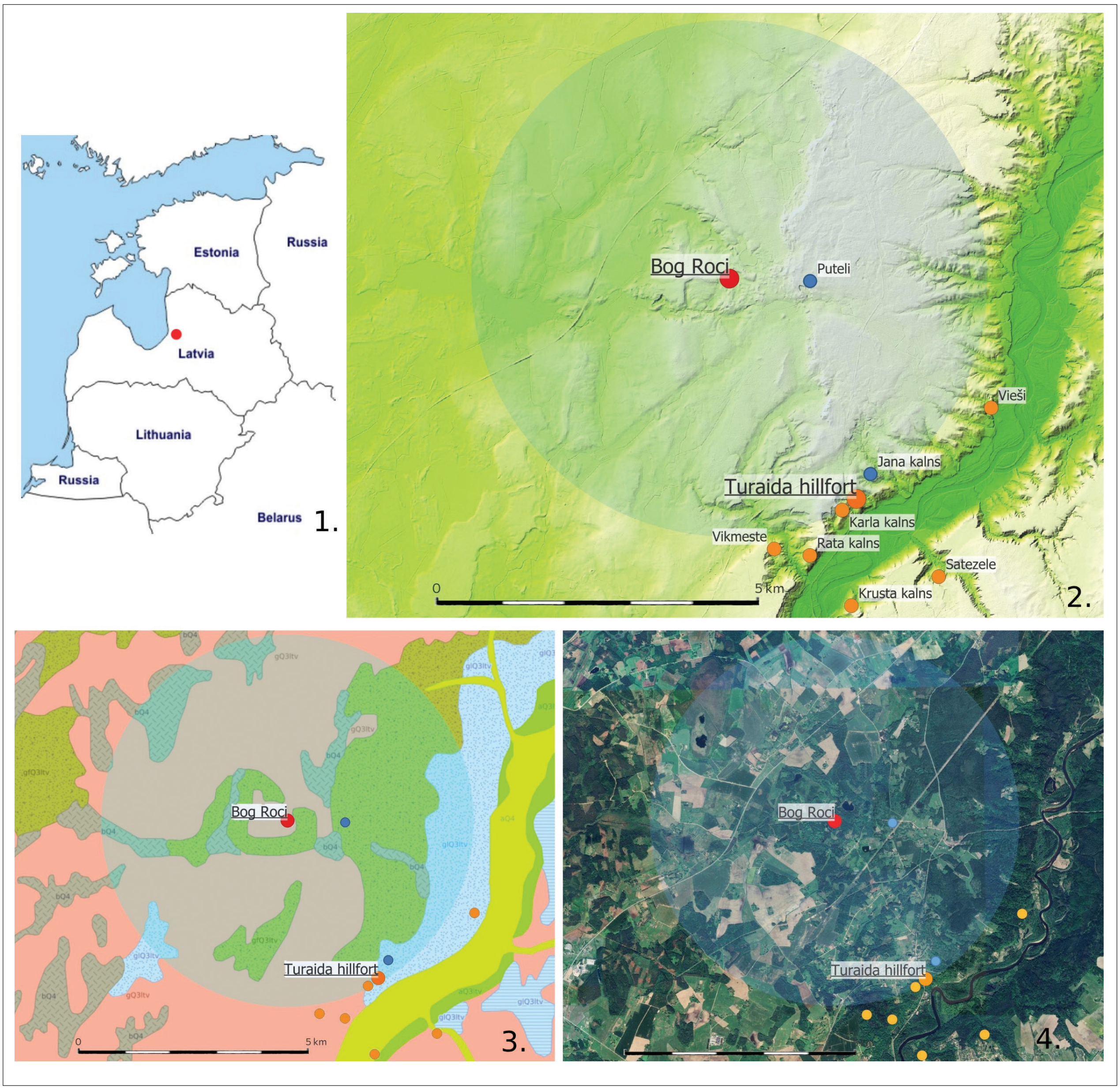

Figure 1. 1. Location of study area. 2. Topographical information with Late Iron Age sites: Roči bog in red, hillforts in orange and cemeteries in blue. Approximation of pollen source area designated in light blue. 3. Region sediment map. 4. Aerial photograph from Google Satellite (2024).

moistest, are occupied by peatlands. Over time, peat has accumulated in these poorly drained depressions, where organic material has decomposed under anaerobic conditions.

The Roči bog is a raised bog located in Sigulda municipality in the Gauja National Park, which is the first and oldest national park in Latvia and protects the Gauja valley and surrounding areas. Average air temperature for this locality is +7.3°C, total precipitation 682.1 mm. Currently, Roči bog vegetation includes *Sphagnum* spp. (*angustifolium*, *divinum*, *girgensohnii*, *palustre*, *majus*), *Pleurozium schreberi*, *Polytrichium strictum*, *Oxyrrhynchium speciosum*, *Dicranum polysetum*, *Pinus sylvestris*, *Calluna vulgaris*, *Empetrum nigrum*, *Eriophorum vaginatum*, *Ledum palustre*, *Rubus chamaemorus*, *Vaccinium oxycoccos* and *Vaccinium uliginosum*.

1.2. Sampling

The surrounding fertile land in the vicinity of Turaida has undergone intensive agricultural change (melioration/drainage), which has affected most of the possible sampling locations. The feasibility study of the area showed that the Roči bog is the optimal research object, with a continuous sediment accumulation allowing for the tracing of environmental change over time. The Roči bog (57º12'48.6", 24º49'07.1"; 4.15 ha") is located 3.4 km northwest of Turaida hillfort — the densest inhabited site of the region. According to the empirical studies, the pollen source area for small- to medium-sized sites, such as the Roči bog, is predominantly <4 km (Poska et al. 2011; Stivrins et al. 2021). The particular area is located neither at the highest nor the lowest point and as such would cover an average area (Fig. 1). The biggest terrain variation is in the west–east direction. Towards the east, the relief becomes elevated for a stretch of 3 km, before a fall towards the Gauja River, and in the western direction, the terrain slopes for an approximately equal amount. To narrow down the area more precisely, further studies on how the elevation affects pollen spread would need to be done, but regretfully this fell outside of the scope of this study. The coverage area includes historically cultivated land, farmsteads and roads that have been used to create agricultural produce and other resources (Femthe Dehls Transp 1683). This area would therefore best illustrate the human-induced vegetation change in the vicinity of Turaida.

The sediment samples were taken on 18 August 2023 by Normunds Stivriņš, Sabīne Krēsliņa, Nauris Jasiūns, Dāvis Matskins, Alise Gunnarssone and Justīne Timermane. Sampling was carried out using two methods: (1) the top sample was cut with a sharp 30 cm long two-blade knife to preserve the natural density of the acrotelm, which would be compressed if cored with a peat auger; (2) with a 1 m long peat corer (chamber diameter 10 cm) and interconnecting metal rods. Coring was done using a parallel coring technique with sediment overlap to avoid potential sediment losses. In total, 2.37 m of sediment was cored. After obtaining the samples, each one was described on site, photographed, moved to a horizontal position and wrapped. The samples were taken to the University of Latvia, where they were stored horizontally in a cold room (at a temperature of 4–6°C). The subsequent laboratory analysis was carried out in the Quaternary Environment Laboratory, Department of Geography and Earth Sciences, Faculty of Science and Technology.

1.3. Chronology

The chronology of the Roči bog profile was established by ^{14}C Accelerator Mass Spectrometry (^{14}C AMS) dating (seven samples of terrestrial plant macrofossils). All dates were submitted to the Accelerator Mass Spectrometry Laboratory at the Vilnius radiocarbon facility (Lithuania). The ^{14}C AMS dates were calibrated using the latest available IntCal20 calibration dataset (Reimer et al. 2020) and produced an age-depth model in the Rstudio (R) environment v 2023.06.2 (R Core Team 2020; RStudio Team 2020) through 'clam' package v 2.5.0 (Blaauw 2010). Chronology provides a minimal and maximal dating for each cm of sediment with the statistically most likely average date for consecutive depths. The age-depth model was constructed for the whole sediment core also to see that the sediment accumulation rate for the site was constant and did not change abruptly. Age for each cm was estimated and used accordingly in the following graphs. When the results are discussed further in the cultural context, chronology is expressed as calibrated age. Although the gathered material covers both BC and AD periods, the studied period encompasses only the AD period.

1.4. Pollen and non-pollen palynomorphs

In total, 28 pollen and non-pollen palynomorph (NPP) subsamples from the topmost 100 cm of the sediment sequence covering the last ~2000 years with the average step of 70 years (min 17, max 305 years; median 43 years) between samples of known volume (1 cm^3) and thickness (1 cm) were treated using standard acetolysis procedure (Berglund and Ralska-Jasiewiczowa 1986; Faegri and Iversen 1989). Known amounts of *Lycopodium* spores (14,285 spores of *Lycopodium clavatum* per tablet; batch no. 100320201; Lund University, Sweden) were added to the samples to estimate the concentration of microscopic objects per cm^3 (Stockmarr 1971) and mounted in glycerol (Erdtman 1969; Cushing 2011). More than 500 terrestrial pollen grains per sample were counted to the lowest possible taxonomic level using the reference collection at the Department of Geography at the University of Latvia and a published pollen key (Faegri and Iversen 1989). The percentage of dry-land taxa was estimated using arboreal (AP) and non-arboreal (NAP) pollen sums (excluding sporomorphs of aquatic and wetland plants). Counts of spores were estimated as percentages of the total sum of terrestrial pollen. NPPs were recorded throughout the pollen analysis and identified using the published literature (Shumilovskikh et al. 2021; 2022; van Geel and Aptroot 2006). Pollen and NPP diagrams were compiled using the 'rioja' plot package in the Rstudio environment (v2024.04.0+735). The zonation follows the Latvian archaeological periodisation (marked by orange solid lines): Middle and Late Iron Age 260–1200; medieval times 1200–1561; post-medieval times 1561–1800.

1.5. Plant macrofossils

Macroscopic plant remains were analysed from 12 samples (volume of each sample 1 cm^3) covering the time period of specific interest from 90 to 1355 CE. The material was rinsed in 0.25 and 0.5 mm mesh sieves. Plant macrofossils of selected plants were studied with a Nikon SMZ800 and Zeiss Semi 2000-C stereoscopic microscope at magnifications of 10x–200x. Species determinations for individual plant macrofossils followed Mauquoy and van Geel (2007).

1.6. Macroscopic charcoal

Macroscopic charcoal analysis was done for the upper 100 cm sediment sequence. Altogether, 100 subsamples were analysed, whereby 1 cm^3 was treated with dilute NaOCl to promote sediment bleaching and disaggregation before sieving through a 160 μm mesh. The sediment residue was added to 20 ml of distilled water and decanted to a petri dish for charcoal counting. Charcoal was identified as brittle, black crystalline particles with angular broken edges using a stereomicroscope at 30x–60x magnification. Fire event reconstruction through CharAnalysis or 'tapas' package in Rstudio (Higuera et al. 2010; Finsinger and Bonnici 2023) was not applied here as we expected significant human impact over the last ~2000 years and such reconstruction would not allow the separation of fire events from fire usage within the vicinity (e.g. fireplaces, fires for domestic usage — cooking and heat, metal smelting, slash-and-burn). Therefore, we further present charcoal concentration per sample to characterise the overall fire usage in the landscape rather than trying to designate fire events, which would not be possible in this context.

2. Results

2.1. Lithology and chronology

The analysed peat sequence reveals a stratified composition with distinct lithological layers. From 0 to 2.10 m depth, the peatland consists of raised bog peat, which is primarily poorly decomposed. However, intervals of average decomposition were observed at specific depths: 0.11–0.30 m, 0.45–0.57 m, 0.81–0.85 m, 0.98–1.00 m, 1.15–1.42 m, 1.60–1.87 m and 1.97–2.10 m. A highly decomposed raised bog peat was recorded in a localised section at 0.30–0.35 m depth.

At depths between 2.10 and 2.30 m, a transition to fen-type (grass) peat was observed, characterised by its high degree of decomposition. Below this fen peat layer, from 2.30 to 2.35 m, the sequence transitions into gyttja with silt, marking the interface between the organic peat accumulation and underlying sedimentary deposits. The sequence terminates at 2.35 m with a silt layer, signifying the end of peat formation and the presence of the mineral substrate below.

Radiocarbon (^{14}C) dating results (Table 1) indicate that the peatland began forming approximately 4150–4020 years ago, corresponding to the period between 2150 and 2020 BC. The age-depth model (Fig. 2) suggests that peat accumulation occurred at a relatively steady rate of 0.5 mm per year throughout the sequence. No significant interruptions or hiatuses in sedimentation were identified, implying a continuous and stable peat development over time. The consistent rate of accumulation reflects a stable environmental setting favourable for sustained peat formation during this period.

2.2. Vegetation dynamics

Early Iron Age (1–260)

During the Early Iron Age, the regional landscape around the peatland was dominated by pine (*Pinus*), which ranged between 20% and 45% in relative pollen abundance, and spruce (*Picea*), which maintained a stable presence at around 20%. Birch (*Betula*) and alder (*Alnus*) also played significant roles, with alder averaging between 6% and 8%. The presence of shrubs such as heather (*Calluna*) and crowberry (*Empetrum nigrum*) suggests periods of relatively dry conditions in the peatland during this time. Human impact on the landscape was minimal, as no substantial agricultural activities are evident from the pollen data.

Table 1. Sample depths with the respective AMS 14C dating of the Roči bog.

Sample ID	Depth (cm)	Radiocarbon age	Calibrated age	Sample type
FTMC-CB62-1	51-52	891 ± 27	1125–1220 AD	*Sphagnum stems*
FTMC-MT53-1	69-70	1268 ± 29	665–775 AD	*Sphagnum stems*
FTMC-MT53-2	97-98	1747 ± 29	240–380 AD	*Sphagnum stems*
FTMC-CB62-2	109-110	1986 ± 27	5 BC–85 AD	*Sphagnum stems*
FTMC-MT53-3	153-154	2545 ± 30	780–50 BC	*Sphagnum stems*
FTMC-MT53-4	208-210	3375 ± 31	1745–1600 BC	*Pinus, Picea needle* fragments, *Betula* sect Albae fruits and female catcin scales
FTMC-MT53-5	232-229	3701 ± 31	2150–2020 BC	Bark, wood fragments,

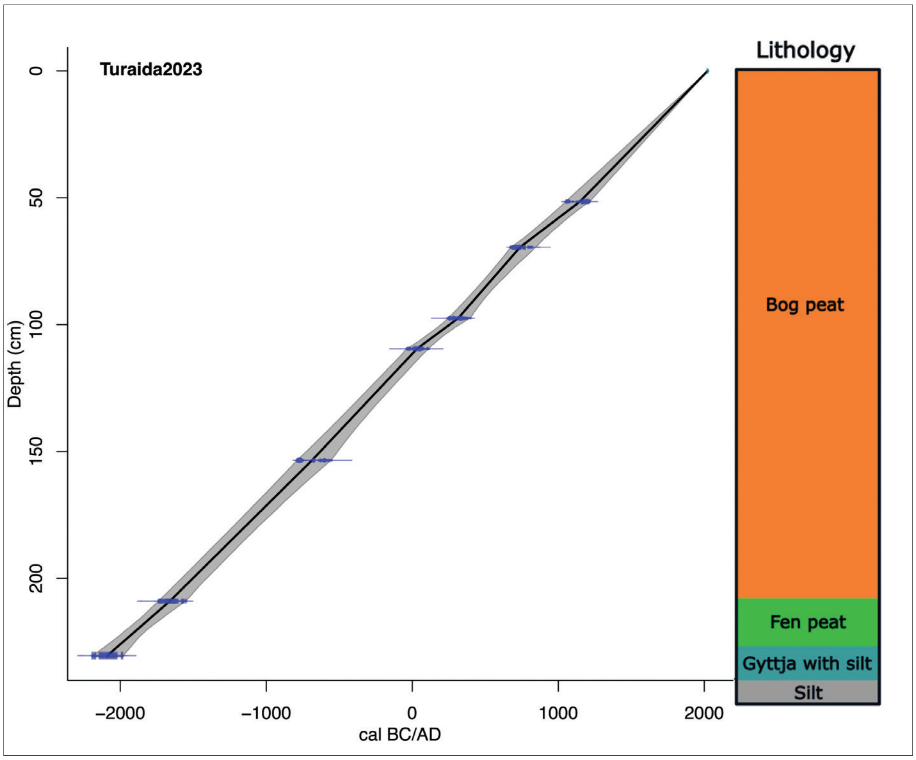

Figure 2. Age-depth model for the Roči bog sediment sequence. Gray area indicates a reconstructed 95% chronological uncertainty band. AMS 14C dates are indicated in blue.

Middle Iron Age (261–800)

In the Middle Iron Age, the vegetation composition remained similar, with pine continuing to dominate. Spruce maintained its relative abundance of 20%, and birch remained stable at around 15%. Alder experienced some fluctuations but generally remained consistent. The first signs of human impact on the landscape appeared around 700, marked by the presence of hemp (*Cannabis sativa*), barley (*Hordeum*), and medicinal plants such as valerian (*Valeriana officinalis*). These changes suggest the gradual introduction of agriculture into the region. The spread of goosefoot (*Chenopodium*) around 750 further indicates early anthropogenic influence on the local environment.

Late Iron Age (801–1200)

Significant changes occurred in vegetation dynamics during the Late Iron Age. Pine remained dominant, but spruce, which reached its peak of 33% around 925, began a dramatic decline, falling to 2% by 1670. Birch increased in prominence from 18% in 1030 to 28% by 1355. Alder, meanwhile, experienced a significant decline around 995, falling to 1.5%, before recovering to 13% by 1285. Dry peatland conditions, indicated by shrubs such as *Calluna* and *Empetrum*, persisted from 890 to 1520. Human activity became more prominent towards the end of the 10th century, as evidenced by the rapid increase in cereal pollen. Oats (*Avena*) appeared in 995, followed by wheat (*Triticum aestivum*) in 1070 and rye (*Secale cereale*) in 1085. These changes suggest the expansion of agricultural practices during this period, with more consistent and widespread crop cultivation.

Middle Ages (1201–1561)

The Middle Ages saw further intensification of agriculture, with cultivated crops such as rye and barley becoming more prominent in the pollen record. From 1210 onwards, rye pollen appeared consistently, while barley (*Hordeum*) persisted in the record from 1285 onwards. This period also saw the first appearance of flax and buckwheat. A notable decline in cereal pollen occurred around 1355–1375, likely indicating a temporary reduction in agricultural activity. However, this was followed by a recovery, with crop pollen reaching its maximum value (3.37%) around 1450. Birch and alder experienced fluctuations during this period, with birch peaking at 28% around 1355, while alder declined after 1520 to 6%–7%.

Post-medieval period (1562–1800)

During the post-medieval period, agricultural activity began to recede, leading to an increase in forest cover. Crop pollen, which had previously reached high values, started to decline after 1650, as forests regained dominance in the landscape. Spruce remained at its lowest levels, and birch stabilised at 22%–24%. The decline in agriculture and the resurgence of forests suggest shifts in land use during this time, possibly due to changes in socio-economic conditions.

Local vegetation dynamics

Locally, the Roči bog site was dominated by sphagnum moss (*Sphagnum* sp.) throughout these periods, indicating stable wetland conditions. Plant macroremains of cranberry (*Vaccinium oxycoccos*), marsh horsetail (*Equisetum palustre*) and members of the heather family (*Ericaceae*) further support this. Pine and spruce trees were found to have grown locally, with macroremains dating to 770, 1010, 1070, 1330 and 1340, suggesting that these species were part of the immediate vegetation around the peatland. These findings align with the regional pollen data, providing a more detailed understanding of local vegetation dynamics in response to both natural environmental changes and human activities.

2.3. Non-pollen palynomorphs

Altogether, 32 NPPs were identified from the Roči bog sediment sequence (Fig. 3). Pine stomata indicators of a local presence of *Pinus* were identified at 395, 960, 1030, 1085–1105, 1175–1230 and 1375–present. Spruce stomata were identified at 260–395, 960, 1030, 1085, 1210–1230, 1450 and 1820 to the present. Only one juniper stomata was found, in 1820. Within coprophilous dung spores, *Podospora* (HdV-368), *Sporormiella* (HdV-113), *Sordaria* (HdV-55A), *Chaetomium* (HdV-7A) and *Delitschia* (TM-006) were found sporadically from 800. In four samples (years 1030, 1522, 1615 and 1820), wing scales of *Lepidoptera* were identified (Fig. 4).

2.4. Fire record

Early Iron Age (1–260)

During the Early Iron Age, fire activity in the region around the peatland was minimal. The amount of macroscopic charcoal found in the samples from this period was low, with only sporadic evidence of fire, typically ranging from 0 to 6 charcoal fragments per sample. This suggests that fires, whether natural or anthropogenic, were infrequent and had limited impact on the landscape.

Middle Iron Age (261–800)

Fire activity remained minimal throughout the Middle Iron Age, with no significant increase in charcoal concentrations. The charcoal record for this period indicates stable environmental conditions with little evidence of

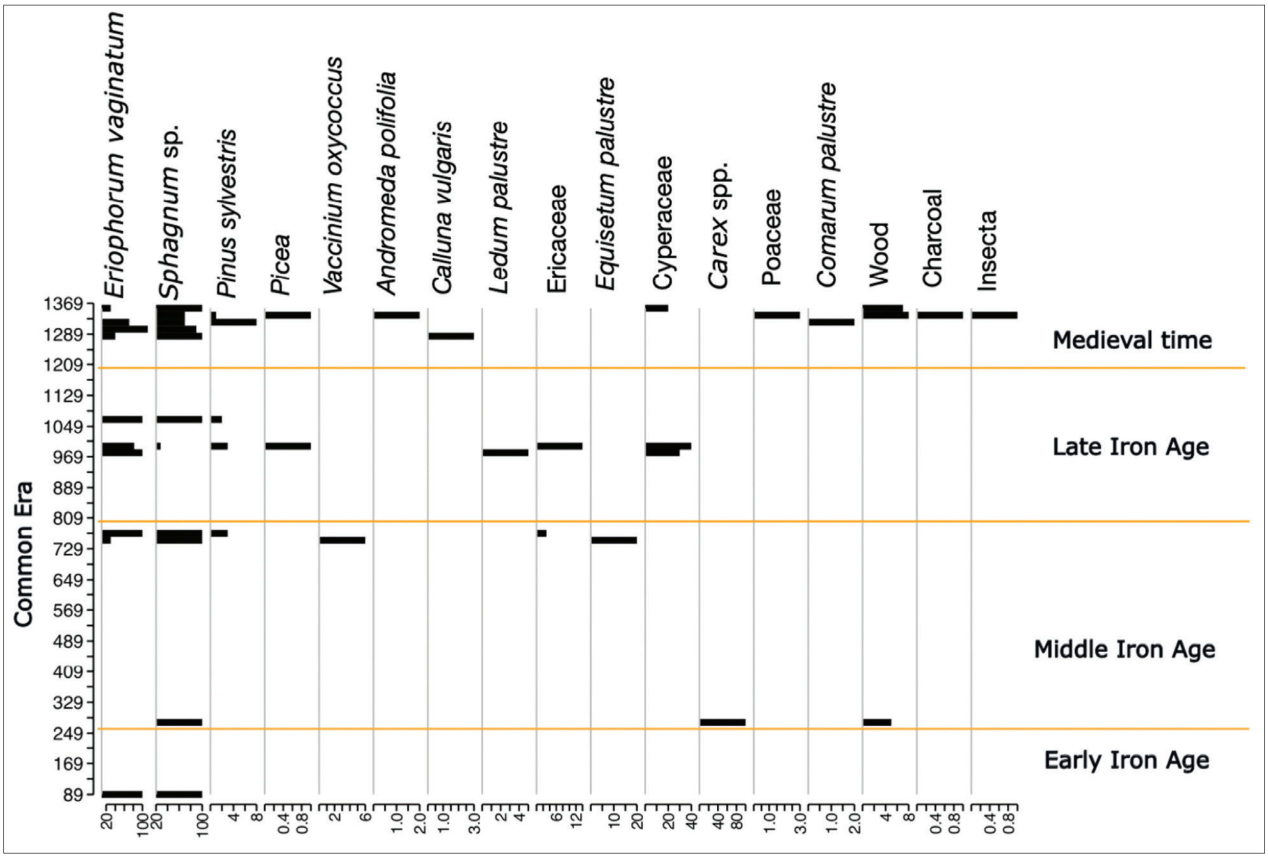

Figure 3. Plant macroscopic remains of the Roči bog. Values on the x-axis are concentration of remains per sample (1 cm3).

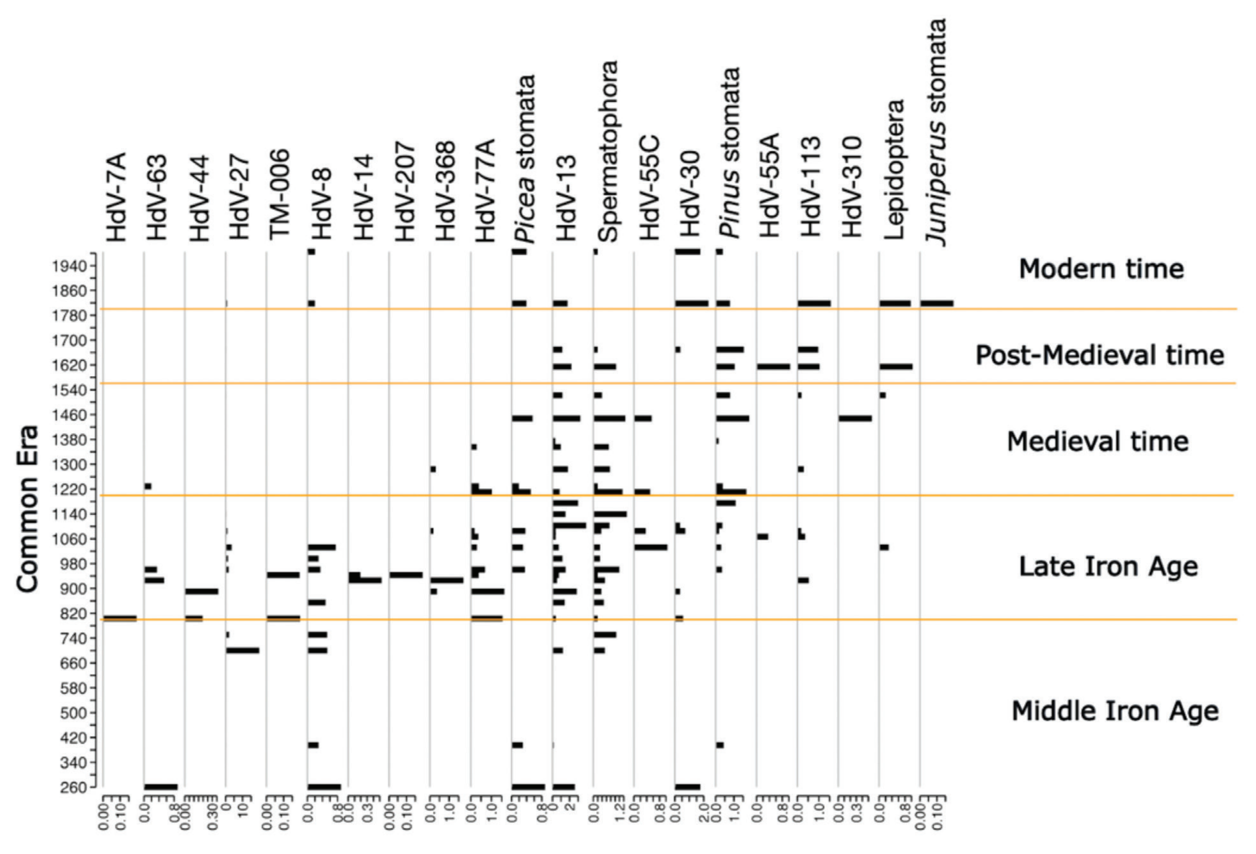

Figure 4. Non-pollen palynomorphs from the Rocu bog: HdV-7A - Chaetomium, HdV-63 - Lasiosphaeria, HdV-44 - Ustulina deusta, HdV-27 - Tilletia, TM-006 - Delitschia, HdV-8 - Microthyrium, HdV-14 - Meliola ellisii, HdV-207 - Glomus, HdV-368 - Podospora, HdV-77A - Geoglossum sphagnophilum, HdV-13 - Entophlyctis lobata, Spermatophora (of Copepoda), HdV-55C - Gelasinospora, HdV-30 - Helicoon pluriseptatum, HdV-55A - Sordaria, HdV-113 - Sporormiella, HdV-310 - Amphisphaerella dispersella, Lepidoptera (wing scale).

extensive burning. Human influence on fire regimes appears to have been limited, and natural fires were also rare during this time.

Late Iron Age (801–1200)

A notable shift in fire activity occurred towards the end of the Late Iron Age. From the mid-10th century, particularly after 961, a distinct increase in charcoal concentrations is observed. The first stage of elevated fire activity occurred between 980 and 1030, which represents the maximum concentration of macroscopic charcoal in the peatland over the past 2000 years. This peak in fire activity may reflect intensified human land use, including forest clearing and agricultural expansion.

Middle Ages (1201–1561)

The Middle Ages can be divided into two phases based on charcoal concentration. From 1030 to 1320, there was a sustained period of high macroscopic charcoal concentration, indicating frequent fire events. This period likely corresponds to continued human activity, including slash-and-burn agriculture or increased land clearing. However, from 1320 to 1465, the fire regime changed significantly, with minimal charcoal concentration and some samples even being charcoal-free. This decrease in fire activity suggests a period of reduced human disturbance or changes in land management practices.

Between 1465 and 1580, the charcoal record indicates a resurgence in fire activity, with increased macroscopic charcoal concentrations. This period of renewed burning could be linked to changes in agricultural practices or land-use expansion as the population grew and human settlement intensified during the late Middle Ages.

Post-medieval period (1562–1800)

During the post-medieval period, fire activity fluctuated. From 1580 to 1705, charcoal concentrations were minimal, indicating fewer fire events and possibly reflecting changes in land use or fire management practices. However, a renewed period of increased fire activity is observed from 1705 to 1875, with pronounced peaks in macroscopic charcoal concentration around 1706, 1725, 1820 and 1875. These peaks may correspond to specific fire events, possibly linked to human activities such as forest clearing, agriculture or increased settlement during this time.

Modern era (post-1875)

From 1875 to the present, the peatland shows little to no charcoal remains, suggesting a significant reduction in fire activity. This decrease may be attributed to modern fire suppression techniques, changes in land management or a shift away from traditional agricultural practices that involved fire. The near absence of charcoal in the recent layers of the peat indicates a stable landscape with minimal fire disturbance in the modern era.

3. Discussion

3.1. Early to Middle Iron Age (1–800)

During the Early to Middle Iron Age, the landscape surrounding the peatland was dominated by dense forest, with minimal human activity (Fig. 3). The pollen record from this period shows that forests were largely composed of pine, spruce and birch, which together constituted about 70% of the vegetation cover. The minimal presence of macroscopic charcoal and the absence of cultivated crops in the pollen record suggest that human settlement in the area was sparse and natural disturbances like wildfires were rare.

The first trace of human influence emerges in the Middle Iron Age, around 700, with the appearance of barley pollen (Fig. 6). This corresponds with the first known permanent human settlement in the Turaida region (Ciglis 2015, p. 13), and in wider central and northern Latvia (Stivrins et al. 2015). It suggests that small-scale agricultural activities, potentially for subsistence farming, began at this time. However, these activities were limited, as indicated by the intermittent presence of barley and the continued dominance of forest species. The relatively low levels of herbivore dung ascospores (indicators of local herbivore presence (Baker et al. 2016)) during this period also point to the human population density remaining low and the landscape being only marginally altered. This is further supported by the sparse archaeological material found in the region that could be attributed to this time period (Ciglis 2015, p. 27; Zemītis et al. 2024, p. 12).

3.2. Late Iron Age (801–1200)

A major shift in the landscape occurs in the Late Iron Age, beginning around the late 9th and early 10th centuries. This period marks the onset of a more substantial and continuous human presence, as evidenced by the first appearance of oats in the pollen record in 995. The earliest archaeological evidence for the appearance of the Liv people in the region is from Kārļa kalns hillfort and Jāņa kalns burials (Fig.1). Although the material in both is sparse, it points to the 10th century (Jemeļjanovs 2014, p. 50; Beitiņa 2015, p. 119; Zemītis 2024, p. 12). It is not clear if the first presence of Livs also links to the establishment of the nearby Turaida hillfort (Fig.1). Excavations of Turaida hillfort have not revealed constructions that were

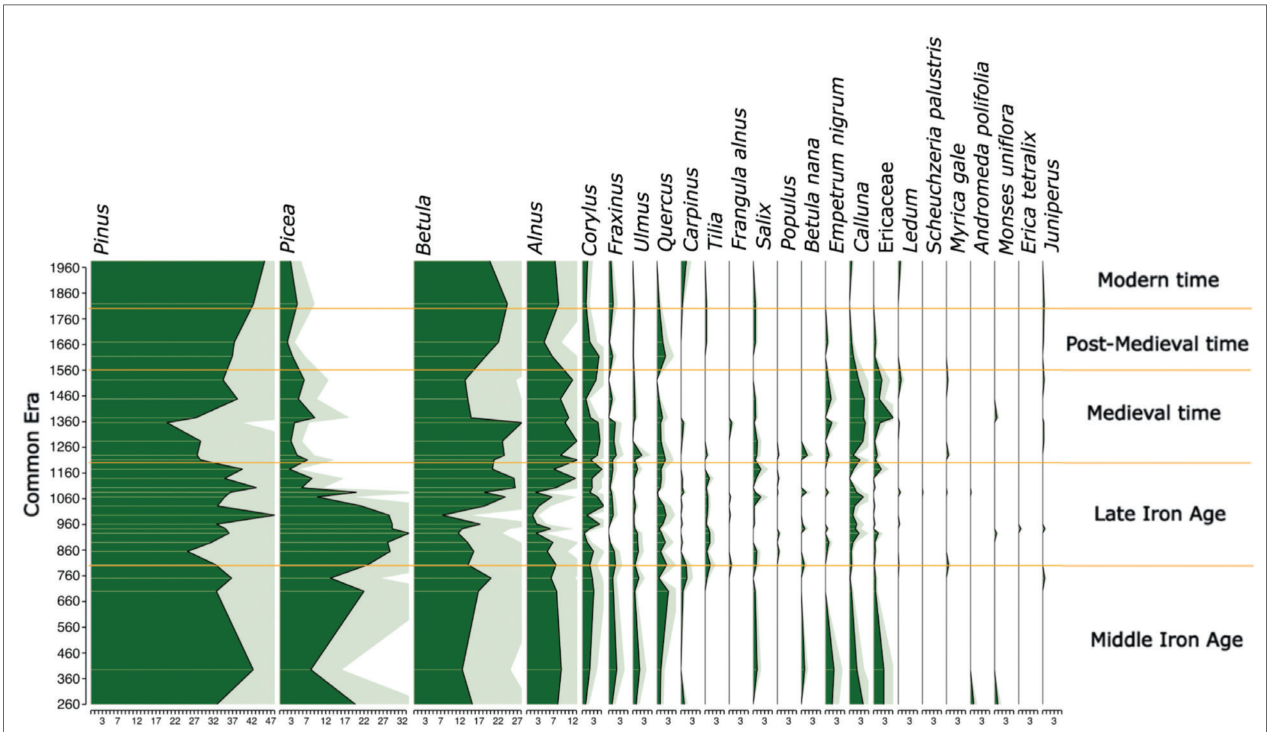

Figure 5. Tree and shrub pollen (%) from the Roči bog. Shading in light green is an exaggeration at x10 for pollen data expressing the change in plant taxa dynamics.

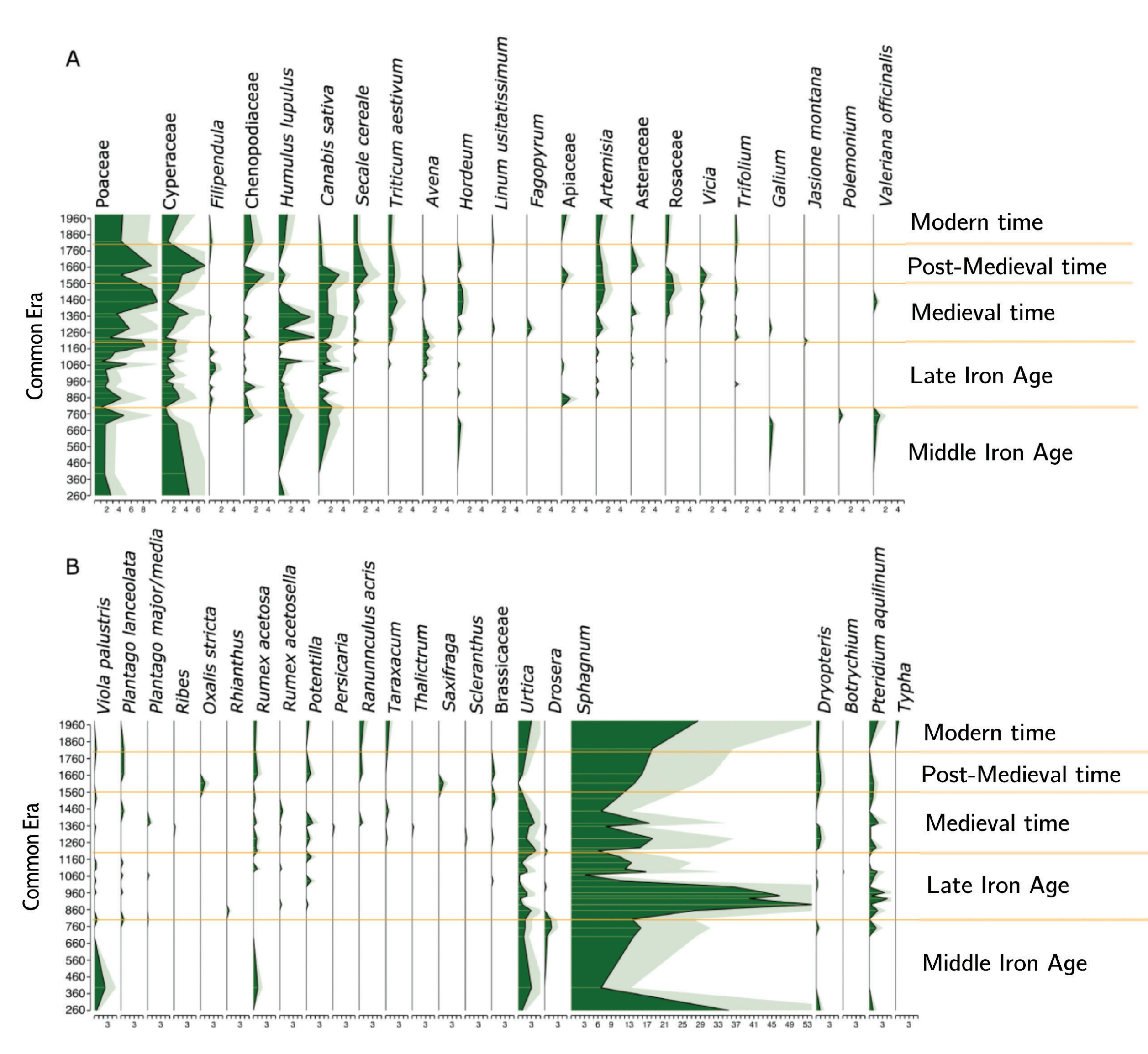

Figure 6. Herb pollen (expressed as percentages (%): A – terrestrial ground herbs, B – terrestrial and wetland herbs and plants from the Roči bog. Shading in light green is an exaggeration at x10 for pollen data expressing the change in plant taxa dynamics.

older than the second half of the 11th century (Graudonis 2003b, pp. 7, 13; Beitiņa 2015, p. 139), however, some artefacts found at Turaida hillfort have been typologically dated to the 10th century (Ciglis 2015, p. 29; Beitiņa 2015, p. 139). At present, the only archaeologically excavated buildings from the Turaida hillfort have been located at the edges of the hill (Graudonis 2003a, pp. 23, 26, 31), as the middle of the hill is taken up by the medieval castle. The continued inhabitation of the site, with many reconstruction phases (including the medieval castle), is likely to have destroyed most of the traces of the first settlers or left them inaccessible to archaeologists.

The expansion of cereal cultivation in the surroundings of Turaida, including the introduction of wheat and rye by the 10th/11th century, suggests that humans had begun to clear land for more extensive agricultural use. Meanwhile, in the wider regional setting, agricultural activities varied, with the earliest pollen-based evidence for agriculture in Latvia as early as 500 BC (Stivrins et al. 2016), and in Estonia and Lithuania around 4000 BC (Poska et al. 2004; 2006; Stančikaite et al. 2002; 2006). The substantial increase in macroscopic charcoal concentrations around 980 AD, representing the highest charcoal levels in the course of the previous 2000 years, points to widespread slash-and-burn practices aimed at clearing the dense forests for farmland. Given that the Quaternary sediments in the western part of the Turaida hillfort primarily consist of till, which is conducive to agricultural use, it is likely that the population expanded by utilising a broader area of land. The rapid increase in the population and the establishment of Turaida hillfort as a densely populated regional centre would support the need to clear new farming land in the previously sparsely inhabited region. The use of agricultural land around Turaida hillfort is directly mentioned in the Chronicle of Henry written in the first half of the 13th century. The chronicle states that the people of Turaida had 'done a lot of evil to Kaupo [a local king] … taking away his fields' (Indriķis 1993, p. 81) and that 'the Turaida Livs wanted to sacrifice him [a bishop] to their gods, because his sown fields gave a better harvest than their own fields, which, flooded by rain, were destroyed' (Indriķis 1993, p. 51) (translation from Latvian to English by Alise Gunnarssone).

From 1030 there was a decrease in and stabilisation of charcoal in the record, possibly indicating farmland having been cleared and the need to remain sedentary, which forced the Livs to transition from slash-and-burn agriculture to a more sustainable type of agriculture — crop rotation. Both two-field and three-field systems were practised at the time in the wider Latvia area (Rasiņš and Tauriņa 1983, p. 152). The two-field system, or fallow farming, seems more likely as neither barley, wheat nor rye were grown in equal amounts to oats. The remaining charcoal amount after 1032 might be explained by the increased population density and the resulting household and craft activities involving fire.

The increase in crop cultivation in the second part of the 10th century is largely due to the cultivation of oats. They first appear in the sediment record in 995. Oats would have been a good choice for newly cleared farmland. Compared to barley, and even wheat, oats are much more tolerant of acidic soils, as well as wet weather (Givens et al. 2004). Even after the introduction of wheat and rye in the area in 1070 and 1210, respectively, oats remained the dominant cultivated cereal throughout the Late Iron Age.

The decrease in spruce and simultaneous increase in birch and alder around this period provides additional evidence for deforestation and landscape transformation. Spruce, which thrives in more fertile soils, declined dramatically as these areas were likely converted to agricultural land (Reitalu et al. 2013; Kasparinskis and Nikodemus 2012). The growing prominence of birch, a pioneer species that thrives in disturbed environments, suggests that previously forested land was being left open or managed for pasture and crop cultivation.

The decline in forest cover during the 11th century was likely not only due to agricultural expansion but was also connected to the demand for timber for building purposes. The construction of Turaida hillfort and other structures required significant amounts of wood, contributing to the reduced forest area.

3.3. Middle Ages (1201–1561)

The Middle Ages saw a continued transformation of the landscape. The charcoal record suggests that while fire use for land clearing decreased after 1030, the presence of cultivated crops like wheat, rye and barley continued to grow. This shift implies the transition from slash-and-burn techniques to more sustainable agricultural practices, such as crop rotation, which allowed for the long-term management of cleared land and continued into the Middle Ages. During the Middle Ages, wheat and rye became permanent staples, suggesting that the establishment of a crusader state may have coincided with a shift in agricultural practices, potentially influenced by new settlers and their farming methods. Going forward, barley gradually replaced oats. Rye seems to have been more difficult or was grown in smaller amounts as it displays more fluctuation in the sediment record. Wheat becomes permanent slightly later — approximately 1284. With the more stable cultivation of these other crops, oats were gradually abandoned. The highest amount of oats recorded was approximately during 1175, after which they went into a decline. The appearance of coprophilous fungal spores in the sediment suggests an increase in livestock farming alongside cereal cultivation, particularly from the 15th century onwards. However, it is more difficult to separate domesticated from wild animals and the increased grazing could be from either source.

The relative stability in fire activity during the Crusades, along with the continued cultivation of crops, indicates that these historical events did not drastically disrupt the established land-use patterns in the region. It is interesting that the charcoal record did not show the period when the Livs were Christianised and subjugated under Livonia (1195–1208) or the burning down of Turaida hillfort (1214) (Graudonis 2003a, p. 49; Jansons 2007, p. 11). The amount of recorded fire activities in the area at this time is similar to the wider time period. It is also worth underlining that wind direction during such episodes of burning is important (i.e. charcoal blown in different directions away from peatland), and not all of the fire events would be recorded in the sediment for this reason.

A notable decline in crop relative abundance and concentration was recorded during the middle of the 14th century (around 1356) (Fig. 7). This might be linked to the Little Ice Age or the Black Death (Wood 2024, pp. 4, 10). Both of these events are often connected as the environmental decline most likely resulted in the *Yersinia pestis* spilling into human populations (Wood 2024, p. 10). It is assumed that *Y. pestis* reached Livonia in 1351, as at this time the *Chronicon Livoniae* reported an increase in mortality. However, there has been some discussion of to what degree it actually affected Livonia (Gerhards 2011, p. 45; Kļaviņš 2019, p. 206; Izdebski et al. 2022, pp.

299–302). The high mortality rate due to disease would have left the previously cultivated fields unworked, reducing the amount of pollen in the air and consequently in the sediment. The possibility of abandonment of fields in this area is bolstered by the increase in birch, which as a pioneer tree would take over free land within 5–10 years of abandonment (Fig. 5) (Izdebski et al. 2022, p. 298). We see, however, that the abandoned fields do not remain so for long and are soon beginning to be recultivated (Fig. 7). The presented data seems to suggest that the vicinity of the Roči bog at least suffered a decline in agriculture at this time, which might be due to the climate cooling or outbreak of disease.

The recovery of crop cultivation in the mid-15th century following a decline suggests that while environmental and demographic factors may have temporarily disrupted agriculture, the region quickly rebounded. By the mid-15th century, agriculture had reached its highest intensity, with wheat, barley and rye as the dominant crops. The continuous presence of livestock, indicated by coprophilous fungal spores, supports the notion of a mixed farming system in the vicinity of the peatland (van Geel 2001; Lee et al. 2022; Dendievel et al. 2022).

3.4. Post-medieval period (1562–1800)

By the post-medieval period, the landscape surrounding the peatland had fully transitioned into a more anthropogenically managed environment. Charcoal concentrations in the peat remained minimal from 1580 to 1705, indicating that large-scale fire events were rare. However, isolated peaks in macroscopic charcoal, particularly around 1706, 1725, 1820 and 1875, suggest occasional fire use (or fire outbreak episodes), potentially linked to agricultural expansion or other land management practices. Fire episodes are most likely a result of human activities considering the long natural fire return interval (261–494 years) for this part of Latvia (Steinberga and Stivrins 2021). Although fire has accompanied human evolution, our understanding of it remains quite poor due to limited macroscopic charcoal studies from the region.

Conclusions

The combined evidence from pollen, charcoal and macroscopic plant remains provides a detailed picture of how the landscape evolved in response to human activities over the past two millennia. This study contributes to a broader understanding of human-environment interactions in the Baltic region, particularly in relation to the long-term transformation of natural ecosystems. The arrival of the Liv population, bringing with them a significant human-induced change in the landscape, marked a transition from dense forests to open agricultural land. The fluctuating relative abundance of tree species, particularly the decline in spruce, suggests intentional land clearing for agriculture, potentially driven by the need for more fertile soils. The utilisation of slash-and-burn techniques and the subsequent shift to more sustainable agricultural practices, such as crop rotation, demonstrate the evolving relationship between humans and their environment.

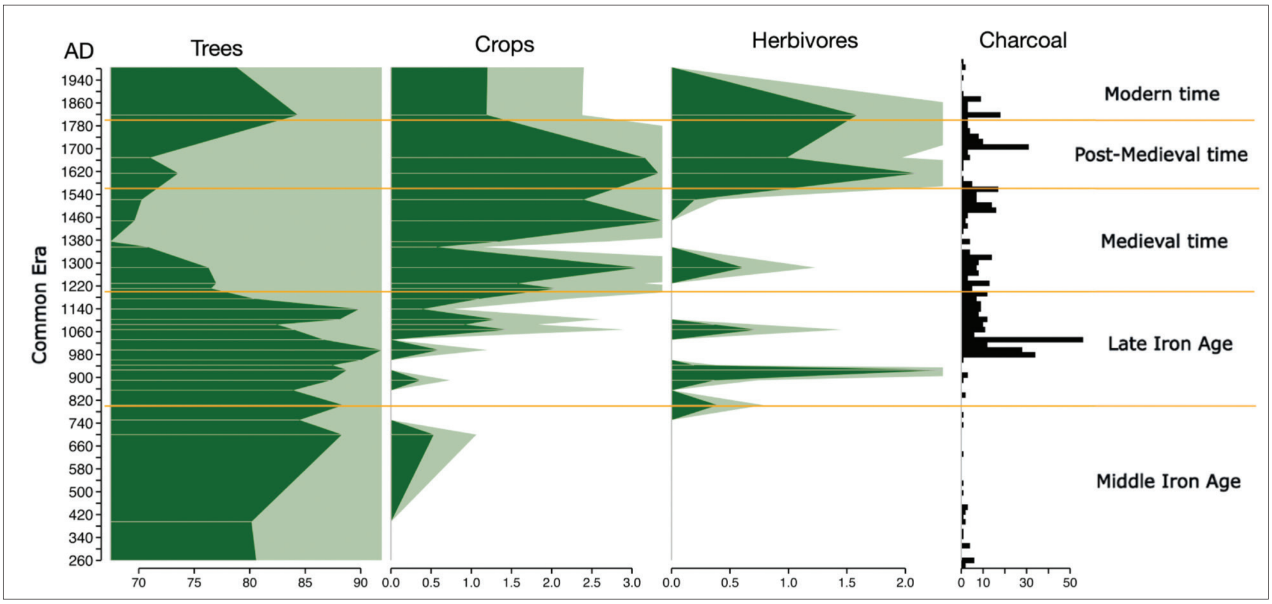

Figure 7. Tree and crop pollen (%), herbivore presence indicating spores (%), macroscopic charcoal (count per sample), and concentration of crop and tree pollen (concentration per sample) from the Roči bog.

Another pressure on forest coverage can be attributed to the need for lumber in the construction of hillforts and settlements. Although the exact construction periods are now difficult to determine due to later developments, the Turaida hillfort was a fortified, growing regional centre constructed entirely from wood.

The cultivation patterns of different cereals over time can signify the adaptation of agricultural practices to local conditions. The dominance of oats during the Late Iron Age, as well as the relatively late intensified adoption of wheat, barley and rye, was most likely due to the available soil type. On the other hand, the decline in agriculture during the 14th century could be the result of sudden environmental changes and the Black Death. Although evidence from other regions in Latvia is lacking, the data from this particular region indicates a sudden disturbance in the general modus operandi.

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Abbreviations

AFST – Animal Feed Science and Technology

Archaeol. Baltica – Archaeologia Baltica

Estonian J. Archaeol – Estonian Journal of Archaeology

Est J. Earth Sci. – Estonian Journal of Earth Sciences

Geol Q – Geological Quarterly

J. Biogeogr. – Journal of Biogeography

MEE – Methods in Ecology and Evolution

Nat. Ecol. Evol. – Nature Ecology & Evolution

Palaeogeogr. Palaeoclimatol. Palaeoecol. – Palaeogeography, Palaeoclimatology, Palaeoecology

Rev Palaeobot Palynol – Review of Palaeobotany and Palynology

Quat. Geochronol. – Quaternary Geochronology

Quat. Int. – Quaternary International

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Žmogaus sukelti augalijos pokyčiai Turaidos apylinkėse geležies amžiuje ir viduramžiais

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Santrauka

Tyrime daugiausia dėmesio skiriama Turaidos apylinkių aplinkos pokyčių geležies amžiuje ir viduramžiais dėsningumams. Derinant žiedadulkių, augalų makroskopinių liekanų ir makroskopinių anglių analizę kartu su istoriniais ir archeologiniais duomenimis, tyrimu siekiama suprasti Gaujos upės kraštovaizdžio transformaciją. Buvo paimti durpių mėginiai (kernai) iš Roči pelkės, esančios netoli Turaidos piliakalnio ir apsuptos istoriškai dirbamų žemių. Roči pelkė susiformavo maždaug prieš 4150–4020 metų, o nuosėdų kaupimosi greitis buvo pastovus.

Analizė parodė, kad ankstyvajame ir viduriniame geležies amžiuje teritorijoje vyravo miškai, o pagrindinės medžių rūšys buvo pušys, eglės ir beržai. Pirmąją žmogaus įtaką gamtai liudija 700 m. po Kr. datuojamuose nuosėdų įrašuose aptinkami miežiai. Miežiai retkarčiais vėl pasirodydavo 890 ir 1070 m. po Kr. IX a. pabaigoje ir X a. pradžioje pastebėtas galutinis žmogaus agrarinės ekspansijos poslinkis, greičiausiai susijęs su lyvių atsiradimu teritorijoje. Staigus makroskopinės medžio anglies koncentracijos padidėjimas apie 980 m. po Kr. ir santykinio eglių gausumo sumažėjimas leidžia manyti, kad siekiant paruošti žemę įdirbiui buvo naudojami šlaito ir deginimo metodai. Vėlyvajame geležies amžiuje pagrindinė grūdinė kultūra buvo avižos.

Tikėtina, kad apie 1030 m. po Kr. buvo pereita nuo žemdirbystės, kai buvo taikoma sėjomaina, prie tvaresnių metodų, tokių kaip dviejų laukų sistema arba pūdymas. Miško plotų mažėjimas nesiliovė dėl medienos poreikio statyboms, pavyzdžiui, Turaidos piliakalnio įtvirtinimui. Nepaisant kryžiuočių valstybės įkūrimo, žemės ūkis ir toliau intensyvėjo be didesnių pertraukų, o apie 1210 m. pradėti nuolat auginti kviečiai ir rugiai. Pamažu avižas pakeitė kviečiai, rugiai ir miežiai, tapę pagrindiniais augalais. XIV a. prasidėjusi „juodoji mirtis“ galėjo turėti įtakos žemės ūkiui, pasėlių dydžio sumažėjimui. Iki XV a. vidurio пasėlių plotai pamažu atsigavo. Koprofilinių grybų sporų buvimas rodo nuolatinį gyvulių ganymą, stebėtą nuo X a.

Apskritai išvados rodo sudėtingą žmogaus veiklos, kraštovaizdžio pokyčių ir žemės ūkio praktikos sąveiką laikui bėgant ir padeda atskleisti istorinę regiono raidą.