Research paper

The Holocene
1–9

DOI: 10.1177/0959683615596821
hol.sagepub.com
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Palaeoenvironmental evidence for the impact of the crusades on the local and regional environment of medieval (13th–16th century) northern Latvia, eastern Baltic

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Abstract

This paper evaluates the impact of the crusades on the landscape and environment of northern Latvia between the 13th–16th centuries (medieval Livonia). The crusades replaced tribal societies in the eastern Baltic with a religious state (Ordenstaat) run by the military orders and their allies, accompanied by significant social, cultural and economic developments. These changes have previously received little consideration in palaeoenvironmental studies of past land use in the eastern Baltic region, but are fundamental to understanding the development and expansion of a European Christian identity. Sediment cores from Lake Trikāta, located adjacent to a medieval castle and settlement, were studied using pollen, macrofossils, loss-on-ignition and magnetic susceptibility. Our results show that despite continuous agricultural land use from 500 BC, the local landscape was still densely wooded until the start of the crusades in AD 1198 when a diversified pattern of pasture, meadow and arable land use was established. Colonisation followed the crusades, although in Livonia this occurred on a much smaller scale than in the rest of the Ordenstaat; Trikāta is atypical showing significant impact following the crusades with many other palaeoenvironmental studies only revealing more limited impact from the 14th century and later. Subsequent wars and changes in political control in the post-medieval period had little apparent effect on agricultural land use.

Keywords

human impact, Latvia, Livonia, macrofossils, pollen, the crusades

Received 14 October 2014; revised manuscript accepted 27 May 2015

Introduction

The medieval period in the eastern Baltic (AD 1198–1561) is dominated by the crusades, a holy war led by the military orders and bishops that over the course of the 13th century conquered modern-day Estonia, Latvia and western Lithuania with the aim of converting indigenous pagan tribal societies to Christianity. The conquest and subsequent colonisation of former tribal territories resulted in significant changes to the ownership, organisation and administration of the landscape, with subsequent changes in patterns of land use over the 13th–16th centuries (Brown and Pluskowski, 2014). The crusades was followed by the development of towns and rural settlements, secured by heavily fortified castles and accompanied by economic expansion and the development of trading and provisioning networks, exemplified by the growth of the Hanseatic League from the 13th century (Sillasoo and Hiie, 2007; Turnbill, 2004). Previous studies of the impact of crusading have focused largely on documentary sources with little consideration of the potential of the palaeoenvironmental record. Documentary sources, often in the form of inventories, demonstrate the diversity and intensity of resource exploitation, but are largely 14th century and later in date and lack the longer term chronological perspective of the palaeoenvironmental record. Although palaeoenvironmental studies over the last two decades have greatly contributed to our knowledge on vegetation change in Latvia (Amon et al., 2014; Heikkilä and Seppä, 2010; Kalnina et al., 2004; Kangur et al., 2009; Kušķe et al., 2010; Ozola et al., 2010; Stivrins et al., 2014), existing research has almost entirely focused on natural long-term vegetation dynamics, with less research on environmental changes occurring during more recent periods of significant and rapid social and cultural change. Thus far, there are only a few well-dated pollen sequences from northern Latvia (Kangur et al., 2009; Stivrins et al., 2015). Moreover, the crusades in northern Latvia are poorly supported

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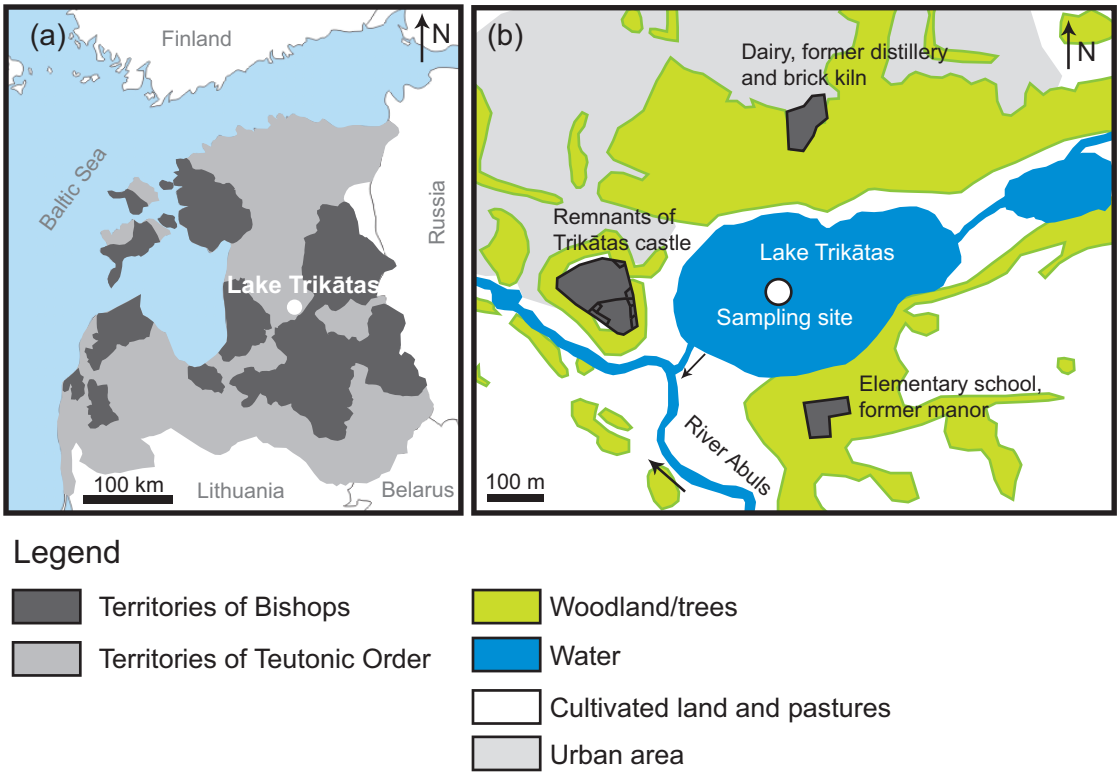

Figure 1. Study area: (a) location of study site in Livonia in eastern Baltic area, black coloured – territories of bishops, grey coloured – territories of Teutonic Order, and (b) Lake Trikāta, coring site and setting around the lake.

by documentary sources and archaeological investigations. Multi-proxy palaeoenvironmental studies therefore play a significant role in understanding changing patterns of land use and environmental impact over the several centuries before, during and after the medieval period.

The present study aims (1) to determine whether the crusades result in increasing anthropogenic impact on the landscape – particularly within the area around Lake Trikāta where tribal grouping very quickly submitted to the rule of the Order, and (2) to assess the effect of human activities on local and regional terrestrial environment before and after the conquest of the crusades.

Study area

Sampling site

Lake Trikāta (water depth 4 m; 57°32′N, 25°42′E) is situated in northern Latvia (Figure 1) in the north Vidzeme lowland 17 km east of Valmiera at an elevation of 50 m.a.s.l. The surface area of the lake is 13 ha. The lake is located in a valley (25 m deep) with an outflow connected with the River Abuls on the western side. The modern vegetation cover along the lake margins and River Abuls comprises *Alnus incana/glutinosa, Betula pendula/pubescens, Picea abies, Pinus sylvestris, Quercus robur*. The surrounding landscape comprises a mixture of cultivated land and pasture (Figure 1) overlaying sandy and podzolic soils (Kasparinskis and Nikodemus, 2012). The quaternary glacial till and alluvial deposits at Trikāta overlie the sandstone bedrock and today's topography was largely formed during the Weichselian glaciation and deglaciation (Zelčs et al., 2011; Zelčs and Markots, 2004).

Lake Trikāta is located in the boreo-nemoral ecotonal zone and climate is continental with mean annual precipitation of 700–800 mm and mean winter and summer temperatures of −6°C and +16.5°C, respectively. The ruins of Trikāta castle lie on a hilly plateau to the west of the lake with an elementary school and former manor on the valley edge overlooking the southern shore and a former distillery and dairy overlooking the northern shore (Figure 1). The immediate surroundings of the castle appear to hold no archaeological significance other than the medieval church of St John to the east of the castle, and extensive agricultural field systems.

History and archaeology of Trikāta

There are a number of historical sources related to Trikāta (German Trikaten; Caune and Ose, 2004; Radiņš, 1996; Urtāns, 1991). The earliest mention of Trikāta appears in the chronicle of Henry of Livonia in AD 1208, as the location of one of two strongholds ruled over by a local Latgalian chieftain (Tamm et al., 2011: 450). The crusades in Livonia began with the conquest of the Livs and Latgalians (AD 1198–1227) by the armies of the Bishops and the Sword Brothers, followed by the conquest of Estonia (AD 1208–1227) and partially successful crusades in Curonia (western Latvia; AD 1219–1290). Following their defeat at the Battle of Saule (AD 1236), the Sword Brothers were merged into the Teutonic Order, known thereafter as the Livonian Order. The stone castle, constructed by the Livonian Order on high ground adjacent to the lake, may have been built on an earlier Iron Age stronghold, although there have been no archaeological excavations in the ground or immediate hinterland of the castle to confirm this. The only stray find, found near the lake, was identified as a brooch of 3rd century AD date. There are no direct sources to confirm the date of construction of the castle, but it is considered to predate the formation of the Parish of St John in AD 1282–1287. Additional documentary sources highlight Trikāta as one of a number of castles listed as corn houses, emphasising their function in the collection, storage and redistribution of agricultural produce (Caune and Ose, 2004). During the medieval period, Trikāta formed part of a network of subsidiary castles in the Cēsis commandery (Caune and Ose, 2004). The castle was heavily damaged during the Livonian Wars (AD 1558–1583), and following the secularisation of the Order (AD 1561), many of the Order's documents were destroyed or spread across Europe (Brown and Pluskowski, 2014). As a consequence, there is a lack of documentary

or archaeological information on Trikāta; any former traces of medieval agricultural land use are likely to have been eroded by continued ploughing over the last half millennia.

Materials and methods

Fieldwork to obtain the core sample from Lake Trikāta was conducted from the ice-covered surface in March 2012 using a 1-m-long Russian-type corer with an 8-m-long sediment sequence recovered at the deepest point of the lake (Figure 1). Samples were documented, packed into film-wrapped 1 m plastic semi-tubes and transported to the laboratory for further analysis. Lithology and sediment features were described in the field.

The organic matter content of the sediment was determined for consecutive 2 cm sub-samples by loss-on-ignition at 550°C for 4 h with the ignition residue representing the mineral matter content. Magnetic susceptibility was measured with a Bartington MS2E meter (Nowaczyk, 2001).

Samples for pollen analysis (36 sub-samples) of known volume (1 cm^3) and thickness (1 cm) were processed using standard procedures (Berglund and Ralska-Jasiewiczowa, 1986). Known quantities of *Lycopodium* spores were added to each sample to allow calculation of pollen concentrations (Stockmarr, 1971). Approximately 1000 terrestrial pollen per sample were counted and identified to the lowest possible taxonomic level using the reference collection at the Institute of Geology at Tallinn University of Technology and published pollen keys (Fægri and Iversen, 1989). The percentage of dry-land taxa was estimated using arboreal and non-arboreal pollen sums (excluding sporomorphs of aquatic and wetland plants). Counts of spores were calculated as percentages of the total sum of terrestrial pollen. Sum of cultural indicators, dry and wet pastures, meadow and ruderal land were grouped according to Behre (1988) and Gaillard (2007). Microscopic charcoal content in pollen slides were estimated as in Finsinger et al. (2008). Plant macrofossil analysis followed Birks (2001). At least 50 cm^3 of sediment was wet-sieved on a 0.25 mm mesh. Retained material of 65 samples on the sieves was examined using a light microscope and identified using literature on plant macrofossils (Rasiņš, 1954; Velichkevich and Zastawniak, 2006, 2008). Pollen and macrofossil diagrams were compiled using TILIA 1.7.16 (Grimm, 2012). In order to place the palaeobotanical data within a cultural context, the pollen and plant macrofossil diagrams were divided according to established Latvian archaeological periods: Bronze Age (1200–500 BC), early Iron Age (500 BC–AD 400), middle Iron Age (AD 400–800), late Iron Age (AD 800–1200), medieval (AD 1200–1550), post-medieval AD 1550–1850 and Modern AD (1850–present; Graudonis, 2001; Vasks et al., 1999).

The chronology of the core was established on the basis of a Bayesian age–depth model constructed from six AMS ^{14}C dates. The dated material, all of terrestrial origin, was processed at the Scottish Universities Environmental Research Centre, United Kingdom (GU) and the Poznan radiocarbon laboratory, Poland (Poz). In addition, seven samples of gyttja bulk material were dated in GU. Radiocarbon dates were converted to calendar years using the IntCal13 calibration dataset (Reimer et al., 2013) and Clam 2.2 programme deposition model (Blaauw, 2010) with a 95.4% of confidence level.

Results

Sediment description, chronology and sediment accumulation rates

The Lake Trikāta sediments (Figure 2) consist of silty and homogenous gyttja with visible variations in colour considered to reflect different sedimentation conditions. Organic matter content (Figure 3f) shows minor fluctuations, with decreasing

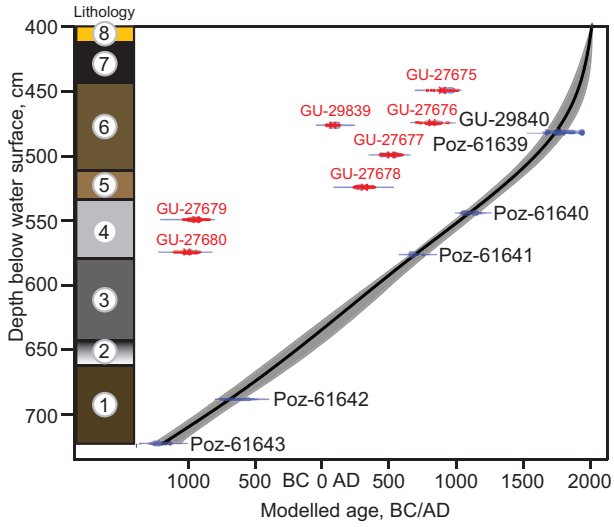

Figure 2. Lithostratigraphy and age–depth model for Lake Trikāta sediment sequence. The grey area represents the range of the modelled ages at 2 sigma. The black graphs show the probability distribution of the calibrated radiocarbon dates; blue graphs indicate calibrated age with error of individual calibrated age; red graphs are rejected and excluded dates from age–depth model. Lithology: 1 – gyttja, silty, calcareous, yellow; 2 – gyttja, silty, calcareous, black; 3 – gyttja, silty, calcareous, dark; 4 – gyttja, silty, calcareous, light brown; 5 – gyttja, silty, calcareous, light grey; 6 – gyttja, silty, calcareous, dark grey brown; 7 – gyttja, silty, calcareous, transition; 8 – gyttja, silty, homogenous, dark brown.

organic matter content from 1145 BC (40%) to AD 1100 (25%). Following two distinct peaks from AD 1110–1340 and AD 1560–1790, the mineral matter content of the sediment increases significantly (Figure 3e). Magnetic susceptibility shows significant fluctuations in value, but with exceptional peaks at 1000 and 900 BC and AD 300 and 600. There is an additional increase in magnetic susceptibility from AD 1400, with values declining significantly at and after AD 1900 (Figure 3f). Five peaks of quartz grains were recorded at AD 400, 1100, 1250, 1500 and 1850 (Figure 3e).

In the course of the Weichselian glaciation, large volumes of carbonaceous sediment were brought from Estonia and deposited over most of Latvia in the process of deglaciation (Zelčs et al., 2011). Accordingly, carbonaceous material may be present in surrounding tills and most lake sediments, contaminating bulk samples and causing reservoir and hard water effects that produce anomalously old radiocarbon ages (Poska and Saarse, 2002). Moreover, our results showed that the error from bulk dating can be more than 1500 years (Table 1, Figure 2); AMS dating of organics of terrestrial origin is highly recommended in any future studies carried out on lake sediments in Latvia. However, a seed of *Spergula arvensis* produced an unexpectedly old date and was rejected (Table 1); hard water error seems unlikely given the terrestrial origin of the seed, perhaps instead reflecting older material reworked into earlier sediments. The applied age–depth model (Figure 2) based on AMS dates of terrestrial macrofossils showed that the average sediment accumulation rate was 0.07 mm yr^{-1} from 1145 BC–AD 1000, 0.09 mm yr^{-1} from AD 1000–1500 increasing rapidly thereafter up to 0.7 mm yr^{-1}.

Pollen and macrofossils

The Bronze Age (1200–500 BC). Arboreal pollen is dominated by *Picea* (20%), *Pinus* (15%), *Betula* (30%) and *Alnus* (20%; Figure 4). Other secondary arboreal pollen includes *Quercus*

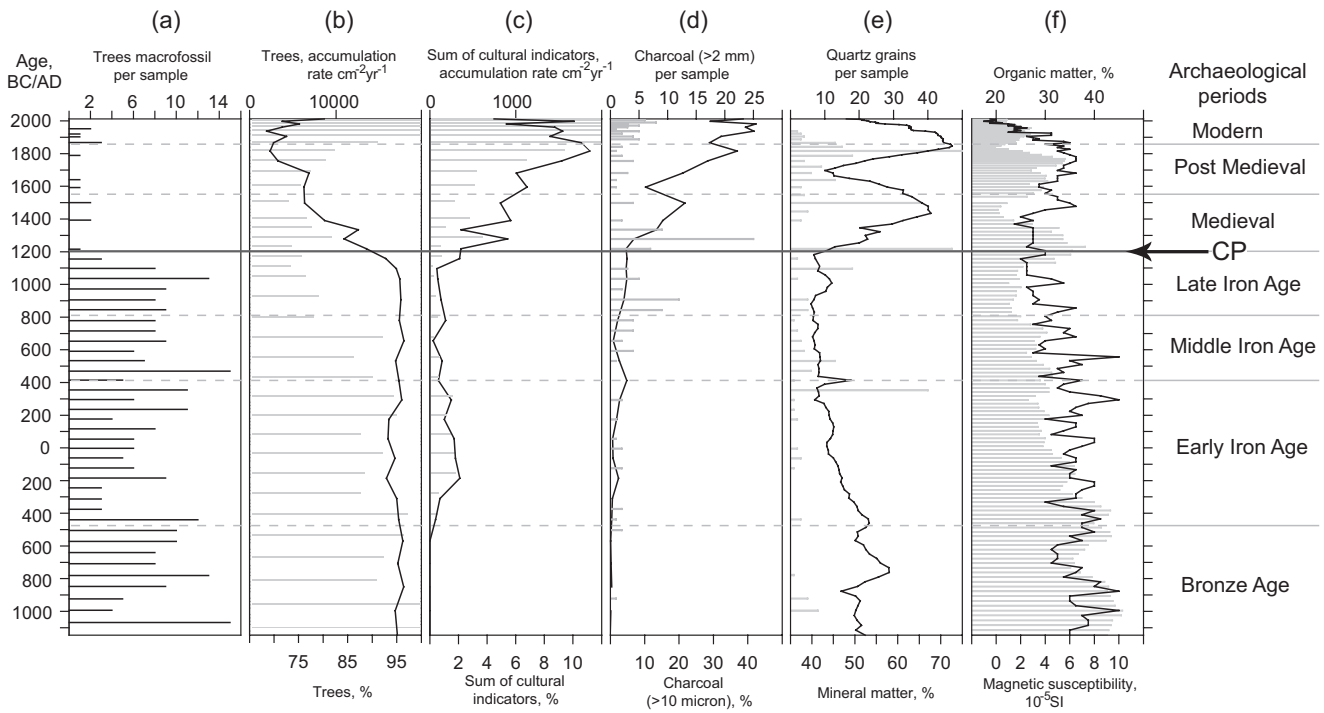

Figure 3. Comparison of main results obtained from Lake Trikāta plotted against time. Bars: (a) tree macrofossil per sample, (b) tree pollen accumulation rate $cm^{-2}yr^{-1}$, (c) sum of cultural pollen indicators accumulation rate $cm^{-2}yr^{-1}$, (d) macrocharcoal (>2 mm) number of remains per sample, (e) quartz grain number per sample, (f) organic matter percentages. Solid line: (b) tree pollen percentages, (c) sum of cultural pollen indicators, percentages, (d) microcharcoal (>10 μ), percentages, (e) mineral matter content, percentages, and (f) magnetic susceptibility, 10^{-5} SI.

Table 1. Radiocarbon ages for Lake Trikāta sediment core.

Depth, cm	Laboratory code	^{14}C date	Calibrated age (cal. yr BP) 2σ	Material dated	Remarks
450	GU-27675	1115 ± 35	1090–935	Bulk gyttja	Hard water error; excluded
475	GU-27676	1200 ± 35	1190–1050	Bulk gyttja	Hard water error; excluded
477	GU-29839	1918 ± 26	1930–1820	*Spergula arvensis*	Hard water error; excluded
481.5	GU-29840	158 ± 26	230–165	*Ranunculus* leaf fragments	
483	Poz-61639	175 ± 30	225–135	Wood	
500	GU-27677	1535 ± 35	1525–1350	Bulk gyttja	Hard water error; excluded
525	GU-27678	1735 ± 35	1720–1555	Bulk gyttja	Hard water error; excluded
545	Poz-61640	915 ± 30	920–760	*Picea abies* needles and fragment of seed wing	
550	GU-27679	2800 ± 35	2990–2840	Bulk gyttja	Hard water error; excluded
575	GU-27680	2840 ± 35	3060–2860	Bulk gyttja	Hard water error; excluded
577	Poz-61641	1345 ± 30	1310–1240	*Picea abies* needle fragment	
689	Poz-61642	2485 ± 30	2725–2440	Wood	
723	Poz-61643	2990 ± 30	3250–3070	Wood	

(5%), *Corylus* (5%) and *Tilia* (4%). The plant macrofossil records include remains of several tree taxa and species (*Betula* sect. Albae, *Alnus glutinosa, Alnus incana* and *Picea abies*) dominant throughout the Bronze Age (Figure 5).

Early Iron Age (500 BC–AD 400). The first cereal grains of *Avena-Triticum* and *Hordeum* were recorded from 500 and 100 BC, respectively (Figure 4). Only *Avena-Triticum* shows a continuous pollen curve since its first appearance. Non-arboreal pollen values were low throughout the early Iron Age. Values of *Alnus* and *Betula* were constant at 20% and 30%, respectively. *Pinus* values increase from 15% up to 20% towards AD 400. *Picea* decreased from 25% at 400 BC to 15% at 200 BC. Similar trends have been recorded in macrofossil data (Figure 5) where *Betula* sect. Albae stayed at the same level during the early Iron Age. Remains of *Alnus glutinosa* and *Alnus incana* decreased notably however. Microcharcoal and macrocharcoal frequencies increased from 500 BC.

Middle Iron Age (AD 400–800). Characterised by an increase in pollen and plant macrofossils of *Picea abies*, with pollen frequencies rising sharply from 15% to 40% through the zone (Figures 4 and 5). *Alnus* and *Betula* decreased to 5% and 25% at AD 700. *Betula* sect. Albae decreases towards the end of the zone. *Rumex, Urtica, Plantago lanceolata* and Poaceae dominate non-arboreal pollen taxa. Grains of *Secale cereale* occur intermittently at low values from AD 750. Frequencies of macrocharcoal increased from AD 600 (Figure 3d). Tree pollen accumulation rate shows a minor decrease from AD 700.

Late Iron Age (AD 800–1200). Marks an abrupt decrease in *Picea* from 40% to 15% by AD 1000. Macrofossils of *Picea abies* show high frequencies but decrease only after AD 1100

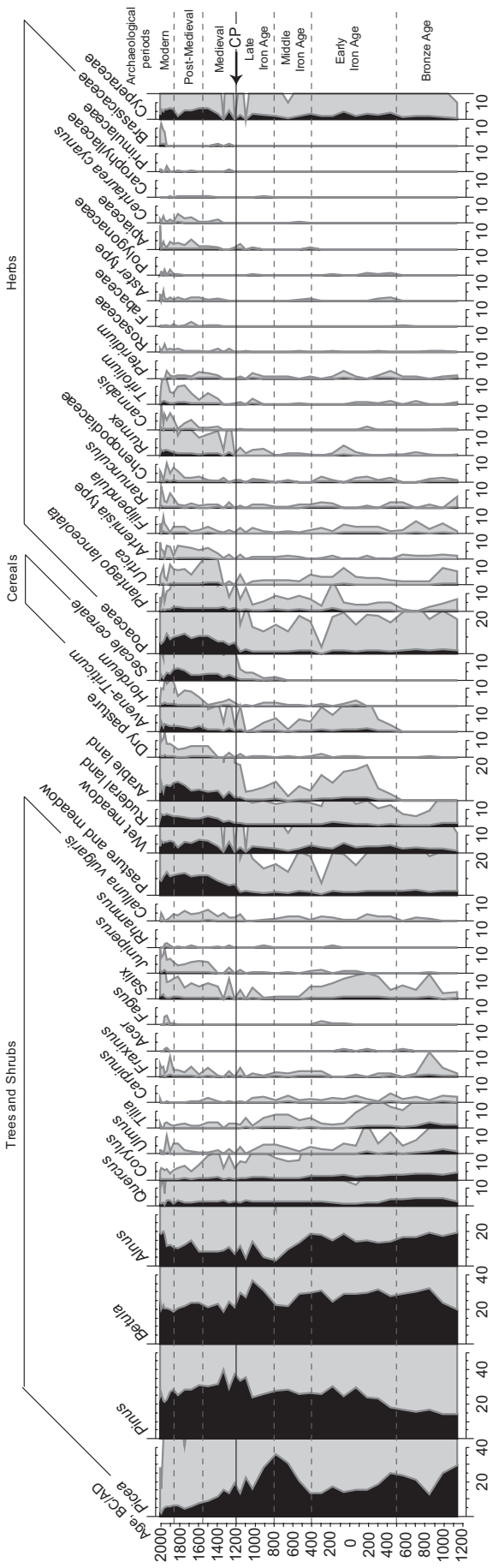

Figure 4. Diagram of selected pollen (percentages) from Lake Trikāta. The grey area shows the multiplication by 10. CP marks the onset of the Crusades.

(Figure 5). *Betula* values increase from AD 800, peaking by AD 1050 but declining thereafter with values for *Pinus* increasing towards the end of the zone.

Medieval (AD 1200–1550). Abrupt changes in vegetation occur from ca. AD 1200 with increasing values for Poaceae, *Artemisia, Rumex, Calluna vulgaris* and cereal grains of *Avena-Triticum, Secale cereale* and *Hordeum* (Figures 3c and 4). At the same time, tree macrofossils diminish (Figures 3a and 5), although pollen frequencies of most arboreal taxa remain constant with only *Picea* declining. The highest concentrations of macroscopic charcoal occur at ca. AD 1250.

Post-medieval (AD 1550–1850). The highest values of *Secale cereale* (10%) ca. AD 1800 (Figure 4). Pollen and macrofossils of *Picea* persist at low values throughout the post-medieval (Figures 4 and 5) with consistent values for other arboreal taxa and only a minor increase of *Alnus* ca. AD 1700.

Modern times (AD 1850–present). Decrease in *Secale cereale*, but increase in *Avena-Triticum, Rumex, Trifolium* and *Alnus* pollen (Figure 4). Tree macrofossils were recovered in low frequencies (Figure 5).

Discussion

Prehistory (1200 BC–AD 1200)

The palaeovegetation records from Lake Trikāta (Figures 4 and 5) indicate a heavily wooded landscape in the vicinity of the lake, with mixed *Betula, Picea, Pinus, Quercus* and *Tilia* woodland dominating until ca. 500 BC. The homogeneity of the sediments, consistently high values of arboreal pollen and organic matter content suggest there is little evidence for human interference in the surrounding landscape (Figures 3f, 4 and 5). There are increasing signs of human impact from 500 BC, with a continuous increase in charcoal particles (Figure 3d) and decrease in macrofossils of *Alnus glutinosa* and *Alnus incana* from 500 BC (Figure 5), the latter associated in many diagrams across the eastern Baltic, and more widely in Poland, with increasing human impact and opening of the landscape (Reitalu et al., 2013; Saarse et al., 2010; Wacnik et al., 2014). *Alnus* possibly grew on the most fertile soils surrounding the lake, cleared by humans for agriculture.

The beginning of continuous cereal cultivation is indicated by consistent values for *Avena-Triticum* pollen from 500 BC and *Hordeum* pollen since 100 BC (Figure 4). The highest values of cultural indicators (Figure 3c) during prehistory date from 200 BC–AD 300, providing clear evidence, in the absence of archaeological remains, for an increase in the intensity of land use at this time. At Lake Trikāta, an agricultural-based economy clearly occurs, later reflecting the variation of practices within and between Baltic regions where at least 4000-year cultivation history is observed close to settlement centres and much later in peripheral areas (Heikkilä and Seppä, 2010; Heinsalu and Veski, 2010; Kalnina et al., 2004; Poska, 2001; Poska et al., 2004; Puusepp and Kangur, 2010; Reitalu et al., 2013; Vasks et al., 1999).

In addition, clearance of woodland for agricultural purposes, pasture and meadows may result in favourable growth condition for certain competitively superior arboreal taxa like *Picea abies* (Figures 4 and 5) and to suppress other taxa (Reitalu et al., 2013). Poska et al. (2004) suggest that an increase in *Picea abies* accompanied by higher values for herb pollen and charcoal frequencies point to the development and intensive use of a pastoral landscape. In addition, because pollen records in lake sediments represent both regional and local vegetation, plant macrofossils can provide information on the vegetation growing directly around the sedimentary basin (Amon et al., 2014; Birks

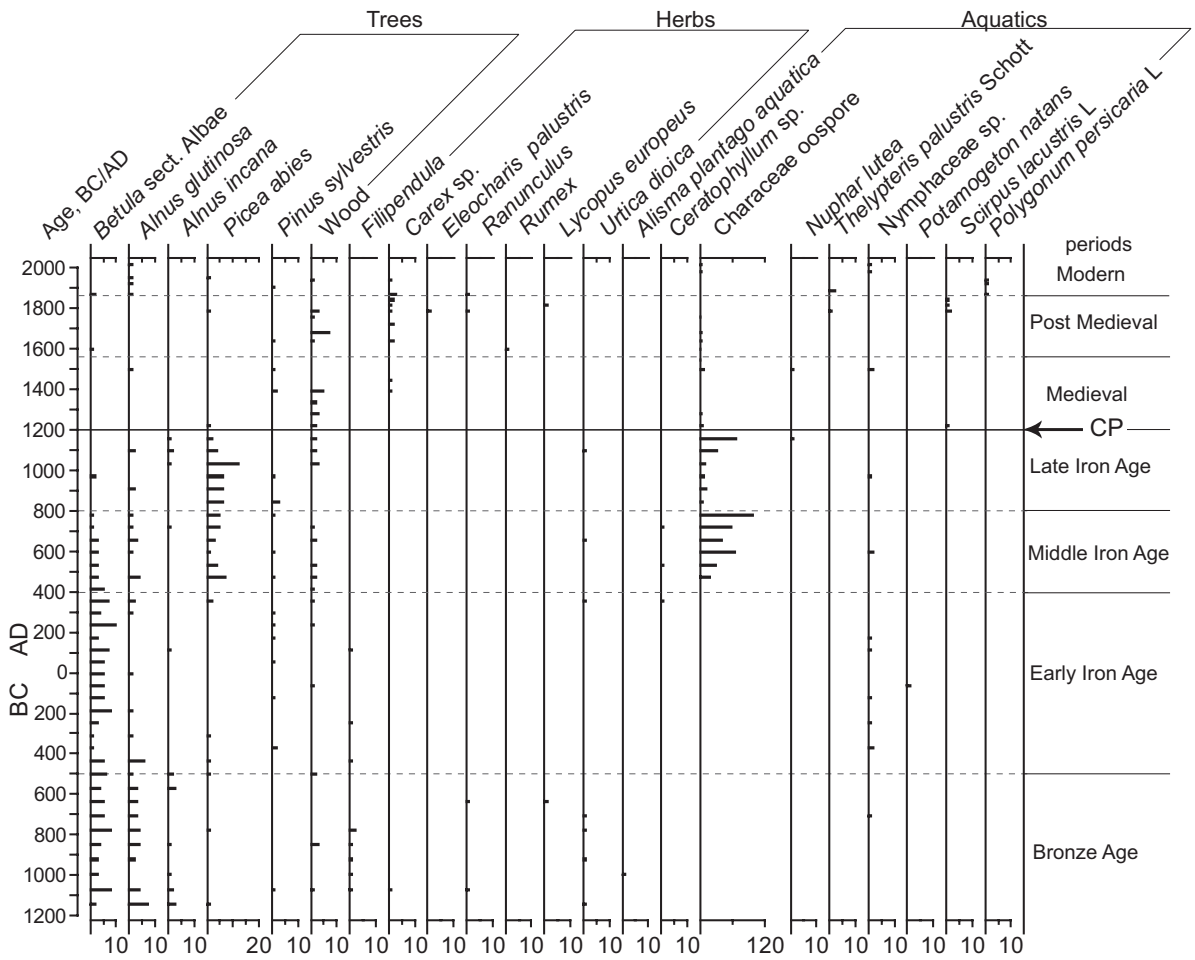

Figure 5. The macroremains found in the lake Trikāta sediment. Values – number of remains per sample. CP marks the onset of the Crusades.

and Birks, 2006). In this sense, the subsequent decline of *Picea* pollen may reflect *Picea* clearance regionally from AD 800, although macrofossils of *Picea*, reflecting its local presence around the lake, decline much later by AD 1200 (Figures 4 and 5). These changes may be related not only to clearance of woodland (Figure 3a and b) but also to the growing need for timber for construction and fuel. More active lake shore clearance of trees could favour erosion of slopes accounting for the continuous abundance of quartz grains in the lake sediments (Figure 3e). Episode of arable intensification (Figure 4) suggests that continuous land use and permanent settlement were established since ca. 500 BC.

Medieval period (AD 1200–1550)

Major changes in vegetation occur from AD 1200 with the increase in cereals (*Secale cereale, Hordeum, Avena-Triticum*), segetal plants and pollen of disturbed ground, meadows and pastureland, accompanied by high charcoal frequencies, and the continued decline in pollen and plant macrofossils of arboreal species (Figures 3a, 4 and 5); together these data imply a massive opening of the woodland surrounding the lake. The lack of tree macrofossils suggests open lake shores. The increase in charcoal correlates with an increase in mineral matter and magnetic susceptibility (Figure 3f) that implies woodland clearance and enhanced agricultural activity resulted in increased soil erosion rates within the lake catchment. The abrupt changes in vegetation from AD 1200, apparent in all palaeoenvironmental and sedimentary proxies (Figures 3–5), suggest a causal link between intensifying land use and the conquest of Latvia by the Order of the Sword Brothers (1209–1227). Furthermore, the establishment of pasture and meadow together with arable land (Figure 4) reflects a diversification of land management practices. The decline in woodland is accompanied by a significant increase in non-arboreal pollen types indicative of disturbed, grazed and cultivated ground, notably *Artemisia, Aster*-type, Chenopodiaceae, *Rumex* type, *Trifolium, Centaurea cyanus* and cereal pollen. The increase in these pollen taxa strongly implies the development of a mosaic pattern of land use. *Centaurea cyanus*, in particular, is a weed strongly associated with cereal cultivation and has been argued to reflect the presence of permanent fields (Poska et al., 2004; Vuorela, 1986). In addition to arable land and wet meadow, land-use management became even more varied with an increase in dry pasture from AD 1400 (Figure 4). The presence of winter and spring cereals also emphasises the development of a rotational crop regime. During medieval times, the three-field system was established with a rotating cultivation of winter crop, summer crop and fallow land (Enters et al., 2008). Cultivated land would be fallow, and presumably could be under graze, and animal manure would have been an important source of nutrient to cycle back into the fields. Higher proportions of *Juniperus* pollen have previously been taken as indicators of the expansion of dry meadow habitats (Veski et al., 2005), that in the context of the Lake Trikāta study suggest meadows could have formed an equal or greater proportion of farmland surrounding the lake.

The 13th century increase in agrarian activity at Trikāta is mirrored by only a small number of pollen sequences across southern Estonia and northern Latvia, including the study of Niinemets and Saarse (2007) at Lake Lasva where an increase in arable and pastoral activity is most apparent from the 12th/13th centuries. The majority of palynological studies generally only show an increase

in cereal cultivation a century after the crusades, of 14th century and later date.

The study of Veski et al. (2005) at Lake Rõuge Tõugjärv (southern Estonia) shows agricultural activity from AD 1350, with pollen analysis from Äriküla, near the Order Castle at Karksi, showing a similar 14th century increase in cereal cultivation. Three pollen sequences from peatlands around Cēsis, central Latvia (former German Wenden and the Head Quarter of the Livonian Order), show a similar pattern of agricultural intensification from the mid-14th century and later (Brown and Pluskowski, 2014). However, a pollen sequence from adjacent to the Iron Age lake settlement and medieval castle at Āriaši, 6 km south-east of Cēsis, shows a decline in agricultural land use from the start of the medieval period, only increasing again during the 14th century (Stivrins et al., 2015), perhaps linked with the construction of the castle during the first half of the 14th century. The palynological sequences from southern Estonia and northern Latvia reflect more broadly the history of land use across medieval Livonia. The crusades in the eastern Baltic differ significantly from Prussia (present-day north-east Poland) where the conquests of the Teutonic Order were accompanied by significant colonisation, evident by the numerous rural and urban foundations (Pluskowski, 2012). Colonisation in Livonia was largely restricted to the major urban centres, such as Riga, with little colonisation of the rural hinterlands, with native populations continuing to follow indigenous patterns of land use (e.g. Mugurēvičs, 2008). Intensification in agricultural activity during the 14th century appears to have occurred in the context of the growing significance of the Hanseatic League and the development of the manorial system, creating an increased demand for agricultural produce (Kala, 2005; Raun, 2002). However, there would have been a requirement to produce cereals to support the castles and new urban centres appearing across Livonia during the 13th century. Documentary sources from the 14th century refer to Trikāta as a cornhouse, responsible for the collection, storage and redistribution of agricultural produce. It is probable that the castle and its hinterland performed a critical function during the initial decades of the crusades in producing and supplying agricultural surplus to castles located within those more unstable zones of Livonia (e.g. Curonia). The staples of primary importance for cultivation and consumption correspond with written sources in Latvia and Estonia, highlighting the dominance of *Avena-Triticum, Hordeum* and *Secale cereale* associated with the Hanseatic League (Sillasoo and Hiie, 2007).

Post-medieval and modern (AD 1550–present)

The Livonian Order was secularised in 1561, representing the transition between medieval and Post-medieval periods, with Livonia subsequently coming under Polish and Swedish control during the late 16th and 17th centuries. Interestingly, there is a reduction in quantities of macroscopic and microscopic charcoal ca. AD 1550–1600 (Figure 3d), indicating a reduction of local and regional fire frequency. It is uncertain whether this is related to broader instability in the landscape, perhaps as a consequence of the Livonian Wars, or a reduction in population, as levels of cultural indicator pollen remain high, instead suggesting continued intensive agrarian activity.

The pattern of intensive agrarian land use is further supported by the development of manors during the 17th century, the first established in AD 1654, with more than 13 in the parish of Trikāta (Enzeliņš, 1931). Extensive agriculture occurred after AD 1750 with a significant increase in cereals. Values for arable, disturbed and pastoral land reach their peak in the period from AD 1800 to 1900 (Figure 3c) at a time of increasing population density. The increase in cultural indicators does not automatically imply an increase in the amount of land under cultivation, but may reflect instead a more efficient use of existing agricultural land achieved through intensification and modernisation of arable farming techniques.

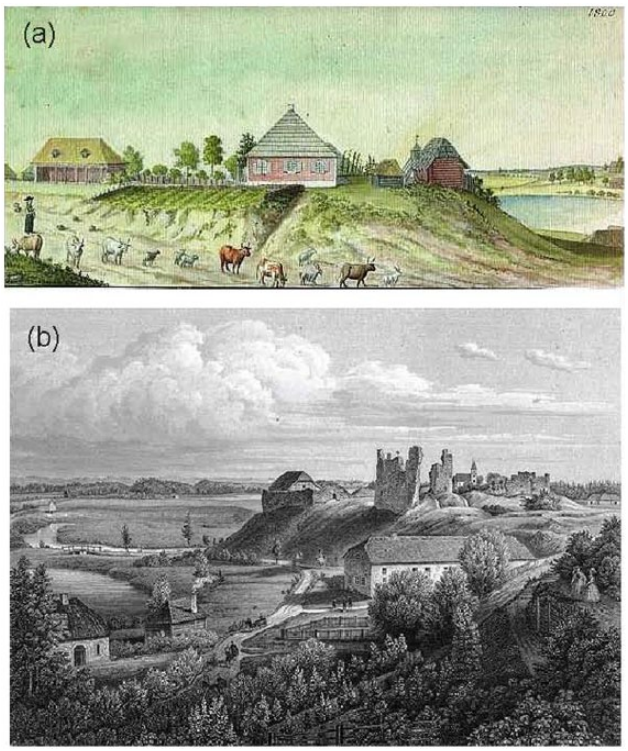

Figure 6. Drawing from (a) AD 1800 by Broce J.K. '*Ansicht des Hofes Trikaten von der Abendseite*' taken from western part of the lake Trikāta, adjacent to remnants of Trikāta castle, Lake Trikāta on the right side of the drawing and, and (b) engraving from AD 1886 by Stavenhagen W.S. showing landscape of surroundings south west direction from diary, Lake Trikāta on the left side of engraving.

Moreover, livestock farming developed alongside cereal cultivation. In AD 1828, a sheep farm was established surrounding Trikāta that by AD 1860 was the biggest livestock farm in northern Latvia including more than 1584 sheep (Enzeliņš, 1932). Because of intensive arable and livestock farming, the landscape developed predominantly open characteristics, demonstrated as such in two historical drawings from AD 1800 (Figure 6a) and AD 1866 (Figure 6b). Both reveal large areas of open fields with isolated stands of tree and point to the presence of a variety of livestock, including cattle and sheep. The palaeorecord from Lake Trikāta, characterised by high cultural indicators, high mineral content of the sediment and quartz grains and low arboreal pollen accumulation rate (Figure 3), shows a reliable reconstruction of land-use history during the 19th century, although tree pollen percentages seem to be over-represented. Extensive land use decreased after AD 1930 at Lake Trikātas as reflected by lower values of mineral matter content, magnetic susceptibility, quartz grains and cultural indicators. Meanwhile higher macrocharcoal frequencies may point to fire in the local vicinity that can be associated with establishment of a distillery, brick kiln and a dairy next to the lake.

Conclusion

The study described in this paper, when set in the context of other palynological studies from Livonia, demonstrate the varied spatial and chronological histories of medieval land use. The picture beginning to emerge from palynological studies suggests that the crusades and conquest of former tribal lands was not accompanied by significant impacts on rural landscapes. Colonisation was limited to the principal urban centres while native

communities continued to follow indigenous patterns of land use; agricultural intensification is not widely apparent until the 14th century, a century or more after the initial crusades. However, the palaeoenvironmental data from Lake Trikāta demonstrates significant woodland clearance and intensified land use from the early 13th century immediately following the crusades, which we interpret as reflecting the important role played by the castle and its hinterland in organising the production, storage and redistribution of local agricultural produce. Trikāta was located on one of the main north-south routes through Livonia within a relatively stable part of the order state and is likely to have performed a key provisioning role as suggested by later 14th century documentary sources.

Funding

Research was supported by European Social Fund's Doctoral Studies and International Programme DoRa, project ETF9031, project EBOR and IUT 1-8. This study runs in cooperation also with the Ecology of Crusading Project (directed by Aleks Pluskowski) funded by the European Union's Seventh Framework Programme (FP7/2007–2013) under grant agreement No. 263735. Thanks to Inga Boškina.

References

Amon L, Veski S and Vassiljev J (2014) Tree taxa immigration to the eastern Baltic region, southeastern sector of Scandinavian glaciation during the Late-glacial period (14,500–11,700 cal. BP). *Vegetation History and Archaeobotany* 23: 207–216.

Behre KE (1988) *The role of man in European vegetation history*. In: Huntley B and Webb IT (eds) *Vegetation History* (Handbook of vegetation science, vol. 7). Dordrecht: Kluwer Academic Publishers, pp. 633–672.

Berglund BE and Ralska-Jasiewiczowa M (1986) *Pollen analysis and pollen diagrams*. In: Berglund B (ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. New York: Wiley, pp. 455–484.

Birks HB and Birks HJB (2006) Multi-proxy studies in palaeolimnology. *Vegetation History and Archaeobotany* 15: 235–251.

Birks HH (2001) *Plant macrofossils*. In: Smol JP, Birks HJB and Last WM (eds) *Tracking Environmental Change Using Lake Sediments: Volume 3 – Terrestrial, Algal, and Siliceous Indicators*. Dordrecht: Kluwer Academic Publishers, pp. 49–74.

Blaauw M (2010) Methods and code for 'classical' age-modelling of radiocarbon sequences. *Quaternary Geochronology* 5: 512–518.

Brown A and Pluskowski A (2014) Medieval landscape transformation in the southeast and eastern Baltic: Palaeoenvironmental perspectives on the colonisation of frontier landscapes. *Archaeologia Baltica* 20: 24–46.

Caune A and Ose I (2004) *Latvijas 12. gadsimta beigu – 17 gadsimta vācu piļu leksikons*. Rīga: Latvijas Vēstures Institūts.

Enters D, Dörfler W and Zolitschka B (2008) Historical soil erosion and land-use change during the last two millennia recorded in lake sediments of Frickenhauser See, northern Bavaria, central Germany. *The Holocene* 18: 243–254.

Enzeliņš H (1931) *Atskats Trikātas novada senatnē*. Rīga: A. Gulbja izdevniecība.

Enzeliņš H (1932) *Skati Valmieras pilsētas, draudzes un novada pagātnē*. Valmiera: Kooperatīvā sabiedrība 'Zeme'.

Fægri K and Iversen J (1989) *Textbook of Pollen Analysis*. New York: Wiley.

Finsinger W, Tinner W and Hu FS (2008) Rapid and accurate estimates of microcharcoal content in pollen slides. In: Fiorentino G and Magri D (eds) *Charcoals from the past: Cultural and Palaeoenvironmental Implications* (BAR international series 1807). Oxford: Archaeopress, pp. 121–124.

Gaillard M-J (2007) *Pollen methods and studies: Archaeological applications*. In: Elias SA (ed.) *Encyclopedia of Quaternary Science*. Amsterdam: Elsevier, pp. 2570–2595.

Graudonis J (2001) *Early Metal period*. In: Graudonis J (ed.) *The Prehistory of Latvia*. Rīga: Institute of the History of Latvia, p. 463.

Grimm EC (2012) *TILIA 1.7.16 Software*. Springfield, IL: Research and Collection Center, Illinois State Museum.

Heikkilä M and Seppä H (2010) Holocene climate dynamics in Latvia, eastern Baltic region: A pollen-based summer temperature reconstruction and regional comparison. *Boreas* 39: 705–719.

Heinsalu A and Veski S (2010) Palaeoecological evidence of agricultural activity and human impact on the environment at the ancient settlement centre of Keava, Estonia. *Estonian Journal of Earth Sciences* 59: 80–89.

Kala T (2005) Estonia from the 13th to 16th centuries. In: Subrenat JJ (ed.) *Estonia: Identity and Independence*. Amsterdam: Editions Rodopi BV, pp. 47–64.

Kalnina L, Cerina A and Vasks A (2004) Pollen and plant macroremain analysis for the reconstruction of environmental changes in the early Metal period. In: Scott EM, Alekseev AY and Zaitseva G (eds) *Impact of the Environment on Human Migration in Eurasia*. Amsterdam: Kluwer Academic Publishers, pp. 276–289.

Kangur M, Koff T, Punning J-M et al. (2009) Lithology and biostratigraphy of the Holocene succession of Lake Ķūži, Vidzeme Heights (Central Latvia). *Geological Quarterly* 53: 199–208.

Kasparinskis R and Nikodemus O (2012) Influence of environmental factors on the spatial distribution and diversity of forest soil in Latvia. *Estonian Journal of Earth Sciences* 61: 48–64.

Kušķe E, Silamiķele I, Kalniņa L et al. (2010) Peat formation conditions and peat properties: A study of two ombrotrophic bogs in Latvia. In: Kļaviņš M (ed.) *Mires and Peat*. Rīga: University of Latvia Press, pp. 56–70.

Mugurēvičs E (2008) *Viduslaiku ciems un pils Salaspils novadā*. Rīga: Latvijas vēstures institūta apgāds, 262 pp.

Niinemets E and Saarse L (2007) Fine-resolution pollen-based evidences of farming and forest development, south-eastern Estonia. *Polish Journal of Ecology* 55: 283–296.

Nowaczyk NR (2001) *Logging of magnetic susceptibility*. In: Smol JP and Last WM (eds) *Tracking Environmental Change Using Lake Sediments: Volume 1 – Basin Analysis, Coring and Chronological Techniques*. Dordrecht: Kluwer Academic Publishers, pp. 155–170.

Ozola I, Ceriņa A and Kalniņa L (2010) Reconstruction of palaeovegetation and sedimentation conditions in the area of ancient Lake Burtnieks, northern Latvia. *Estonian Journal of Earth Sciences* 59: 164–179.

Pluskowski A (2012) *The Archaeology of the Prussian Crusade: Holy War and Colonisation*. London: Routledge, 427 pp.

Poska A (2001) *Human Impact on Vegetation of Coastal Estonia during the Stone Age* (Comprehensive summaries of Uppsala dissertations from the Faculty of Science and Technology, 652). Uppsala: Uppsala Universitet.

Poska A and Saarse L (2002) Biostratigraphy and 14C dating of a lake sediment sequence on the north-west Estonian carbonaceous plateau, interpreted in terms of human impact in the surroundings. *Vegetation History and Archaeobotany* 11: 191–200.

Poska A, Saarse L and Veski S (2004) Reflections of pre- and early-agrarian human impact in the pollen diagrams of Estonia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 209: 37–50.

Puusepp L and Kangur M (2010) Linking diatom community dynamics to changes in terrestrial vegetation: A palaeolimnological case study of Lake Ķūži, Vidzeme Heights (Central Latvia). *Estonian Journal of Ecology* 59: 259–280.

Radiņš A (1996) *Ceļvedis Latvijas Senvēsturē*. Rīga: Zvaigzne ABC.

Rasiņš A (1954) *Latvijas PSR nezāļu augļi un sēklas*. Rīga: Latvijas Valsts izdevniecība.

Raun TU (2002) *Estonia and Estonians*. 2nd Edition. Stanford, CA: Hoover Institution Press.

Reimer PJ, Bard E, Bayliss A et al. (2013) Intcal13 and marine13 radiocarbon age calibration curves 0 – 50,000 years cal BP. *Radiocarbon* 55: 1869–1887.

Reitalu T, Seppä H, Sugita S et al. (2013) Long-term drivers of forest composition in a boreo-nemoral region: The relative importance of climate and human impact. *Journal of Biogeography* 40: 1524–1534.

Saarse L, Niinemets E, Poska A et al. (2010) Is there a relationship between crop farming and the *Alnus* decline in the eastern Baltic region? *Vegetation History and Archaeobotany* 19: 17–28.

Sillasoo Ü and Hiie S (2007) An archaeobotanical approach to investigating food of the Hanseatic period in Estonia. In: Karg S (ed.) *Medieval Food Traditions in Northern Europe*. Copenhagen: National Museum of Denmark, pp. 73–96.

Stivrins N, Brown A, Reitalu T et al. (2015) Landscape change in central Latvia since the Iron Age: Multi-proxy analysis of the vegetation impact of conflict, colonization and economic expansion during the last 2000 years. *Vegetation History and Archaeobotany* 24: 377–391.

Stivrins N, Kalnina L, Veski S et al. (2014) Local and regional Holocene vegetation dynamics at two sites in eastern Latvia. *Boreal Environment Research* 19: 310–322.

Stockmarr J (1971) Tablets with spores used in absolute pollen analysis. *Pollen et Spores* 13: 615–621.

Tamm M, Kaljundi L and Selch JC (2011) *Crusading and Chronicle Writing on the Medieval Baltic Frontier: A Companion to the Chronicle of Henry of Livonia*. Farnham: Ashgate Publishing.

Turnbill S (2004) *Crusader Castles of the Teutonic Knights. The Stone Castles of Latvia and Estonia*. Oxford: Osprey Publishing.

Urtāns J (1991) *Ziemeļvidzemes pilskalni*. Rīga: AVOTS, 70 pp.

Vasks A, Kalnina L and Ritums R (1999) The introduction and Pre-Christian history of farming in Latvia. *PACT* 57: 291–304.

Velichkevich FY and Zastawniak E (2006) *Atlas of the Pleistocene Vascular Plant Macrofossils of Central and Eastern Europe: Part 1 – Pteridophytes and Monocotyledons*. Krakow: W. Szafer Institute of Botany, Polish Academy of Sciences.

Velichkevich FY and Zastawniak E (2008) *Atlas of the Pleistocene Vascular Plant Macrofossils of Central and Eastern Europe: Part 2 – Herbaceous Dicotyledons*. Krakow: W. Szafer Institute of Botany, Polish Academy of Sciences.

Veski S, Koppel K and Poska A (2005) Integrated palaeoecological and historical data in the service of fine-resolution land use and ecological change assessment during the last 1000 years in Rõuge, southern Estonia. *Journal of Biogeography* 32: 1473–1488.

Vuorela I (1986) Palynological and historical evidence of slash-and-burn cultivation in South Finland. In: Behre K-E (ed.) *Anthropogenic Indicators in Pollen Diagrams*. Rotterdam: Balkema, pp. 53–64.

Wacnik A, Kupryjanowicz M, Mueller-Bieniek A et al. (2014) The environmental and cultural contexts of the late Iron Age and medieval settlement in the Mazurian Lake District, NE Poland: Combined palaeobotanical and archaeological data. *Vegetation History and Archaeobotany* 23: 439–459.

Zelčs V and Markots A (2004) *Deglaciation history of Latvia*. In: Ehlers J and Gibbard PL (eds) *Quaternary Glaciations – Extent and Chronology of Glaciations*. Amsterdam: Elsevier, pp. 225–243.

Zelčs V, Markots A, Nartišs M et al. (2011) *Pleistocene glaciations in Latvia*. In: Ehlers J, Gibbard PL and Huges PD (eds) *Quaternary Glaciations – Extent and Chronology: A Closer Look*. Amsterdam: Elsevier, pp. 221–229.