

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

Agnieszka Wacnik · Mirosława Kupryjanowicz ·
Aldona Mueller-Bieniek · Maciej Karczewski ·
Katarzyna Cywa

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Abstract Pollen analysis of sediments from three lakes and analysis of plant macroremains including charcoal from archaeological sites in the Mazurian Lake District provide new data for the reconstruction of vegetation changes related to human activity between the 1st and 13th century AD. At that time settlements of the Bogaczewo culture (from the turn of the 1st century AD to the first part of the 5th century AD), the Olsztyn Group (second part of the 5th century AD to the 7th or beginning of the 8th century AD), and the Prussian Galinditae tribes (8th/9th–13th century AD) developed. The most intensive woodland clearing occurred between the 1st and 6th/7th century AD. Presence of Cerealia-type, *Secale cereale* and *Cannabis*-type pollen, as well as macroremains of *Hordeum vulgare*, *S. cereale*, *Triticum spelta*, *T. cf. monococcum*, *T. cf. dicoccum*, *Avena* sp. and *Panicum miliaceum* documented local agriculture. High *Betula* representation synchronous with microcharcoal occurrence suggests shifting agriculture. After forest regeneration between c. AD 650 and 1100, the area was

strongly deforested due to the early medieval occupation by Prussian tribes. The archaeobotanical examination of samples taken in a cemetery and a large settlement of the Roman Iron Age revealed strong differences in the taxonomic composition of the fossil plant remains. An absolute dominance of birch charcoal in the samples from the cemetery indicates its selective use for funeral pyre construction. There is a difference between cereals found in both contexts: numerous grains of *Triticum* have been found in the cemetery, while in the settlement crops were represented mostly by *Secale* and *Hordeum*. Grass tubers, belonging probably to *Phleum pratense*, are among the particularly interesting plant remains found in the cemetery.

Keywords Pollen analysis · Plant macroremains · Charcoal · Grass tubers · Secondary *Betula* woods · Human impact · Roman Iron Age · Middle Ages

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A. Wacnik (✉) · A. Mueller-Bieniek · K. Cywa
W. Szafer Institute of Botany, Polish Academy of Sciences,
Lubicz 46, 31-512 Kraków, Poland
e-mail: a.wacnik@botany.pl

M. Kupryjanowicz
Institute of Biology, University of Białystok, Świerkowa 20b,
15-950 Białystok, Poland

M. Karczewski
Institute of History and Political Sciences, University of
Białystok, Plac Uniwersytecki 1, 15-420 Białystok, Poland

Introduction

The studies of the postglacial vegetation dynamics, with natural and anthropogenic aspects of their development in the Mazurian Lake District have a tradition of several dozen years (Ralska-Jasiewiczowa 1966; Kupryjanowicz 2008; Wacnik et al. 2012; Kołaczek et al. 2013). So far the main source of palaeoenvironmental proxies has been palynological studies, supplemented rarely by carpological and anthracological analyses. In the last two decades new interdisciplinary investigations have taken place tending toward the reconstruction of cultural landscape development in the direct vicinities of archaeological sites dated to the Roman Iron Age, Migration Period and the early Medieval Period (e.g. Lityńska-Zajac 1997; Nowakowski

2009; Karczewska and Karczewski 2007; Karczewski 2011; Szal et al. 2013).

The beginning of the Common Era around 2,000 years ago was the time of distinct increase of floristic diversity. The deforestation caused by farmers led to a mosaic landscape registered in pollen records from the Roman Iron Age onwards in different countries from the Baltic region (e.g. Berglund et al. 2008; Heinsalu and Veski 2010; Stančikaitė et al. 2004, 2009). A significant step in the formation of the cultural landscape has also been documented in Poland, for example by isopollen maps (Ralska-Jasiewiczowa et al. 2004). However, to date we have only a few pollen sequences from the former territory of the Prussian tribes in NE Poland illustrating human-environment interactions from the Roman Iron Age to the Middle Ages (Kołaczek et al. 2013; Pawlikowski et al. 1982; Wacnik et al. 2012).

The reconstructions of past climate variability in Central and Northern Europe indicate crucial changes during the last two millennia, influencing among other things human activity. According to these reconstructions, during the Roman (ca. AD 50–250) and Medieval Warm Period (9th–13th century AD) the climate was characterized by humid and warm summers that stimulated the development of settlement and agriculture (e.g. maximum expansion and deforestation of the Western Roman Empire around AD 250). In contrast the Migration Period (ca. AD 250–550) and the “Little Ice Age” (13th century AD—ca. 1820), which were generally a time of historical crisis, were characterized by a more unfavorable climate (e.g. Hass 1996; Briffa 2000; Grudd et al. 2002; Niggemann et al. 2003; Ljungqvist 2010; Büntgen et al. 2011). The relationship between climate changes recorded from the first century AD onwards and their cultural, political, economic and demographic consequences have been discussed in European literature by many authors (e.g. Berglund 2003; Chew 2007; Eriksson et al. 2008; Weninger et al. 2009; Fraser 2011; McCormick et al. 2012).

The beginning of the Common Era was also the time of important cultural/settlement transformations in the Baltic region where the activity of new cultures groups was initiated. One of seven of these groups, distinguished by Nowakowski (2009), belonging to the western Balts, was the Bogaczewo culture (the turn of 1st century—first part of 5th century AD), which developed in the Great Mazurian Lake District (see also Cieśliński 2009; Karczewski 2006, 2011) and left numerous remains of its settlement in the microregion presented in this paper.

Our study is focused on providing new information on vegetation changes that resulted from human activity and natural processes in the Great Mazurian Lake District from the beginning of the first millennium AD until the Middle Ages. The main goals are:

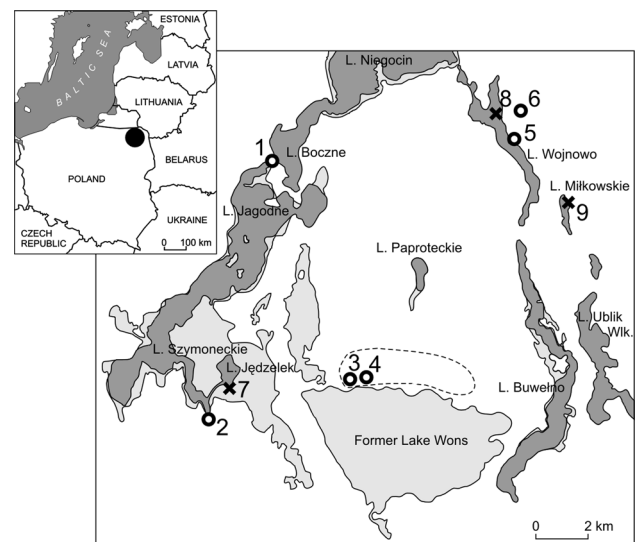


Fig. 1 The studied area with the reconstruction of lake ranges in the 1st millennium AD, location of archaeological sites, and coring sites for palynological research. The present ranges of lakes are marked in dark grey while their reconstructed range is marked in light grey (after T. Popławski, in Karczewski 2011, slightly modified). 1 cemetery at Bogaczewo-Kula, 2 cemetery at Górki, 3 settlement at Paprotki Kolonia (site 41), 4 cemetery at Paprotki Kolonia (site 1), 5 stronghold at Staświny (site 1), 6 cemetery at Staświny, 7 coring site at Lake Jędrzele, 8 coring site at Lake Wojnowo, 9 coring place at Lake Miłkowskie

- to analyze the character/intensity of exploitation of local wood resources;
- to reveal which plants were favored by humans and used for alimentary, cult, or other purposes;
- to document the changes of intensity and methods of agriculture and other economic exploitation of this area;
- to verify the role of the Teutonic Order activity in formation of large deforested areas on former Prussian Galinditae tribe territory.

For our research two large settlement centres studied archaeologically at Paprotki Kolonia and Staświny have been chosen (Fig. 1). The existence of the first one was restricted to the development of the Bogaczewo culture (the Roman Iron Age, the early Migration Period) and the Olsztyn Group (the late Migration Period) societies, while the second situated on the shore of Lake Wojnowo was also occupied in the Middle Ages by the Galinditae tribe.

Our palaeobotanical studies consist of plant macro- and microremain analyses, such as seeds, fruits, charcoal, tubers and pollen, and are supplemented by local archaeological data on settlement intensity and chronology.

Study area

The studied sites are located in the Great Mazurian Lake District (NE Poland; Fig. 1), which is a part of the Province

of West-Russian Lowlands and the Sub-province of East Baltic Lake Districts (Kondracki 2000). The limits of the major phases of the Weichselian glaciation (Leszno phase, Poznań phase, Pomeranian phase) meet in the Mazurian Lake District area. During the Pomeranian phase, two arch-shaped depressions were created there by the glacier, which are today occupied by the Łyna River valley in the west and by a system of large lakes in the east (Kondracki 2000).

The soil cover is strongly differentiated with the predominance of the zonal types, namely brown soils and podzols. Hydrogenic and semi-hydrogenic soils cover the low lying terrains along rivers and near lakes (Bednarek and Prusinkiewicz 1999).

The characteristic feature of the Great Mazurian Lake District is a large number of lakes; the five largest lakes (9.58–114 km² in surface area) are joined by canals. The river network is poorly developed (Kondracki 2000). Large parts of the area are covered by peatlands (16 % of the total area), and gytija lands (1 % of the area; Gotkiewicz et al. 1995).

The present climate of the region is one of the coldest in Poland with a mean annual temperature of 6.5 °C. The mean January temperature is –4.5 °C, while that for July is 17.5 °C. The mean annual precipitation is c. 570 mm with the predominant rainfall in summer (Woś 1999). The presence of large lakes and patches of forest strongly influence local climates (Kondracki 2000). The length of the growing season is about 180–190 days.

The potential natural vegetation of this area (Fig. 2) would be mostly poor subboreal types of lowland lime-oak-hornbeam forests with spruce (*Tilio-Carpinetum*) and lowland alder and ash-alder forests (*Fraxino-Alnetum* and *Circaeo-Alnetum*) on periodically inundated soils. Small patches of habitats for *Carici elongatae-Alnetum*, *Potentillo albae-Quercetum typicum* and subboreal type of *Peucedano-Pinetum* occur. At some distance from the sites forest communities of *Quercu-Pinetum* and *Vaccinio uliginosi-Pinetum* could be found. Nowadays, different types of pine and mixed pine forests from the *Dicrano-Pinion* and *Piceion abietis* alliances prevail on sandy soils, while oak-hornbeam forests from the *Carpinion betuli* alliance develop on the morainic substrates (Matuszkiewicz 2002, 2008a, b). The area is situated at the border of a continuous distribution range of *Fagus sylvatica* and *Acer pseudo-platanus* (Zajac and Zajac 2001).

Archaeological context

Archaeological data show a very strong increase of human activity and the development of the Bogaczewo culture settlement network at the beginning of the Roman Iron Age (Fig. 3a). In the first century AD four new settlement

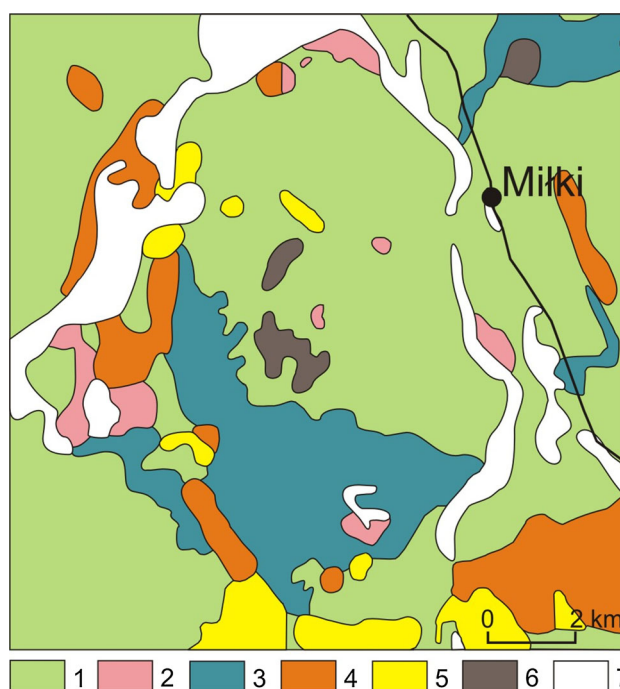


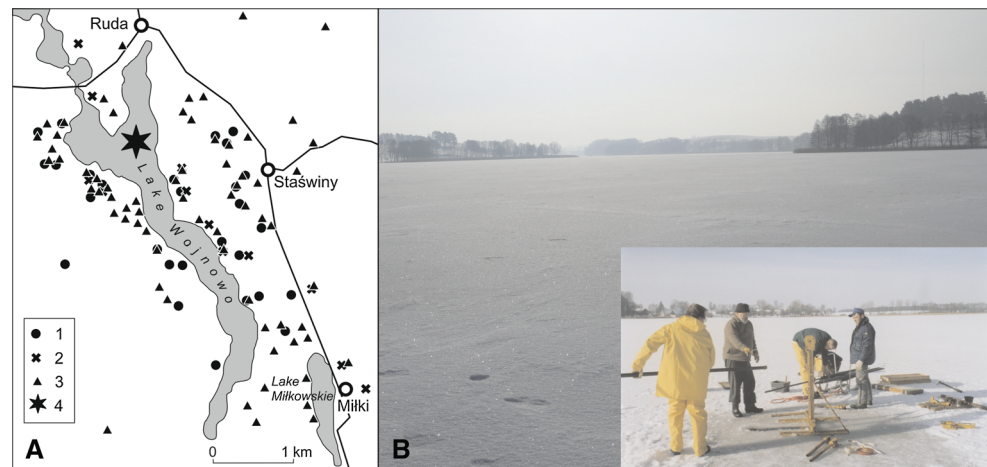
Fig. 2 Map of the potential natural vegetation of the studied area (after Matuszkiewicz 2008a). 1 *Tilio-Carpinetum*, 2 *Carici elongatae-Alnetum*, 3 *Fraxino-Alnetum*, 4 *Quercu-Pinetum*, 5 *Peucedano-Pinetum*, 6 *Potentillo albae-Quercetum typicum*, 7 lakes

microregions appeared in the Great Mazurian Lake District. The most stable elements of each of these were cemeteries discovered at Bogaczewo-Kula, Górkło, Paprotki Kolonia, and Staświny (Fig. 1). The Bogaczewo culture (1st century—1st part of the 5th century AD) persisted until the early phase of the Migration Period (e.g. Karczewski 2006, 2011).

Some important changes in the settlement pattern took place in the second part of the fifth century AD, when the Bogaczewo culture was replaced by the Olsztyn Group. The relationship between these two archaeological groups is still not clear, but it should be emphasized that in this region people of the Olsztyn Group often buried their dead ancestors at the cemeteries previously used by the Bogaczewo culture society. Such a situation is clearly visible in the cemeteries at Bogaczewo-Kula and Paprotki Kolonia. The settlement pattern of the Olsztyn Group is less recognized, and the present distribution maps can reflect both the real settlement pattern in the late Migration Period or the actual state of archaeological research.

The relationship of the late Olsztyn Group settlement and the early beginning of the subsequent Prussian tribal settlement in the early Middle Ages (8th/9th century AD) is also unclear because of the shortage of archaeological data. Until now no cemeteries of this age were discovered in this area. The information about the medieval settlement is based only on the results obtained from the excavations at

Fig. 3 Distribution of archaeological sites in the Staświny area (after Karczewski 2008) and field work on Lake Wojnowo. **a** 1 sites dated to the early Iron Age, 2 sites dated to the Roman Period, 3 sites dated to the early Medieval Period, 4 coring site on Lake Wojnowo. **b** view over Lake Wojnowo and coring on the frozen lake



the Staświny stronghold, site 1, and from archaeological surveys (e.g. Karczewska and Karczewski 2007; Karczewski 2008). The settlement of the Olsztyn Group located on the northern shore of the former Lake Wons disappeared at the end of the Migration Period. No traces of the medieval occupation were discovered there. Such a situation could have been related to the ongoing natural process of the lake terrestrialization. A different situation was observed around Lake Wojnowo, where the medieval microregion is clearly distinguishable, with the central point most probably placed in the stronghold at Staświny, which was both, a settlement and probably also a cult site.

In the whole studied period settlements were placed on slight elevations on lake shores. Sandy soils were preferred. Cemeteries also were situated on elevations, but in this case the other important factors were the location between two lakes (Bogaczewo-Kula and Paprotki Kolonia) or on riverbanks (Staświny); the soil type was not important (Karczewski 2011). The studied area was occupied by the Prussian Galinditae tribe till the subjugation by the Teutonic Order in the 13th century AD.

Study sites (Figs. 1, 3a)

Lake Miłkowskie (53°51'N, 21°50'E; 124.8 m a.s.l.) is a channel lake of glacial origin with water surface of 23.7 ha; the maximum water depth is 15 m in the northern part but the average depth is 4.2 m (Choiński 1991). The lake is connected by its outflow with Lake Wojnowo and both of them belong to the catchment area of Lake Niegocin. Lake Miłkowskie is situated at a distance of 5–6 km from the Paprotki Kolonia archaeological site and 4 km from the Staświny stronghold.

Lake Wojnowo (53°57.901'N, 21°49.854'E; 115 m a.s.l.) with a water surface area of 176.3 ha fills a glacial gully about 4.6 km long and has several connections with

other lakes. There are two depressions in the lake bottom, in the southern part the maximum depth is 14.2 m, in the northern part 11.7 m. Lake Wojnowo is situated at a distance of 5–7 km from the Paprotki Kolonia archaeological site and less than 1 km from the medieval stronghold at Staświny.

Lake Jędzelek (53°53'N, 21°43'E; 115.7 m a.s.l.) is situated within the area of three villages, at a distance of ca. 2 km from the Paprotki Kolonia archaeological site (Fig. 1). Its water surface has decreased from 67.0 ha to 37.5 ha in the last few decades. The maximum water depth is 1.2 m, but its average depth is 0.8 m. The lake is connected with two other lakes by small watercourses. A broad zone of mires and wet meadows surrounds the lake on all sides.

Paprotki Kolonia (site 1; 53°54'N, 21°46'E; c. 120.9 m a.s.l.), is a cremation cemetery from the Roman Iron Age, the early phase of the Migration Period (Bogaczewo culture) and the developed phase of the Migration Period (Olsztyn Group). It is situated 1.7 km from the Paprotki village at a slight elevation between two peat bogs. The area of the cemetery is ca. 2,970 m².

Paprotki Kolonia (site 41; 53°53'N, 21°47'E; ca. 122 m a.s.l.), is an open settlement from the Roman Iron Age, the early phase of the Migration Period (Bogaczewo culture) and the developed phase of the Migration Period (Olsztyn Group). It is situated 1.3 km from the Paprotki village at the northern shore of a peat bog (former Lake Wons). It is a part of the extensive complex of archaeological sites which are very probably remnants of a large settlement (Paprotki Kolonia site 41) connected with the cemetery (site 1); the site is situated ca. 600 m to the east of the cemetery. The archaeological features are located above ground water level so all the uncharred (not waterlogged) remains are interpreted as some recent contamination (Karczewski et al. 2009).

Table 1 The lithology of palynological profiles

Profile	Lithology ¹
Lake Miłkowskie	0.01–3.7 m—gyttja rich in organic matter, relatively poor in iron compounds and silica. Lamination occurs in the whole section: irregular between 2.20 and 0.25 m, regular below and above that depth 3.7–7.8 m—gyttja with downwardly increasing amount of carbonates, with irregular lamination
Lake Wojnowo	0–7.8 m—fine detritus gyttja, homogenous, dark olive at the top and brown at the bottom
Lake Jędzelek	0.01–0.52 m—sedge peat, dark brown 0.52–6.0 m—detritus gyttja, grey, with fragments of mollusc shells in the bottom and with sand in the upper section

Only the upper part of profiles which are the subject of this paper are described

Materials and methods

Pollen analysis

In Lake Miłkowskie twin sediment cores up to 24.59 m long were acquired from a floating platform by means of Więckowski's piston-corer from its deepest part (15 m deep; Wacnik et al. 2012). The upper 7.8 m of the profile is presented in this paper.

The sediment from Lake Wojnowo was collected from the ice cover in the northern lake deep (11.7 m deep) by means of Więckowski's piston-corer (Fig. 3b). A profile 18.7 m long was taken from the two holes, from which core sections of 2 m were taken alternately with 20 cm overlap. The upper 7.8 m of the profile is presented in this paper. From a mire around Lake Jędzelek a profile of 6.0 m length was taken with a Russian sampler (Table 1).

Pollen samples of 1 cm³ were taken and prepared by Erdtman's acetolysis method. They were preliminarily treated with HCl and HF in order to remove carbonate and silica, and then boiled with KOH (Berglund and Ralska-Jasiewiczowa 1986). Tablets containing *Lycopodium* spores were used to calculate the microcharcoal concentration (Stockmarr 1971). Counting of sporomorphs was continued until a number of at least 700 grains of trees and shrubs was identified in each sample.

For taxonomical identification, pollen keys and atlases (Beug 2004; Reille 1995, 1998), together with a reference collection of modern pollen slides were used. In the profiles from Lakes Miłkowskie and Wojnowo charcoal microfragments (10–100 μm and >100 μm) were counted in parallel with pollen.

The results are presented as percentage pollen diagrams drawn with POLPAL for Windows (Nalepka and Walanus 2003). Percentages were calculated from the total sum, which included trees, shrubs and herbaceous plants

(AP + NAP = 100 %), but excluded sporomorphs of aquatic and bog taxa as well as cryptogams.

The pollen diagrams were divided into local pollen assemblage zones (L PAZ) and subzones (L PASZ) using ConSLink numerical analyses (Nalepka and Walanus 2003). The palynological results from Lakes Miłkowskie and Wojnowo profiles were plotted on the calibrated BC/AD time scale, while from Lake Jędzelek they were plotted on a metrical scale because only one single radiocarbon date was obtained from this site.

Plant macroremains

Soil samples (0.5–60 l) were collected from each layer of defined origin in every feature and then handled by a flotation method with the use of sieves of 0.5 mm mesh size. Plant material containing seeds, fruits and charcoal was studied with a binocular microscope at magnifications of 6× to 70× and with a metallurgical microscope at magnifications of 50× to 500×. Identification was with the help of the reference collections of the W. Szafer Institute of Botany, Polish Academy of Sciences, in Kraków.

Seeds and fruits were studied in 80 samples collected from 39 archaeological features (pits) in the settlement at Paprotki Kolonia (site 41), and 388 samples from 186 cremation graves (urn and pit graves), a funeral pyre and offering pits with horse skeletons discovered at the cemetery at Paprotki Kolonia (site 1).

Charcoal was analysed in 32 samples taken from site 41 and 288 samples from site 1. A total number of 1,297 charcoal particles from the settlement and 6,527 from the cemetery were identified. In approximately one-third of the samples from the settlement, and in about half of the samples taken from graves, there were no seeds and fruits; the majority of the empty samples were of small volume. The sampling methods, especially in respect of sample volume, were changed over time. At the early stage of the study samples of less than one litre were analysed, while at the final stage, when the excavations were conducted at the cemetery, samples up to 60 l were floated and sieved.

The charred carpological data from all samples collected in the settlement at Paprotki Kolonia and at the cemetery are given in Table 2. The data from the settlement are divided into two chronological periods, most of them (22 features) are dated to the Roman Iron Age and only 3 features to the late Migration Period. All data from the cemetery are given without division into chronological periods as most of the graves have inexact chronology covering the whole period of the cemetery's existence (from the late pre Roman Iron Age to the late Migration Period; Karczewski 2011). As the volume of samples varied, the frequency (= ubiquity) of the remains in archaeological features seemed to be the most valuable

Table 2 Results of carpological studies

Archaeological site		PK41	PK41	PK41	PK1	PK1	PK1
Vol (l)		39			187		
No. of samples		80		25 (=100%)	388		109 (=100%)
		No. (n)	Features	Frequency	No. (n)	Features	Frequency
Cultivated plants							
<i>Avena</i> sp.	a	1	1	4			
cf. <i>Avena</i> sp.	s/f	2	2	8			
<i>Hordeum vulgare</i> (hulled)	s/f	7	3	12	17	6	5.5
cf. <i>Hordeum vulgare</i>	s/f	2	2	8	4	3	2.8
<i>Hordeum/Secale</i>	r	2	2	8			
<i>Secale cereale</i>	s/f	11	3	12			
<i>Triticum</i> cf. <i>dicoccum</i>	s/f				5	4	3.7
<i>T.</i> cf. <i>monococcum/dicoccum</i>	s/f				1	1	0.9
<i>Triticum</i> sp. and cf.	s/f	8	2	8	112	37	33.9
<i>T.</i> cf. <i>monococcum</i>	gb	1	1	4			
<i>T. spelta</i>	gb	1	1	4			
<i>Triticum</i> sp.	gb	7	4	16			
<i>Triticum</i> sp.	sb	6	2	8			
cf. <i>Triticum</i> sp.	r				1	1	0.9
Cerealina indet.	s/f	42	7	28	108	58	53.2
cf. Cerealina	s/f	3	3	12	13	12	11
<i>Panicum miliaceum</i>	s/f	2	2	8	1	1	0.9
Others							
<i>Arrhenatherum elatius/Phleum pratense</i>	ot				39	24	22
cf. Asteraceae indet.	s/f				1	1	0.9
cf. <i>Bromus</i> sp.	s/f	1	1	4			
<i>Carex</i> sp.	s/f				1	1	0.9
<i>Chenopodium</i> sp.	s/f	16	7	28			
<i>Chenopodium t. album</i>	s/f	43	11	44	49	27	24.8
<i>Corylus avellana</i>	s/f				1	1	0.9
Cyperaceae indet. and cf.	s/f	2	2	8			
<i>Digitaria</i> sp. and cf.	s/f				34	15	13.8
<i>Echinochloa crus-galli</i>	s/f				7	6	5.5
Fabaceae indet.	s/f				2	2	1.8
<i>Fallopia convolvulus</i> and cf.	s/f	7	5	20	7	5	4.6
<i>Fragaria/Potentilla</i>	s/f				2	2	1.8
<i>Galium spurium</i>	s/f	1	1	4			
<i>Galium</i> sp.	s/f	2	1	4	3	3	2.8
<i>Galium/Veronica hederifolia</i>	s/f				1	1	0.9
<i>Lithospermum arvense</i>	s/f	2	2	8			
<i>Mentha</i> sp.	s/f				1	1	0.9
Panicoidae and cf.	s/f	3	3	12	42	16	14.7
<i>Plantago lanceolata</i>	s/f				4	4	3.7
cf. <i>Poa annua</i>	s/f	1	1	4			
Poaceae (small grained)	s/f	16	6	24			
cf. Poaceae (small grained)	s/f	2	2	8	6	5	4.6
Poaceae indet.	s/f	2	2	8	9	8	7.3
<i>Polygonum aviculare</i>	s/f				4	4	3.7
<i>P. lapathifolium/persicaria/minus</i>	s/f	11	7	28	5	5	4.6
<i>Polygonum</i> sp.	s/f	1	1	4			
Polygonaceae indet.	s/f	1	1	4	1	1	0.9
cf. <i>Potentilla</i> sp.	s/f	1	1	4			
<i>Ranunculus</i> cf. <i>acris</i>	s/f				1	1	0.9
cf. Rubiaceae	s/f	2	2	8			
<i>Rumex acetosella</i>	s/f	1	1	4	4	2	1.8
<i>Scleranthus annuus</i>	s/f				37	4	3.7
<i>Setaria viridis</i>	s/f				189	27	24.8
cf. <i>Setaria</i> sp.	s/f				6	6	5.5
<i>Stellaria</i> sp.	s/f				1	1	0.9
<i>Trifolium</i> sp. and cf.	s/f				4	2	1.8
<i>Viscum album</i>	s/f				1	1	0.9
Indet.		38	15	60	236	91	83.5
Indet. buds	ot				21	10	9.2

PK41 Paprotki Kolonia site no. 41, PK1 Paprotki Kolonia site no. 1

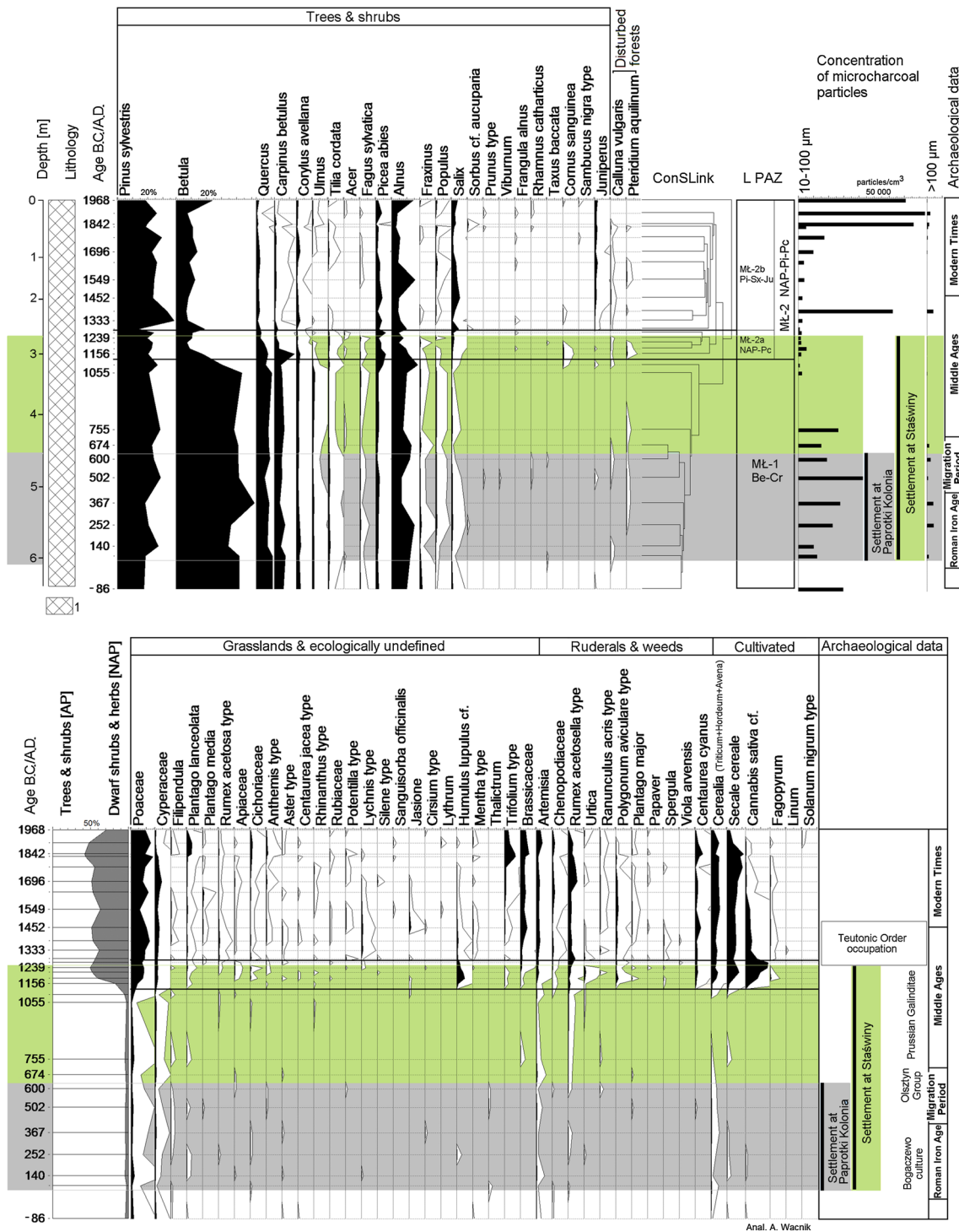


Fig. 4 The top part of the percentage pollen diagram from Lake Miłkowskie presenting changes of vegetation in relation to the local settlement history from ca. 86 years BC to about the 20th century AD (selected taxa). 1 detritus gyttja. For explanation of abbreviations see Fig. 7

factor in judging the importance of a taxon. In that calculation archaeological features that contained plant macroremains (seeds/fruits/chaff) were taken as 100 % (site 41, n = 25; site 1, n = 109). Only the charred plant remains were subjected to further studies and interpretation because

some uncharred (neither waterlogged nor mineralized) remains were most probably recent contamination, which is common in dry sites. Plant nomenclature follows “Flowering Plants and Pteridophytes of Poland. A checklist” (Mirek et al. 2002).

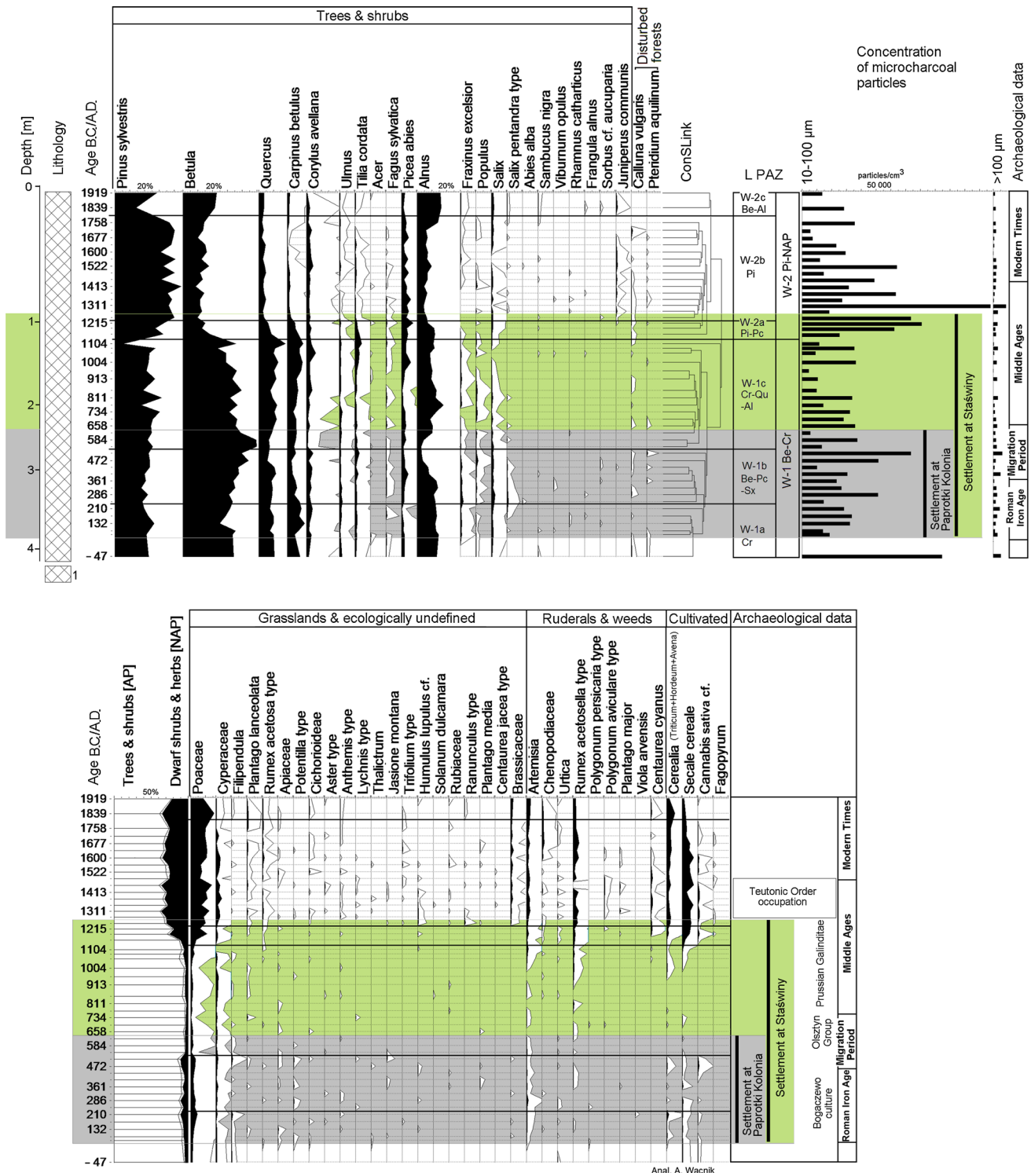


Fig. 5 The top part of the percentage pollen diagram from Lake Wojnowo presenting changes of vegetation in relation to the local settlement history from ca. 47 years BC to about the 20th century AD (selected taxa). *I* detritus gytja. For explanation of abbreviations see Fig. 7

Chronology

The chronology of pollen profiles from Lakes Miłkowskie and Wojnowo is based on AMS radiocarbon dating done in

the Poznań Radiocarbon Laboratory (ESM Table 1), and the age-depth models constructed by means of the “free-shape” algorithm, developed by Goslar et al. 2009 (see also Wacnik et al. 2012). The striking similarity of the pollen

records in Lake Jędzelek and in the above sites permitted the obtaining of a credible timescale for this profile despite having only one radiocarbon date. The dating of archaeobotanical samples is based on archaeological data (Karczewski 2011).

Results

Pollen analyses

The pollen sequences from Lakes Miłkowskie (Fig. 4; ESM Table 2), Wojnowo (Fig. 5; ESM Table 3) and Jędzelek (Fig. 6; ESM Table 4), obtained within a radius of 1–12 km from the Paprotki Kolonia and the Staświny archaeological sites, reflect a history of vegetation strongly influenced by the local human societies. A comparison of the pollen diagrams shows a great similarity in changes of the taxonomic composition of woodlands, confirming the reference character of the palynological data for the whole microregion. Furthermore, a good correlation between phases of intensified anthropogenic transformation of the vegetation indicated in the pollen diagrams and periods of archaeologically confirmed settlement activity was also revealed (Fig. 7). There are also several distinguishing features registered in the pollen sequences as a consequence of, for example, varied size of basins and distribution of the settlement. One of them was the sharp reduction of *Betula*, *Carpinus*, and *Quercus* parallel to the increase of *Pinus* and herb representation in the Lake Jędzelek record between AD 100 and 300, not so clear in the other diagrams.

Palynological data revealed that at the beginning of the first millennium AD, when the settlements of the Bogaczewo culture began to develop, the whole area was still strongly forested. Hills covered with rather dry soils formed from loam or loamy sands were most probably overgrown with mixed forests consisting mainly of *Pinus sylvestris*, *Betula*, *Quercus* and *Picea abies*. In the vicinity of Paprotki Kolonia the habitats suitable for pine woods occurred especially on the moraine hills covered with loamy sandy soils and with a low ground water level, occurring also for example on the western fringes of the settlement microregion and to the north of Lake Jędzelek.

Brown soils were partly grown over with deciduous forests, similar to the present-day Tilio-Carpinetum composed of *Quercus* (*Q. robur*), *Tilia cordata*, *Carpinus betulus*, *Acer* (*A. platanoides*) and *Ulmus* (*U. scabra*), locally with a small admixture of *Betula* (*B. pendula*) and *Picea abies*. The undergrowth of such communities consisted mainly of *Corylus avellana* and sporadically *Rhamnus catharticus*, *Viburnum*, *Frangula alnus*, *Cornus sanguinea* and *Sambucus nigra*. *Juniperus communis* grew

in cleared, grazed forests with *Calluna vulgaris* and *Pteridium aquilinum*. On acid brown soils woods similar to the present-day Potentillo albae-Quercetum (Matuszkiewicz 2002) could have been formed as a result of the anthropogenic transformation of poorer stands by extensive animal grazing. The moderate forest grazing could have resulted in a sustainable production of herbage and browse in the understory, supporting the maintenance of livestock. Cleared woodland also provided a larger amount of fodder for wild game. Wet alderwoods (of the modern Carici elongatae-Alnetum-type), spread on periodically flooded and low lying spots without an outlet, around the lakes and along watercourses. In such areas habitats with *Fraxinus*, *Alnus*, *Ulmus*, *Betula* and *Salix*, developed, having *Frangula alnus*, *Rhamnus catharticus*, *Cornus sanguinea* and *Sorbus* cf. *aucuparia* in the undergrowth. Some wet depressions and surfaces along lake shores and water courses were overgrown by swamp woods similar to *Betula pubescens*-*Thelypteris palustris* composed of *Betula pubescens* with an admixture of *Pinus*, *Alnus* and *Picea* (e.g. Matuszkiewicz 2008b). The most characteristic feature of this period was a common presence of secondary communities dominated by *Betula* with a small admixture of *Populus* (probably *P. tremula*) in the vicinity of palynological sites. Woodland clearings, dated to the Roman Iron Age and the Migration Period were registered in the pollen record from all analysed profiles, but especially well in those from Lakes Wojnowo and Jędzelek (Figs. 6, 7). Farmers did not create extensive woodless areas. However, considering the possibility that the occurrence of herbs, particularly of cultivation indicators, could be masked by wind pollinated trees (overrepresented in the pollen rain), we may suppose that meadows and fields were the permanent, though not the dominant element of the local landscape. Vegetation changes related to the activity of the Bogaczewo culture populations were characterized by increased diversity of herbaceous plants. Among the cultivated plants Cerealia (*Triticum*-type, *Hordeum*-type, *Avena*-type, *Secale cereale*) and most probably *Cannabis sativa* were recorded. According to the pollen data alone the cultivation of *S. cereale* and *Triticum* had greater significance, while *Hordeum*, *Avena*, and probably *Cannabis sativa* were grown on a smaller scale. However, this conclusion was modified on the basis of carpological finds from Paprotki Kolonia (see below). The first pollen grains of *Centaurea cyanus* were registered around AD 500 while its continuous presence started from AD 1100. The curve of *C. cyanus* corresponds with that of *S. cereale* and Cerealia.

Carpological analyses

The archaeobotanical data showed that the inhabitants of Paprotki Kolonia cultivated several crops known in the

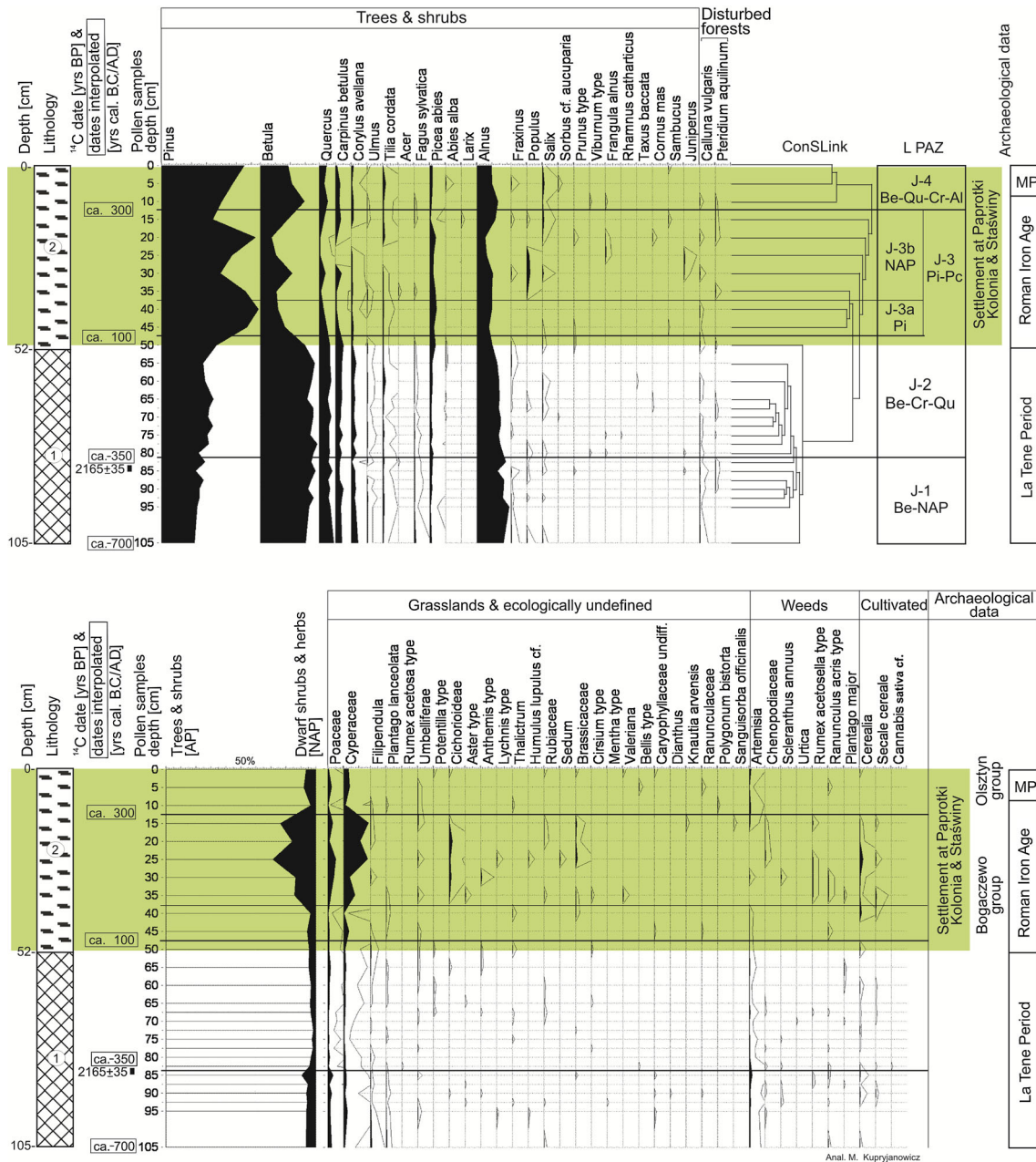


Fig. 6 The top part of the percentage pollen diagram from Lake Jędzelek presenting changes of vegetation in relation to the local settlement history from ca. 700 years BC to about the 4th–5th century

AD (selected taxa). Lithology: 1 detritus-clay gyttja, 2 sedge peat, MP Migration Period. For explanation of abbreviations see Fig. 7

Roman Iron Age and Migration Period (Table 2, Fig. 10). The most common cereals were *S. cereale* (rye) and *Hordeum vulgare* (hulled barley) but glume wheats like *Triticum spelta* (spelt), and probably *T. cf. monococcum* and *T. cf. dicoccum* (einkorn and emmer) as well as *Avena* sp. (oats, cultivated or wild) and *Panicum miliaceum* (millet) were also present. Chaff remains of glume wheats were found only in the settlement. Most of the grains found in the settlement and in the cemetery could only be

identified as *Cerealia* indet. as the material was poorly preserved.

On the basis of carpological material we can compare the set of taxa obtained from the settlement (site PK41) with that from cremation graves (PK1, Table 2). In both cases cereal grains, *Chenopodium album*-type and *Chenopodium* sp. (goosefoot) seeds are very frequent but we can see some differences in the composition of the identified crops. *Triticum* sp. is more common in the graves than in

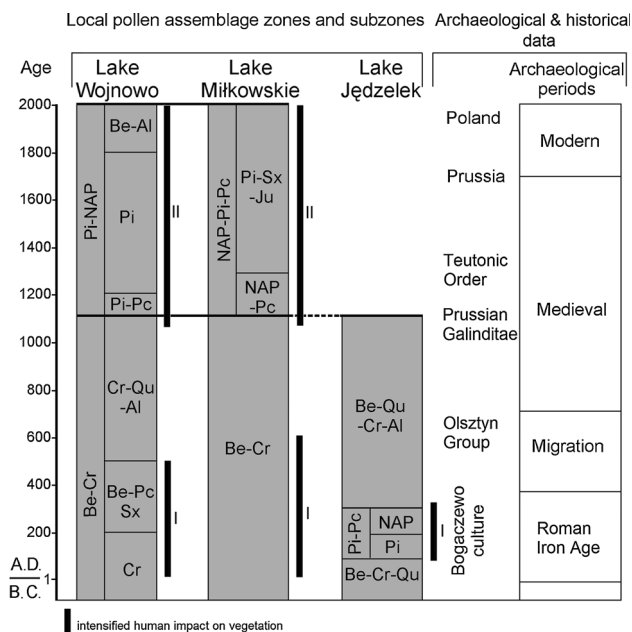


Fig. 7 Correlation of the local pollen assemblage zones (L PAZ) and subzones (L PASZ) from the studied sites. Al—*Alnus*, Be—*Betula*, Cr—*Carpinus*, Ju—*Juniperus*, NAP—herbs, Pc—*Picea*, Pi—*Pinus*, Qu—*Quercus*, Sx—*Salix*

the settlement, in contrast to *Hordeum vulgare* which is more frequent in the settlement. *Secale cereale*, probably cf. *Avena* sp., and cereal chaff were found only in the settlement. Also diaspores of *Chenopodium* and *Polygonum* spp. (knotgrass), with the exception of *P. aviculare*, *Fallopia convolvulus* (black bindweed) and Poaceae indet. (small grained grasses), were more frequent in the samples from the settlement. In contrast, in the cremation graves tubers of *Phleum pratense* or *Arrhenatherum elatius* ssp. *bulbosum*, grains of *Setaria viridis* and *S. cf. viridis* (green foxtail), *Digitaria* sp. and cf. *Digitaria* sp. (finger-grass) as well as other Panicoidae (including cf. *Setaria*, cf. *Echinochloa crus-galli*) are very common. Grass tubers and grains of *S. viridis* are absent in the settlement but this could result from the much lower number of samples/smaller amount of sediment taken from this site. Also diaspores of some grassland species as *Scleranthus annuus* (very abundant in one sample from grave no. 463), *Plantago lanceolata*, *Trifolium* sp., *Fragaria/Potentilla* and *Ranunculus* cf. *acris* were found only in the cemetery samples. In one grave also one seed of mistletoe (*Viscum album*) was found.

Anthracological analyses

Taxonomical determination of charcoals recovered from the deposits of the settlement at Paprotki Kolonia, site 41, revealed the presence of 12 tree and shrub taxa: *Alnus*, *Fraxinus excelsior*, *Betula*, *Carpinus betulus*, *Corylus*

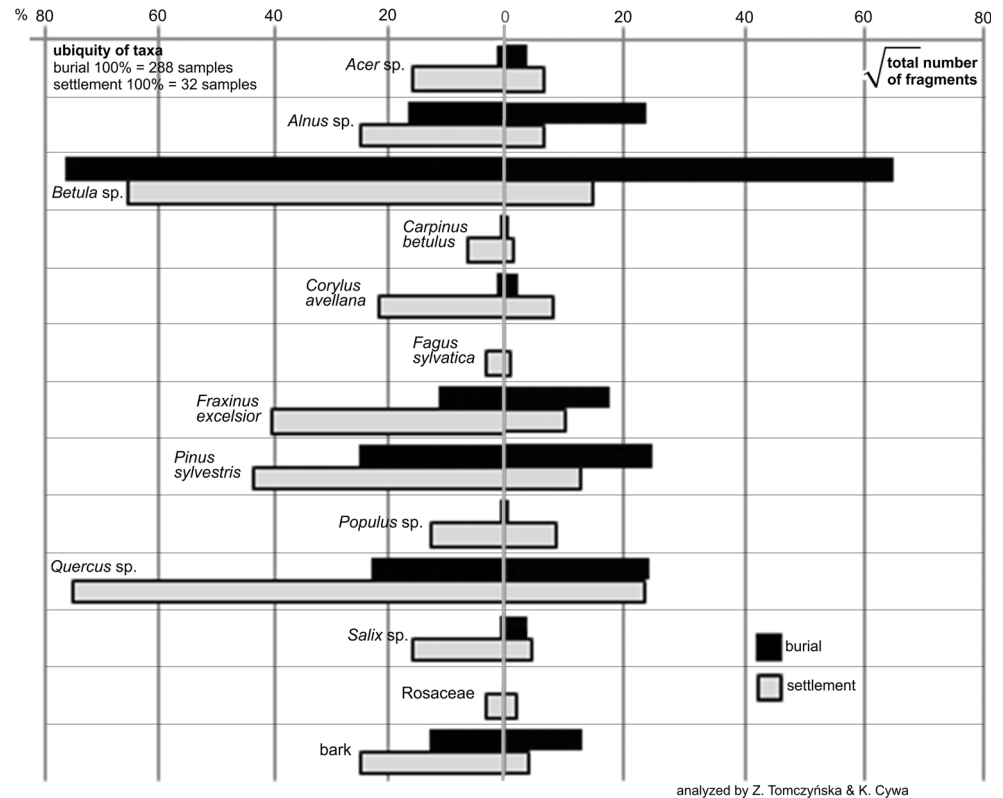
avellana, *Acer*, *Quercus*, *Pinus sylvestris*, *Populus*, *Salix*, Rosaceae and *Fagus sylvatica*. In the samples from the cemetery at Paprotki Kolonia site 1 all above mentioned taxa, with the exception of *Fagus*, were also found (Fig. 8).

Betula wood was a main component of charcoal collected from the cemetery (64 %), while *Quercus* was the most numerous in samples from the settlement (42 %). Charcoal of *Betula* was the only wood charcoal present in 108 graves, and in another 44 graves *Betula* was a strongly dominant component in relation to the other taxa. In the samples from the settlement *Betula* charcoal reached only 17 % in total. In this site *Betula* never was the only component of charcoal samples and rarely predominated numerically, instead relatively numerous were pieces of *Pinus* (8 %), *Fraxinus* (8 %), *Corylus* (5 %), *Populus* (6 %), *Salix* (2 %) and *Acer* (3 %). In the samples from the cemetery *Pinus* (9 %), *Quercus* (9 %) and *Alnus* (9 %) were relatively numerous, while *Corylus*, *Populus*, *Salix* and *Acer* together reached c. 0.6 %. An interesting phenomenon was the presence of a single *Fagus* charcoal particle found in a sample from the settlement because the site is situated beyond the present-day range limit of this tree in Poland.

The analysis of taxa frequency in the examined samples (Figs. 8, 9) showed that in the materials from the settlement most often *Quercus* and *Betula* (in more than 60 % of the samples) occurred as well as *Fraxinus* and *Pinus* (in approximately 40 %). *Corylus* and *Alnus* frequency reached slightly more than 20 %. In the samples from the cemetery *Betula* most often appeared, recorded in almost 80 % of samples, while the presence of *Quercus* and *Pinus* was observed only in about 25 % of the samples.

The taxonomical composition of charcoal in the samples from different chronological periods was compared separately for both archaeological sites (Figs. 8, 9). In the samples from the burial ground relating to the early Roman Iron Age the domination of *Betula* (71 % particles) was recorded, with a relatively high proportion of *Alnus* (9 %) *Fraxinus* (8 %) and *Quercus* (7 %), and a small admixture of *Pinus* (3 %). In the graves from the late Roman Iron Age the predominance of *Betula* (88 %) and high percentages of *Alnus* (12 %) fragments were maintained. In the late phase of the Migration Period *Betula* (14 %) and *Alnus* (8 %) were still present in the charcoal spectrum, but a significant increase was shown by *Pinus* (75 %) and *Populus* (2 %). In the material from the settlement, in the consecutive chronological periods, a numerical predominance of *Quercus* and the presence of numerous *Betula* among the charcoal fragments were always observed. Also in the early Roman Iron Age, *Fraxinus* (10 %), *Pinus* (9 %) and *Acer* (5 %), and in the late Roman Iron Age *Populus* (20 %), *Corylus* (15 %) and *Alnus* (8 %) were recorded. In the late phase of the Migration Period a

Fig. 8 Ubiquity and the square root of the number of charcoal fragments of individual taxa from Paprotki Kolonia sites 1 and 41



significant increase of *Pinus* (25 %) and *Salix* (14 %) was registered.

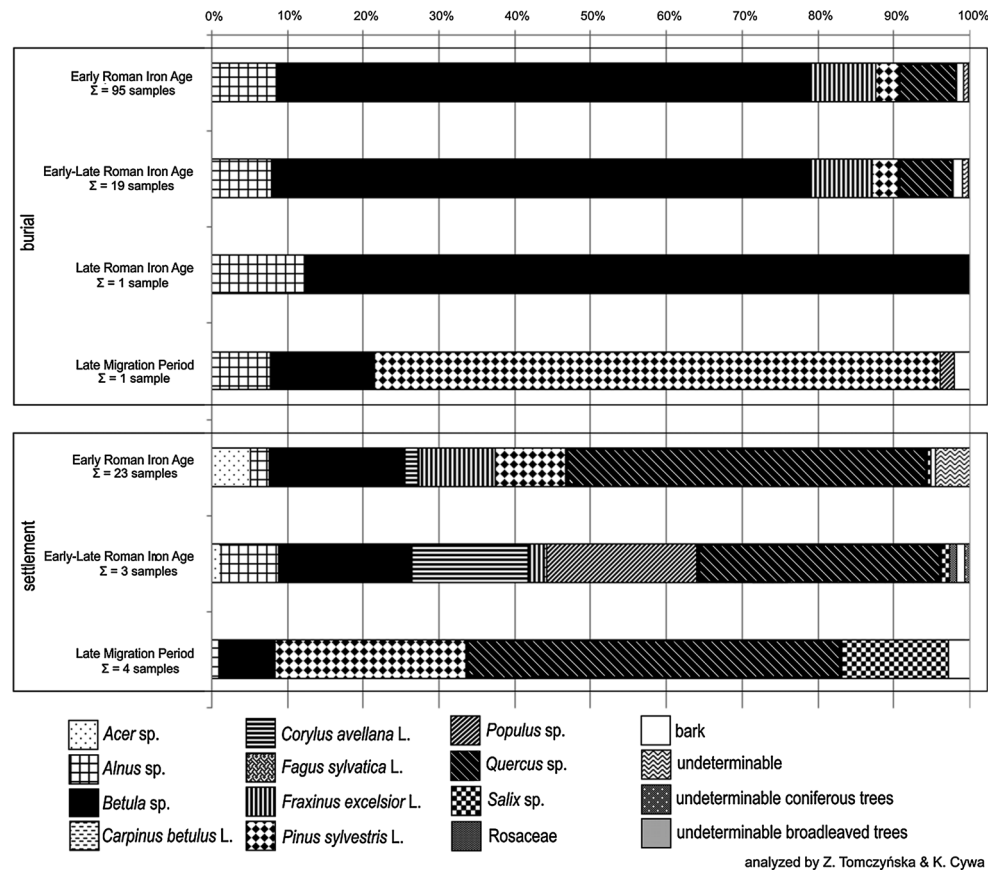
Discussion

Changes in woodland communities in the context of land use history

The palynological record confirmed the common occurrence of birch-dominated woodlands in the Miłki-Staświny area between 1200 BC and AD 1100. This phenomenon was clearly of local character, as observed also in a few late Holocene sections of the pollen diagrams from northern Poland, but however of a different date (e.g. Pawlikowski et al. 1982; Madeja et al. 2010; Wacnik et al. 2012; Karpńska-Kończak et al. 2013; Szal et al. 2013). In our opinion the expansion of *Betula* in the studied region (accompanied by the increase of anthropogenic indicators) did not result exclusively from the increase in area of swamp woods similar to *Betula pubescens-Thelypteris palustris* naturally growing around the lakes and in wet depressions, but was rather the effect of enlargement of the secondary *Betula*-dominated woods in the area. According to Hynynen et al. (2010) *Betula* grows vigorously only as a dominant tree in a stand with relatively wide spacing and a low degree of within-stand competition. For this reason *Betula* expansion can be treated as an indicator of severe

destruction of previous woodlands (Faliński 1997). Based on observations carried out in Białowieża Forest in north-eastern Poland *Betula* was among the first pioneer trees overgrowing abandoned fields after the cessation of cultivation (e.g. Adamowski and Bomanowska 2011). The existence of cleared areas during the Roman Iron Age and Migration Period is confirmed for example by a higher representation of herbs, illustrated in the pollen record from Lakes Wojnowo and Jędzelek (Figs. 5, 6). In the sediments from Lake Wojnowo the rise of *Betula* representation was also accompanied by the increase of microcharcoal concentrations at c. 100–550 BC while extensive changes of local woods were noted at ca. AD 450–600. Similar phenomena were observed also in Lake Miłkowskie (Fig. 4) where a clear increase in charcoal concentration as well as changes of woodland communities were stronger at ca. AD 150–650. Later, the decreased frequency of human impact indicators suggests a less active Prussian population. Vegetative regeneration with sprouting is a natural characteristic of birch. Exposing mineral soils through burning has a strongly positive influence on *Betula* regeneration (Cameron 1996). Evans (1984) found in his study that soils exposed for 2–3 years after fire are ideal places for natural *Betula* regeneration. Long-lasting existence of *Betula* woods suggests that systematic clearance of the same areas prevented the development of further stages of woodland succession. In this context it seems possible to connect the regular presence of cereal pollen and increased charcoal

Fig. 9 Percentages of charcoal fragments of individual taxa in the total number of samples from different chronological periods



microparticle concentration in lake deposits (also particles over 100 µm indicating local intentional use of fire or accidental conflagrations) in the period of high *Betula* pollen representation (observed especially in Lakes Miłkowskie and Wojnowo) with fire use in land cultivation methods. This type of agriculture persisted in Northern Europe until the 20th century AD (e.g. Hamilton 1997; Jääts et al. 2010).

In slash-and-burn agriculture small plots were regularly chosen for fire cultivation. It started with the removal of natural vegetation by clearing and burning. Due to this process nutrients stored in the plant biomass were released and became available for crop uptake. Burning was also credited with increasing the pH of soils (Viro 1974). Fields were cultivated for a short time and when the crop yields decreased as a result of increased weed pressure, degradation of soil and the lowering of its fertility, they were temporarily abandoned and new areas were cleared. In the fallow phase once-cultivated plots were overgrown by secondary forests (Kleinman et al. 1995; Jääts et al. 2010). According to historical sources from Estonia these forest types were composed of *Betula*, *Alnus incana* and *Picea* (Jääts et al. 2010). Also at present, in Estonia almost all abandoned fields are overgrown by *Betula pubescens* or *Alnus incana* (Saarse et al. 2010). Recent observations of

communities representing a short-lasting pre-forest stage of succession in poor habitats that also occur in the Mazurian Lake District showed the domination of *Betula pendula* and significant participation of *Populus tremula* in their composition (Wojcik 1991; Młynkowiak and Kutyna 2009).

The length of fallow was different. Jääts et al. (2010) when describing one of the fire cultivation methods used in later centuries in Estonia (up to the 20th century), suggested the re-use of the same plots after 20–60 years. Hamilton (1997) described shifting agriculture from southern Sweden with a 20–30 year rotation cycle but also mentioned that most of the slash-and-burn cultivations operated on a 3–4 year cycle. Experimental observation by Rösch et al. (2004) drew attention to the fact that the slash-and-burn system depends on the availability of wood used as fuel to burn the forested ground. In this respect rotation cycles could not be short.

We believe that the development of fast growing birch thickets reflected in the pollen record (especially from Lakes Wojnowo and Miłkowskie) might have been related to the use of such practices in the area of our interest (Figs. 5, 6). The extensive exploitation of *Betula* wood by local inhabitants in the Paprotki Kolonia area was confirmed by exceptionally frequent charcoal macroparticles

of *Betula* found on archaeological sites and by the reduction of *Betula* pollen evident in the record from nearby Lake Jędzelek (AD 100–300, Fig. 6).

The main source of *Betula* timber could have been the drying out of parts of mires as well as secondary brushwood communities dominated by *Betula*, which developed on the abandoned fields used probably in the shifting agriculture system.

The taxonomical analysis of wood exploited by the population of the Bogaczewo culture at Paprotki Kolonia confirmed the use of taxa accessible in local forests (with the exception of *Fagus*) (Figs. 8, 9). The analysis of *Fagus* pollen concentration from the Lake Miłkowskie sediment revealed that beech did not grow in the local forests (Wacnik et al. 2012). In this context we suspect that the occurrence of a single fragment of *Fagus* wood in the settlement could have been a result of its import and use for example as part of a tool. The exploitation of local wood resources could have caused a significant decrease of *Quercus*, *Betula*, *Fraxinus*, *Alnus* and *Corylus* representation in woodland communities. We can suppose that in the Paprotki Kolonia and Staświny areas all types of forests were exploited, including secondary woods with *Betula* and locally also *Alnus* woods.

The greatest reduction of *Alnus* abundance occurred between the third and seventh centuries AD and was spatially asynchronous (Figs. 5, 6, 7). Reduction of *Alnus* populations could have resulted from forest clearings in the marginal lake zones caused by local settlers but the climatic factor cannot be excluded (e.g. Larsen et al. 2008; Saarse et al. 2010). The analogous phenomenon was observed in other pollen records from NE Poland (Madeja 2013; Noryskiewicz 2013) as well as across the whole of the northern Baltic countries during the Late Iron Age (between AD 900 and 1000), where anthropogenic factors were suggested as the dominant cause (Saarse et al. 2010).

Well-developed agriculture in the Roman Iron Age and Migration Period is documented by carpological finds from Paprotki Kolonia, which suggested *Hordeum vulgare* and *Secale cereale* as the most common crops. The high representation of *Secale* in the settlement indicates that poor soils were farmed at that time. On the other hand numerous grains of *Triticum* spp. found in the cemetery suggest its higher value for the settlers. Among the cultivated plants *Avena* sp., *Panicum miliaceum* and probably *Cannabis sativa* were also grown on a smaller scale. Similar results were reported from Wyszembork, another archaeobotanical site from the Mazurian Lake District (comp. Lityńska-Zajac 1997). Because of the low number of plant macroremains preserved on sites from this region it is very difficult to present reliable information about cultivation structures. However, according to Lityńska-Zajac (1997, 2005) the introduction of ploughing in the Roman Iron Age

initiated a gradual formation of more specialized agrophytocenoses.

In the pollen record segetal and ruderal taxa were represented by *Artemisia*, Chenopodiaceae, *Urtica*, *Polygonum persicaria*-type, *Rumex acetosella*-type and *Viola arvensis*. Interesting was the early occurrence (ca. AD 500) of *Centaurea cyanus*, a weed of winter crops usually connected with rye cultivation (e.g. Bakels 2012). Fruits of *C. cyanus* were found at Wyszembork in features of similar age as Paprotki Kolonia (Lityńska-Zajac 1997, 2005). According to Bakels (2012) analyzing the appearance of *C. cyanus* in the Netherlands and Germany, “if cornflower was present before the High Middle Ages it was still rare”. Observations made for the Polish territory confirmed the low number of fruit remains as well as pollen dated to the Roman Iron Age and their increase in the early Medieval Period (Makohonienko 2000; Lityńska-Zajac 2005). Representation of taxa, related mostly to grassland communities, such as Poaceae, *Potentilla*-type, *Anthemis*-type, *Plantago lanceolata*, *P. media*, *Jasione montana*, *Trifolium*, *Campanula* and *Rumex acetosa*-type was also slightly higher.

The composition of wild growing plants found in the settlement at Paprotki Kolonia, with the domination of diaspores of field weeds and ruderals growing on fertile soils and having fruits/seeds edible and resistant to decay (*Chenopodium album* and *Ch. sp.*, *Polygonum lapathifolium/persicaria/minus* and *Fallopia convolvulus*), is quite typical for this type of context. The relatively abundant and frequent grains of Poaceae indet. can indicate the presence of some remnants of animal fodder or other uses of hay (for example insulation).

The traces of economic settlement activities registered in the pollen diagrams decline about AD 650–1000, though the occupation of the Staświny area continued (Karczewska and Karczewski 2007). We suppose that palynological observations reflect well the general reduction of population density in the Galindia territory around the sixth century AD suggested by archaeologists (Okulicz 1981; Karczewska et al. 2005). Cultivation indicators almost completely disappeared from the pollen rain between ca. AD 650 and AD 1100 while the regeneration of forests with *Quercus*, *Carpinus*, *Tilia* and *Alnus* was intensified (Figs. 5, 6).

From c. AD 1100 stronger and more persistent anthropogenic disturbances of the natural environment were initiated. Large scale deforestation resulted from stabilization of settlement and intensification of agriculture. In the Staświny area significant damage to woods in the late Medieval Period (it cannot be excluded that this type of activity was introduced earlier) was caused by local iron production, requiring a constant supply of large amounts of firewood. Such a type of local economic activity was

confirmed by the results of excavations at Staświny (site no. 73, Karczewski unpublished). It is also suggested by the earliest historical, medieval names of the villages Staświny and near-by Ruda, situated on the north shore of Lake Wojnowo, which were Eiserstuhl and Ruhden, both names connected with iron production (Karczewska et al. 2005). At the same time the representation of human indicators increased, including cultivated plants such as cereals (*Triticum*, *Avena*, *Hordeum*, *Secale*), *Fagopyrum* and *Cannabis*, as well as weeds such as e.g. *Centaurea cyanus* and *Polygonum aviculare*. *C. cyanus* became a very common crop weed which gained importance together with the enlargement of the arable fields and regular *Secale* cultivation in the Middle Ages (Behre 1992; Okuniewska-Nowaczyk et al. 2004). The expansion of *C. cyanus* was also observed in neighboring territories from ca. AD 1000–1100 (e.g. Niinemets and Saarse 2007; Stančikaitė et al. 2009; Bakels 2012; Groenman-Van Waateringe 2012). The progress in agrarian techniques (introduction of the plough coulter reinforced with iron together with the three-field system) and permanent fields allowed more efficient land cultivation. The great local differences reflected in the pollen spectra from the Great Mazurian Lake District emphasize the individual features of the vegetation in the surroundings of particular sites related to the varying intensity of settlement processes (cf. Wacnik et al. 2012; Kołaczek et al. 2013; Szal et al. 2013).

The phenomenon of the large scale early deforestation of the area of Lakes Miłkowskie and Wojnowo in the pre-Teutonic Order period was clearly of a local character (Wacnik et al. 2012). Analogous observations were recently made in the Lake Sałęt microregion (the Mrągowo Lake District; NE Poland; Szal et al. 2013) with a similar history of settlement.

Plant remains from the cremation graves of the Bogaczewo culture at Paprotki Kolonia

An interesting phenomenon is the use of *Triticum* grains in the cremation ceremonies. Probably pure wheat grain was used in the ceremonies (Table 2). The relatively high representation of wheat grains and the absence of rye commonly found in the settlement suggest the higher value of the former for the settlers (Kupryjanowicz et al. 2013).

The abundance and frequency of *Setaria viridis* grains seems interesting. That some of the grains belong to cultivated *S. italica* cannot be excluded, nevertheless the abundance of these grasses in the cemetery cannot be accidental. The number of their grains varied from 1 to 60 per grave. *S. viridis* is nowadays one of the most pernicious weeds, in Poland characteristic of the Panico-Setarion alliance (communities of weeds growing in mesotrophic, sandy and moderately moist soils). Its spikelets are also

green when ripe so the plant can be used for dry bouquets and decorations. This feature would be important in cremation ceremonies but it also cannot be excluded that the plant grew commonly in the area together with the other Panicoideae grasses and was frequently used as kindling. The precise identification of the grains was not possible because of their bad preservation but reliable exclusion of cultivated *S. italica* would help in better understanding their abundant occurrence in the cemetery. *S. italica* was fairly commonly found in Roman cremations in northern Italy (Rottoli and Castiglioni 2011) but in those studies of cemetery data, cereals and pulses are of little significance in contrast to fruit remains. Fruits known as luxury foods in Central Europe during the Roman period, for example *Olea* (olive), *Prunus dulcis* (almond), *Phoenix dactylifera* (date), *Pistacia vera* (pistachio), *Punica granatum* (pomegranate) and *Ficus carica* (fig), were also found in cremation graves in that time and area (Bakels and Jacomet 2003). The use of cereals, pulses and wild fruits in Roman cremations in central France could in part reflect ancient Iron Age practices there (Bouby and Marinval 2004).

The predomination of *Betula* in the samples from the cemetery in comparison to the settlement suggests intentional, selective use of its wood for construction of the funeral pyre (Figs. 8, 9). According to M. Moskal-del Hoyo (2012) the dominance of one or a few tree and shrub taxa in charcoal samples from a burial ground located in terrain with potentially very diverse vegetation, suggests the selection of material. At the same time, the availability of raw materials for pyre preparation can be the most essential factor in the selection of material (Figueiral et al. 2010). However, the ritual requirements or symbolic motives should be considered as a very important or even basic factor in timber selection. *Betula* wood could have been desirable for the funeral ceremony due to its properties. The duration of the cremation process depends mainly on the proper structure of a pyre (Cenzon-Salvayre and Durand 2011) and the quality of timber (Deforce and Haneca 2012). Unpeeled *Betula* wood, due to the content of betulin in the bark, burns quickly even in a fresh state, and achieves a high temperature (Website: Otwarta Encyklopedia Leśna, accessed 2014; Gale and Cutler 2000). Comparatively frequent occurrence of *Quercus*, *Pinus* and *Alnus* charcoals in the samples from the cemetery could also have resulted from the properties of their wood. *Quercus* wood enables a relatively high temperature to be reached during the long burning time of its logs. *Pinus* wood, due to its content of resinous substances, starts to burn relatively quickly (Karczewski 2011). During *Pinus* wood burning a specific aroma is exuded which can obscure the smell of the burning body (Moskal-del Hoyo 2012). A very intense scent is also produced by burning *Alnus* wood. The archaeological studies at Paprotki

Kolonia cemetery revealed that funeral pyres were burnt many times at the same place; hence they occupied small areas, strongly alkaline as a result of charcoal and ash accumulation. Fire from funeral pyres did not spread in the limited area of the cemetery and plant remains found in burial pits could come directly from the place of cremation as part of the pyre or from the nearest surroundings, being incidentally introduced into the pits. In our case we suggest that, apart from plant material used for pyre construction, most of the charred plant remains were deliberately selected and laid on a pyre because of their ritualistic significance (e.g. Petrucci-Bavaud et al. 2000).

The occurrence of grass tubers and other remains of grassland plants in the graves from the cemetery at Paprotki Kolonia in the Roman Iron Age and Migration Period

The appearance of tubers formerly identified as *Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl ssp. *bulbosum* (onion couch grass, bulbous oat grass) in cremation graves (Karczewski et al. 2009; Mueller-Bieniek 2012) is very interesting as similar tubers were also found in other sites in W and N Europe, dated to the Neolithic, Bronze and Iron Ages. A great part of these findings comes from cremation graves (Engelmark 1984; Robinson 1988, 1994; Viklund 2002; Preiss et al. 2005; Cooremans 2008; Jacomet and Brombacher 2009; Jensen et al. 2010; Roehrs et al. 2013). Their presence was explained or discussed in few ways but mainly as remnants of some kindling material or as a ritual plant (e.g. Kirleis et al. 2012). All species of *Arrhenatherum* often have basal internodes swollen and globose (Tutin et al. 2010) but only two of them grow in southern regions of Europe (*A. palaestinum* Boiss. and *A. albus* (Vahl) W. D. Clayton). *A. elatius* grows in most of Europe, in meadows and on roadsides, in some regions also as a weed (S. Jacomet personal communication), but it is absent from much of the north-east. The subspecies, which does not produce swollen internodes (ssp. *elatius*), grows throughout the range of the species while the bulbous subspecies (ssp. *bulbosum*), producing up to 8 swollen, globose basal internodes, grows mainly in S and W Europe (Tutin et al. 2010).

However, *Arrhenatherum* is not the only grass producing tubers. *Phleum pratense* L. (timothy grass), which grows in grasslands and is commonly cultivated for fodder, has two subspecies differing in chromosome numbers and in ligule, panicle and awn characters (Tutin et al. 2010). The ssp. *pratense*, which does not produce tubers, grows almost throughout the whole of Europe similarly to the tuber-producing ssp. *bertelonii* DC., which is rarer in the northern part of the species' European range (Tutin et al. 2010). According to Polish sources ssp. *bertelonii* (= ssp.

nodosum (L.) Trabut = *Ph. hubbardii* Honck.) grows in dry pastures and grasslands while the ssp. *pratense* is common in meadows and pastures, including moist ones (Rutkowski 2008). Nowadays *A. elatius* ssp. *bulbosum* seems to be absent in Poland (L. Frey, K. Zarzycki, W. Szymański personal communication; in the KRAM - Herbarium of the Institute of Botany PAS all specimens of *A. elatius* do not have tubers) which is in accordance with the general range of the subspecies. In the past it was probably also absent in the Mazurian Lake District, one of the coldest parts of Poland. According to Stankov and Taliev (1949) *Ph. pratense* L. (with no division to subspecies) has the lower parts of its stems swollen (Figs. 617, 1067 in Stankov and Taliev 1949). In all the area of the European part of the former USSR, it grows in meadows, forests (!), on hills and slopes and is a very good fodder plant. *A. elatius* grows in meadows and there is no information about subspecies and the presence of bulbs (Stankov and Taliev 1949: listed as *A. elatius* M. et K.). *A. elatius* is present in the NE of the European part of the former USSR, mostly as an introduced valuable fodder plant (Tolmachev 1974). *Phleum pratense* is represented there by both subspecies found in Poland. Ssp. *nodosum* is known there as a more southern but smaller type (up to 50 cm) and ssp. *pratense* as a more northern but larger plant (up to 120 cm) (Tolmachev 1974). According to the authors ssp. *nodosum* is more frequent in the steppe zone and in the Mediterranean while ssp. *pratense* is more common in the forest zone of Eurasia. As a valuable fodder plant *Ph. pratense* is cultivated even near the Arctic tree line (forest-tundra) (Tolmachev 1974). Until now no visible differences between the bulbs of the two species have been noted during studies of modern, artificially carbonized specimens. Nevertheless the subject needs more comprehensive studies including field botanical research and morphological and anatomical studies of tubers. As *A. elatius* is not resistant to severe climate and frosts (Nowiński 1950) and its bulbous form is absent (or at least very rare) in Poland, now we can suppose that the bulbs found in the graves from the cemetery in Paprotki Kolonia belong rather to *Ph. pratense*. The bulbous form of *Ph. pratense* grows mostly on poor, sandy soils, and doesn't create turf. Also it is not resistant to grazing. Hay from *Ph. pratense* is highly valuable fodder for horses (Czarnocki 1950).

Irrespective of the identification of grass bulbs from Paprotki Kolonia as belonging to *Ph. pratense* or *A. elatius* their presence in graves can be explained in a similar way (Fig. 10). They could have been growing on the spot and reached the pyre from their natural habitat by chance, indicating that the pyre was located on grassland, most probably not grazed, in rather dry, poor soil. This, however, is at variance with the archaeological information about the environmental conditions of pyre sites in Paprotki. The

Fig. 10 Paprotki Kolonia, charred plant macroremains; cemetery (site 1): 1 *Triticum* sp., a dorsal, b lateral; settlement (site 41): 2 *Hordeum vulgare*, a dorsal, b ventral, c lateral; 3 *Secale cereale*, a–c as above; 4 *Digitaria* sp., 5 *Scleranthus annuus*, 6 *Setaria viridis*, 7 *Plantago lanceolata*, 8 *Viscum album*, 9–12 grass tubers *Phleum pratense*/*Arrhenatherum elatius* ssp. *bulbosum*; scale bar 1 mm (Phot. K. Cywa)



more plausible explanation is that grass was purposely collected at some distance for ritual use during the funeral, a custom which was not strictly connected with a specific grass species but only with its ability to produce bulbs. On the other hand the presence of some other plants (i.e. *Plantago lanceolata*, *Trifolium* sp., *Scleranthus annuus*; Table 2; Fig. 10), whose charred remains were found in graves fairly frequently and sometimes in large quantities, confirms the possibility of an autochthonic origin of some plants growing in grasslands, also in poor soil. Nevertheless their occurrence can be also explained in other ways, for example as kindling, because the origins of wild plants in the graves can be variable.

Conclusions

Newly collected palaeobotanical data in the vicinity of the Paprotki Kolonia and Staświny settlement centres documented strong anthropogenic transformation of local vegetation in the last two millennia. In the palynological records two human impact phases were distinguished. The first one, dated to ca. AD 50 and AD 600/650, was attributed to the activity of the Bogaczewo culture and the Olsztyn Group. The role of agriculture in the local economy decreased in the Dark Age Cold Period from ca. AD 650, when cultivated fields were partly abandoned and reverted into woodland communities. The second phase of the

human impact was initiated in the Medieval Warm Period, ca. AD 1100 as a result of the activity of the Prussian Galindians, and has continued to the present day.

The palaeobotanical results are in good correlation with changes of the local settlement intensity confirmed by the archaeological finds. Archaeobotanical studies showed a leading role for *Secale cereale* and *Hordeum vulgare* (hulled) among cultivated crops in the Roman and the Migration Periods. Glume wheats, like *Triticum spelta*, and probably *T. cf. monococcum* and *T. cf. dicoccum* as well as *Avena* sp. (cultivated or wild), *Panicum miliaceum* and *Cannabis sativa* were grown but on smaller scale. The long existence of semi-natural *Betula* brushwood over vast areas was revealed and related to the systematic clearings of the same areas. The use of the burning cultivation method with a rather long rotational cycle, the re-use of the same plots, and the important role of secondary *Betula* woods in the slash-and-burn agriculture was suggested.

An intensive exploitation of woodlands in the Roman and the Migration Periods registered in the pollen records was strongly supported by the results of on-site anthracological investigations. Taxonomical determination of charcoals confirmed the economic use of twelve tree and shrub taxa accessible in the local forests (with exception of *Fagus*). Strong differences in the taxonomic composition of plant macroremains (both charcoal and fruits or seeds) obtained from the cemetery and the large settlement at Paprotki Kolonia illustrated a deliberate choice of the plant material.

A few interesting phenomena related to the funeral ceremonies in the Roman and Migration Periods were noted, such as:

- intentional, selective use of *Betula* wood for construction of the funeral pyre;
- the use of *Triticum* grains in the cremation ceremonies interpreted as a manifestation of its high value for settlers (as that crop was scarcely noticeable in the settlement);
- high representation of *Setaria viridis* grains in the cemetery possibly used intentionally for decorative or other purposes;
- the presence of tuberous internodes (bulbs, tubers) most probably of *Phleum pratense*, possibly used during funerals as a symbol of “prosperity and rebirth”; it must be underlined that the remains were formerly identified as tubers of *Arrhenatherum elatius* ssp. *bulbosum* but that plant was excluded on the basis of its present distribution in Europe and the present lack of the bulbous form of *A. elatius* in Poland.

The existence of extensive areas deforested in the pre-Teutonic Order period in the Great Mazurian Lake District has been demonstrated and interpreted as a local feature

characteristic of the Staświny-Miłki area and resulting from its settlement history. High representation of cereal pollen as well as crop weeds e.g. *Centaurea cyanus* suggests the existence of permanent fields and change in the agrarian technique during that time. It cannot be excluded that the reduced woodland area was partly connected with the metallurgical activity carried out at Ruda and Staświny from the Middle Ages onwards.

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