Trees and shrubs used in medieval Poland for making everyday objects

Katarzyna Cywa¹

Received: 5 December 2016 / Accepted: 27 September 2017 / Published online: 29 October 2017
© The Author(s) 2017. This article is an open access publication

Abstract

This article presents the results of the wood identification of 3,867 everyday objects dated from the 9th to the 15th century AD, which were excavated from 48 medieval strongholds and early urban centres in Poland. The analyses have shown that medieval craftsmen used the wood of 27 tree and shrub taxa. The timber used the most was *Pinus sylvestris* (pine), *Quercus* sp. (oak), *Fraxinus excelsior* (ash) and *Alnus* sp. (alder). Pine was used mainly to make vessels out of staves (curved pieces of wood) such as buckets and tubs, and for torches for lighting; oak was used for furniture, barrels, cart axles, spades and club hammers used by carpenters. Ash wood was the main material used for making turned bowls, and alder for making articles which were to be in long-lasting contact with water, such as beaters and scoops. Wood studies agree with historical records about the intensive use of yew wood, which finally caused the decrease of *Taxus baccata* in woodlands in the 14th and 15th centuries. Also, the wood of shrubs such as *Euonymus* sp. (spindle) and *Sambucus* sp. (elder) was quite often used. The choice of wood for the specific needs of a particular craft in medieval Poland was done selectively and it was determined by the particular function of the object being made, but at the same time it was limited by availability from the local woodlands. Regional differentiation in the selection of raw material is best indicated in the case of *Abies alba* (fir). Chronological analysis of the use of wood shows that the number of items made of timber from deciduous trees in all regions of Poland decreased in the late Middle Ages when compared to the Piast period of the early Middle Ages.

Keywords Wood anatomy · Ethnobotany · Wood qualities · Medieval crafts

Introduction

In medieval Europe, timber was both one of the most important and readily available raw materials which was used in various commercial fields and absolutely essential for making all kinds of items used in everyday life (Mączak 1981; Sönke 2000; Miśkiewicz 2010). This has been shown by archaeological excavations carried out on sites containing

well preserved organic material in, for instance, Novgorod, Russia (Brisbane and Hather 2007), Mikulčice, Czech Republic (Poláček et al. 2000) or in an early medieval cemetery in Oberflacht, Germany (Filzer 1992), where numerous everyday wooden objects were discovered. Similar evidence was also provided by archaeological investigations in Poland, such as at Ostrówek in Opole (Bukowska-Gedigowa and Gediga 1986) or Rynek Warzywny in Szczecin, where objects made of wood and bark formed the second most significant group of finds, after those made of leather (Kowalska and Dworaczek 2011).

The great diversity of functions and dimensions of everyday wooden objects which have been found in many medieval archaeological sites raises questions about the identification of the timber used. Recognising how various kinds of timber were used in medieval crafts is significant for understanding both the woodworking techniques and the management of woodlands by medieval societies. The selective use of some kinds of wood could result in changes to the taxonomic composition of woodlands.

Communicated by A. Salavert.

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s00334-017-0644-9>) contains supplementary material, which is available to authorized users.

✉ Katarzyna Cywa
k.cywa@botany.pl

¹ W. Szafer Institute of Botany Polish Academy of Sciences, Lubicz 46, 31-512, Kraków, Poland

So far, no detailed botanical analyses of medieval objects of everyday use have been carried out in Poland which have reviewed the results of wood anatomical investigations from either a few sites or whole regions. The available archaeological reports which describe the assemblages of wooden artefacts from Polish sites most often concentrate on the form and function of the objects and the type of woodworking techniques used (Dziekoński and Kóčka 1939; Rulewicz 1958; Wilgocki 1995; Earwood 2002/2003; Słowiński 2004). A few papers about the kinds of timber used for making wooden objects have a local character and are mostly published in Polish (Table 1).

The studies of wooden objects from the Mikulčice site in the Czech Republic (Poláček et al. 2000) or Žemutinė Pilijs (Lower Castle) in Vilnius (Pukienė 2008) are examples of botanical analyses of useful wood from central and eastern Europe. The taxonomic composition of medieval wood finds from western Europe has been well studied, for instance, from Charavines, France, Elisenhof and Haithabu, Germany (Müller 2008 and the literature cited) and Oberflacht, Germany (Filzer 1992).

The Middle Ages was the first historical epoch in Poland (Salamon and Waško 2000) and this was a time of intensive changes connected with, among other things, the transition from tribal societies to the beginnings of a state, the establishment of hundreds of early urban centres and the development of handicrafts. Archaeological sources make it possible to distinguish three chronological phases within the early Middle Ages in Poland which differ from each other by the degree of social development and organization of craft production (Buko 2011). These phases are first the early Slavonic period in the second half of the 5th to the 7th century AD, followed by the tribal groupings culminating with the beginning of the Piast dynasty in the 8th to the first half of the 10th century, and finally the Piast state period from the second half of the 10th to the first half of the 13th century (Fig. 1). It should be stressed that the early medieval settlement of Poland was not uniform. It proceeded most quickly in Wielkopolska (Great Poland) and in the southern part of the uplands of Małopolska (Little Poland) (Kornaś 1972; Makohonienko 2004; Buko 2011), which were the most densely populated areas during the late Middle Ages (Fig. 2a), dated in Poland from halfway through the 13th to the turn of the 15th and 16th centuries (Fig. 1; Miśkiewicz 2010). According to Makohonienko (2004), important changes in the development of the vegetational and cultural landscape of Poland took place during the last 2,000 years, but in many regions the most intensive change of plant cover from woodland to mainly open land through human activity was from ca. 1,000 BP. This process is most evident in Wielkopolska and Małopolska and corresponds very well with the leading role of Ziemia Krakowska, the area around

Kraków and central Wielkopolska in the 11th century in the formation of the Polish state by the first Piast dynasty (Makohonienko 2004).

The aims of the present investigations, based on rich source material, were as follows: (1) to discover which trees and shrubs were used in medieval Poland for making everyday objects; (2) to find out whether the choice of wood for those purposes was motivated by the specific properties of the timber; and (3) to study possible regional differences in the use of timber for various crafts.

The present-day vegetation of Poland

Poland is situated in the Holarctic Euro-Siberian area (49°00'–54°50'N, 14°07'–24°08'E), in the group of central European vegetational provinces (Medwecka-Kornaś 1972; Wasylikowa 2004; Richling 2009). An important division separating the physical-geographical parts of western and eastern Europe runs through eastern Poland. Most of the part of Poland that belongs to western Europe shows no geographical zonation of vegetation, whereas zonation is distinctly marked in the flat south-western part of the geological East European Platform lying within Poland's borders. The influences of oceanic and continental climates meet in Poland (Medwecka-Kornaś 1972; Kondracki 2009; Wołkowycki 2010). The temperatures of the summer months increase from west to east, while those of the winter months decrease and the annual temperature amplitude increases too. This temperature pattern is responsible for the transitional character of the vegetation (Wasylikowa 2004; Kondracki 2009). Several plants reach the limits of their ranges in Poland, including some trees and shrubs, such as *Fagus sylvatica* (beech), *Quercus petraea* (sessil oak), *Acer pseudoplatanus* (sycamore), *A. campestre* (field maple), *Tilia platyphyllos* (large-leaved lime), *Abies alba* (silver fir), *Taxus baccata* (yew) and *Crataegus laevigata* (hawthorn) (Medwecka-Kornaś 1972; Wołkowycki 2010).

Most of Poland is situated in a subatlantic deciduous and mixed woodland zone belonging to the subatlantic mountainous, Carpathian and middle European vegetational zones. Besides these, two zones are distinguished in eastern Poland, namely the sub-boreal zone with conifer and mixed conifer woods in north-eastern Poland and the woodland steppe zone, east of the river Wieprz (Medwecka-Kornaś 1972; Matuszkiewicz 2008; Richling 2009). Nine main geobotanical divisions are distinguished, reflecting the basic differentiation of Polish vegetation (Fig. 2b; Matuszkiewicz 2008). In the Polish flora the total number of tree and shrub species is small and only amounts to 40 (Pawłowska 1972; Mączak 1981; Danielewicz 2012a).

Table 1 Sites and deposits with previously published identifications or archived medieval wooden finds from Poland

No.	Site	Site code	Coordinates	Identification	References	Chronology	Function	Count
1	Bródno Stare 2	Wawa BS 2	52°17' 48.59"N 21°3' 34.60"E	Unknown author	Robak (2009); Ruskowska et al. (2011)	10th–start of 11th c	Log and bark lining of box for cereals, wheel	3
2	Brzeg	Breg	50°51' 38.13"N 17°28' 12.37"E	Unknown author	Głosek and Kajzer (1977); Polak (1999)	14th c	Bow	1
3	Czermino 2	Czmn 2	50°39' 33.54"N 23°42' 32.90"E	Cywa K	Cywa (2017)	10/11th–13th c	Scoop handle, board, slat, vessel turned on both sides	8
4	Drohiczyn	Droh	52°23' 38.48"N 22°39' 31.50"E	Cywa K	Cywa (2016)	14th–15th c	Spindle	1
5	Elbląg, Stary Rynek 38	Elbg SR 38	54°09' 29.07"N 19°23' 44.78"E	Unknown author	Popławska and Lachowicz (2014)	End 15th or start of 16th c	Recorder and block from mouthpiece	2
6	Gdańsk 1	Gdsk 1	54°21' 16.59"N 18°39' 31.03"E	Unknown author	Barnycz-Gupieniec (1959)	End of 10th c.–13th c	Various	165
7	Gdańsk 2	Gdsk 2	54°21' 13.45"N 18°39' 14.17"E	Unknown author	Barnycz-Gupieniec (1961)	13th c. and 14th–15th c	Turned vessels	29
8	Inowrocław 19	Inow 19	52°47' 49.72"N 18°15' 36.04"E	Unknown author	Grabska (1979)	Half of 13th c.–14th c	Various	152
9	Kołobrzeg Armii Krajowej	Kolb AK	54°10' 36.36"N 15°34' 28.62"E	Unknown author	Polak (1999)	Second half of 13th c.–14th c	Bow	1
10	Kołobrzeg E. Gierczak	Kolb EG	54°10' 25.85"N 15°34' 29.60"E	Ważny T, Łotocka Z & Oktała J	Polak (1998a, b); Nyborg and Rębkowski (1998)	Third quarter of 13th c.–4th quarter 14th c	Various	31
11	Kołobrzeg Ratuszowa 9–13	Kolb Ra	54°10' 37.64"N 15°34' 36.42"E	Łotocka Z & Oktała J	Polak (1996)	Third quarter 13th c.–3rd quarter 14th c	Various	30
12	Kraków Kazimierz	Krkw Kz	50°3' 5.25"N 19°56' 4.94"E	Reymanówna M	Wasylikowa (1958)	14th–15th c	Barrel	1
13	Kraków Mały Rynek	Krkw MR	50°3' 40.39"N 19°56' 25.72"E	Gluza I	Gluza (2009)	14th–15th c	Various, pieces of worked wood of unknown function	60
14	Kraków Rynek Główny	Krkw RG	50°3' 41.74"N 19°56' 12.76"E	Gluza I	Zaitz (2006)	End of 13th c.–half of 15th c	Roof shingles	2
15	Kraków Wawel benches*	Krkw Wa 1a	50°3' 17.50"N 19°56' 13.30"E	Unknown author	Gostwicka (1965)	Middle Ages	Carved benches	2
16	Kraków Wawel X	Krkw Wa X	50°3' 12.37"N 19°56' 7.42"E	Reymanówna M	Wasylikowa (1978); Wasylikowa (1991)	Middle Ages	Various, pieces of worked wood of unknown function	79
17	Kraków Zakrzówek	Krkw Za	50°2' 24.25"N 19°55' 00.72"E	Gluza I	Gluza (1977)	Mid 11th–mid 13th c	Various	28
18	Kraków Sławkowska 17**	Krkw Sł 17	50°3' 52.23"N 19°56' 19.40"E	Lityńska-Zajac M	Puziuk and Tyniec (2013)	Late Middle Ages	Maces	3
19	Kruszwica 4	Krsz 4	52°40' 22.36"N 18°19' 37.62"E	Surmiński J & Gądziński Z	Dzieduszycki (1976)	Half of 11th c.–beginning of 16th c	Various	30

Table 1 (continued)

No.	Site	Site code	Coordinates	Identification	References	Chronology	Function	Count
20	Międzyrzecz Wielkopolski	MidzW	52°26' 42.17"N 15°34' 18.69"E	Unknown author (vessels), Stepnik T	Woźnicka (1961); Łaskiewicz and Micha- lak (2007); Stepnik (2013)	13th c.–16th c	Stave-built and turned ves- sel, handles of hatchets	353
21	Nysa flute	Nysa fl	50°28' 17.89"N 17°20' 2.8"E	Unknown author	Popławska and Lachowicz (2014)	After AD 1350, before 1420	recorder	1
22	Opole Ostrówek I–IV	OpOstr I–IV	50°40' 02.89"N 17°55' 07.15"E	Surmiński J	Bukowska-Gedigowa and Gediga (1986); Robak (2009)	10th–second half 12th c	Various	544
23	Ostrów Lednicki	OstrLed	52°31' 40.12"N 17°22' 45.51"E	Zielski A, Stepnik T	Zielski 1993; Grupa 2000; Szulca (2000); Tokarski (2000); Stepnik (1996)	Middle Ages	Various functions of objects	204
24	Płock Grodzka 14/16	PłGr 14	52°32' 36.67"N 19°41' 16.66"E	Sokulska A	Trzeciecki (2000); (Polak 2000); Popławska, Lachowicz (2014)	Late Middle Ages	Spoon, stave-built and turned vessels	4
25	Płock Grodzka 6	PłGr 6	52°32' 36.67"N 19°41' 16.66"E	Sokulska A	Trzeciecki (2000); Polak (2000); Popławska and Lachowicz (2014)	Late Middle Ages	Recorder and mouthpiece block, stave of barrel	3
26	Puck	Puck	54°43' 4"N 18°24' 31"E	Unknown author	Popławska and Lachowicz (2014)	End of 14th–mid of 15th c	Recorder and mouthpiece block	2
27	Stargard Szczeciński	Stargd	53°20' 15.32"N 15°2' 42.64"E	Bobik I	Bobik (2012)	Turn of 13/14th–mid 14th c	Stave-built and turned vessels	135
28	Szczecin Rynek Warzywny	SzRW	53°25' 31.07"N 14°33' 44.05"E	Molski B, Jasnowska J & Surmiński J	Rulewicz (1958); Molski (1968); Gorczyński et al. (1969); Kowalska and Dworaczek (2011)	End of 8th and 2nd decade 10th c.–mid of 13th c	Various	66
29	Szczecin Wzgórze Zam- kowe excav. V and I	SzWZ V	53°25' 34.29"N 14°33' 36.83"E	Jasnowska J	Cnotliwy et al. 1983	7/8th–mid of 13th c	Various	17
30	Szczecin-Podgrodzie, quarter I	SzPd I	53°25' 34.74"N 14°33' 45.19"E	Jagielska I	Głosek and Uciechowska- Gawron (2009/2010); Jagielska (2009/2010)	AD 1170–1197	Shield	1
31	Szczecin-Podzamcze, quar- ter V, excav. V**	SzPo V/V	53°25' 31.96"N 14°33' 42.03"E	Cywa K	Cywa (2016)	Period before settlement of the city with German law, 15th c	Spindle	1
32	Szczecin-Podzamcze, quar- ter V, excav. VI**	SzPo V/VI	53°25' 31.96"N 14°33' 42.03"E	Bobik I, Cywa K	Słowiński (2004); Wilgocki (1995); Cywa (2016)	Middle Ages	Various	63
33	Szczecin-Podzamcze, excav. II and III	SzPo II, III	53°25' 32.69"N 14°33' 45.01"E	Stepnik T	Łosiński et al. (2003); Robak (2009)	Turn of first and second decade of 12th–5th dec- ade of 13th c	Various	89

Table 1 (continued)

No.	Site	Site code	Coordinates	Identification	References	Chronology	Function	Count
34	Toruń Bankowa 14/16**	Torn Ba	53°0' 30.26"N 18°36' 14.99"E	Stawska V	Catalogue card of the district museum in Toruń (unpublished)	First half of 13th–15th c	Spade	1
35	Wolin 1, 4	Woln 1, 4	53°50' 33.96"N 14°37' 00.41"E	Stępnik T	Stępnik (2014)	End of 10th and 1st half of 11th c	Various	133
36	Wrocław Ostrów Tumski	WrOstr	51°6' 56"N 17°2' 34"E	Jasnowska J & Gądziński Z	Ostrowska (1962)	11/12th–start of 13th c	Various	46
37	Wrocław Rynek	WrRyn	51°6' 38.55"N 17°1' 50.32"E	Pyszyński W	Wysocka (2001); Wysocka (1999); Pyszyński (2001)	Mid of 13th–end of 14th c	Various	89
38	Wrocław, Szewska and Olawska	WrSzOl	51°6' 37.98"N 17°2' 5.53"E	Pyszyński W	Piekalski (2010)	Middle Ages	Stave-built and turned vessels	67
39	Wrocław, Węzienna 10–11	WrWie	51°6' 46.94"N 17°1' 57.90"E	Unknown author	Świątek (1999)	Second half of 13th c.–half of 15th c	Various	151
Number of objects (total)								2,598

*Objects do not come from archaeological excavations

**Other objects from the site have been identified in the latest wood investigations by the author (Table 2)

Materials and Methods

For this study, a taxonomic database of medieval everyday wooden objects from Poland was created, using two data sources: First, identifications previously published by other authors (Table 1) and second, recent wood identifications done by the author (Table 2).

A large range of wooden articles was used for various aspects of everyday life and work in medieval Poland. The majority of the examined objects represent simple items which are commonly found at the sites of that period. Among them are the remains of cooper's wares from wooden staved vessels such as staves and the end discs of small buckets (Fig. 3, 4, 9), and small stave-built bowls (Fig. 3, 5). There were also turned vessels and other objects, including bowls (Fig. 3, 6), plates (Fig. 3, 2, 7) and lids (Fig. 3, 10); there were hollowed-out and carved vessels such as scoops (Fig. 3, 1), spoons (Fig. 3, 19, 23) and pegs (Fig. 3, 24, 26), and also various tools (Fig. 3, 25, 27, 31, 32, 34), children's toys, weapons (Fig. 3, 30), musical instruments (Fig. 3, 33) and parts of footwear (Fig. 3, 28). Other items taken into consideration included wicker baskets (Fig. 3, 13), bark containers, floats for fishing nets (Fig. 3, 3) and some small construction elements, for example, fragments of workbenches and wooden structures of various sorts (Fig. 3, 12, 18). Remains included means of transport, furniture (Fig. 3, 14) and objects interpreted as parts of buildings, such as roof remains (roof shingles), wall or floor insulation, and even a latrine seat and cover (Fig. 3, 20, 29). The analysis also included wood identification of small objects of unknown function (Fig. 3, 35) and/or representing woodworking waste.

A total of 3,867 wooden objects were identified after being excavated from 48 sites in Polish strongholds and early urban centres (Fig. 4) and dated to the period from the 9th to the 15th century (ESM 2). In the case of the sites at Szczecin Rynek Warzywny, Wrocław Ostrów Tumski, Płock Grodzka 14/16, Płock Grodzka 6 and Kraków Zakrzówek, the authors of the original publications gave no exact numbers of articles made of particular wood taxa. Therefore, in the present paper the following principle was followed: the mention of a taxon as wood used for making a certain category of objects was counted as one.

The objects were arranged into larger groups according to their functions (Fig. 5), in which the tree and shrub taxa most often used for making them can easily be found. In some cases there are apparently similar groups, for example “big stave-built vessels” and “stave-built vessels”. Cooperage (barrels and other articles made with staves) of known sizes was put in the first group, and in the latter the products whose sizes were not specified in the source article.

In order to indicate areas of medieval Poland where a particular kind of wood was especially intensively used, mean

Table 2 New wood identifications by the author

No.	Site; site code	Coordinates	Chronology	Function	Counts	Owner institution
1	Czermno 70; Czmn 70	50° 39' 35.46" N 23° 42' 29.86" E	Turn of 10/11th – 13th c.	Handle of sickle	1	Ośrodek Archeologii Gór i Wyżyn Instytutu Archeologii i Etnologii Polskiej Akademii Nauk w Krakowie (Centre for Archaeology of Hills and Uplands of the Institute of Archaeology and Ethnology Polish Academy of Sciences in Kraków)
2	Kraków town; Krkw Mi	50° 3' 41.88" N 19° 56' 23.19" E	Late Middle Ages	Stave-built vessel, float	2	Muzeum Archeologiczne w Krakowie (Archaeological Museum in Kraków)
3	Kraków Wawel VI, V, X, VII, XI; Krkw Wa VI i in.	50° 3' 13.47" N 19° 56' 06.15" E	Middle Ages	Various	129	Zamek Królewski na Wawelu (Royal Castle on Wawel)
4	Kraków, Grodzka 57; Krkw Gr	50° 3' 25.38" N 19° 56' 16.75" E	Late Middle Ages	Peg, dowel pin for making rope	2	Muzeum Archeologiczne w Krakowie (Archaeological Museum in Kraków)
5	Kraków, Rynek Główny Ratusz; Krkw RGR	50° 3' 41.33" N 19° 56' 11.11" E	Early Middle Ages	Stave-built vessel	2	Muzeum Archeologiczne w Krakowie (Archaeological Museum in Kraków)
6	Kraków, Sławkowska 14/6; Krkw Sł 14	50° 3' 49.42" N 19° 56' 14.81" E	Late Middle Ages	Baton shaped object with unknown func- tion	1	Muzeum Archeologiczne w Krakowie (Archaeological Museum in Kraków)
7	Kraków, Sławkowska 17*; Krkw Sł 17	50° 3' 52.23" N 19° 56' 19.40" E	Late Middle Ages – modern times	Stave-built and turned vessel, peg	10	Muzeum Archeologiczne w Krakowie (Archaeological Museum in Kraków)
8	Radom 2; Radm 2	51° 24' 04.67" N 21° 7' 51.95" E	Mid 9th – mid 13th c.	Various	161	Muzeum im. Jacka Malczewskiego w Radomiu (Jacek Malczewski Museum in Radom)
9	Szczecin-Podzamcze, quarter V, excavation IV; SzPo V/IV	53° 25' 31.96" N 14° 33' 42.03" E	2nd quarter 13th – end 14th c.	Various	100	Muzeum Narodowe w Szczecinie (National Museum in Szczecin)
10	Szczecin-Podzamcze, quarter V, excavation V*; SzPo V/V	53° 25' 31.96" N 14° 33' 42.03" E	Period before loca- tion of the city – 15th c.	Various	41	Muzeum Narodowe w Szczecinie (National Museum in Szczecin)
11	Szczecin-Podzamcze, quarter V, excavation VI*; SzPo V/VI	53° 25' 31.96" N 14° 33' 42.03" E	Middle Ages	Various, floats	542	Muzeum Narodowe w Szczecinie (National Museum in Szczecin)
12	Toruń, Bankowa 14/16*; Torn Ba	53° 0' 30.26" N 18° 36' 14.99" E	1st half 13th – 15th c.	Various	213	Muzeum Okręgowe w Toruniu (District Museum in Toruń)
13	Wolin 3; Woln 3	53° 50' 31.42" N 14° 36' 59.24" E	Middle Ages	Various	65	Ośrodek Archeologii Średniowiecza Krajów Nadbałtyckich Instytutu Archeologii i Etnologii Polskiej Akademii Nauk w Szczecinie (Centre for Medieval Archaeology of the Bal- tic Region of the Institute of Archae- ology and Ethnology Polish Academy of Sciences in Szczecin)
Number of objects (total)					1,269	

* These sites were previously investigated by other authors (Table 1)

values were calculated which give the average number of articles made from each wood taxon at all sites where it occurred. For example, *Pinus* was found at 30 sites, with an average of 46 articles made of pine per site (ESM 3). The maps of site distribution have been drawn on this basis, showing the sites from which the number of items made of a particular wood taxon was equal to or greater than the average number of items of the taxon from all sites where

it occurred (Fig. 6). These calculations make it possible to compare the results of wood identification of the archaeological finds with the modern ranges of trees and shrubs in Poland, and with pollen data providing information about the role they played in medieval woodlands.

To compare finds of different ages, which came from dozens of sites, each of them was attributed to one of the main chronological periods of the Middle Ages in Poland (ESM

Fig. 1 The chronological divisions of the Middle Ages in Poland. Period I, the early Slavonic period; II, the tribal and formation of the Piast state; III, the Piast state period; IV, late Middle Ages

2, Fig. 1). If the dating of these finds crossed the limits of these periods, for example between Period II and Period III (ESM 2, period column), then these were not taken into consideration in the analyses dealing with the chronological aspect (Figs. 7, 8).

Wood analysis

Fossil wood of most of the trees and shrubs growing in Poland can be identified only to genus level by anatomical studies. *Picea* (spruce) and *Larix* (larch) are not usually

distinguished from each other, in spite of the fact that the anatomical features theoretically useful for more detailed identification have been described (Anagnost et al. 1994). In this article it was necessary to treat it uniformly as one taxon, *Picea/Larix*, because the data come from various authors, who made identifications to varying degrees of precision.

Wood for microscopic examination was cut directly from the outer surfaces of the objects (Gale and Cutler 2000), corresponding to transversal, longitudinal radial and longitudinal tangential sections. In some cases, when the surface of an object was badly damaged, larger pieces of ca. 0.5 cm³ were collected. The identification was done with the aid of a transmitted light microscope by studying the diagnostic features visible in the three anatomical sections (Lityńska-Zajac and Wasylkowa 2005; Gärtner and Schweingruber 2013). For verification, reference material in the collections of the W. Szafer Institute of Botany, Polish Academy of Science was used, as well as publications on wood and bark anatomy (Greguss 1945; Schweingruber 1978; Benkova and Schweingruber 2004; Schweingruber et al. 2011).

Fig. 2 **a** historical regions of early medieval Poland (after Iwaszczuk 2014) and population density in the 15th century (after Gędek 2015, changed); **b** geobotanical divisions of Poland. A, Dział Pomorski (Pomerania); B, Dział Brandembursko-Wielkopolski (Brandenburg and Great Poland); C, Dział Wyżyn Południowopolskich (southern Polish uplands); D, Dział Wołyński (Volhynia); E, Dział

Mazowiecko-Poleski (Mazovia and Polesie); F, Dział Północny Mazursko-Białoruski (Mazuria and Belarus); G, Dział Sudecki (Sudetes); H, Dział Zachodniokarpacki (west Carpathians); I, Dział Wschodniokarpacki (east Carpathians) (after Matuszkiewicz 2008, changed); the main vegetation zones in Europe are indicated on the map (after Kondracki 2009, changed)

Results

The identification of medieval wooden objects revealed the occurrence of 27 tree and shrub taxa (Table 3), and also *Viburnum* sp. (viburnum, wayfaring tree), although only

half of them were commonly used and were important as timber for woodworking crafts.

The analyses show that *P. sylvestris* (pine) wood was the most frequently used, for 36% of artefacts (Fig. 9a). *Picea/Larix*, *Fraxinus*, *Quercus*, *Taxus*, *Alnus*, *Abies*, *Acer*, *Betula*, *Salix*, *Euonymus*, *Sambucus* and *Fagus* were

Fig. 3 Selected objects of everyday use from Polish archaeological sites (for extended descriptions, see ESM 1); 1, scoop, *Alnus* sp.; 2, plate turned on both sides, *Acer* sp.; 3, float, pine bark; 4, end disc of a stave-built vessel, *Abies alba*; 5, stave-built bowl, *Pinus sylvestris*; 6, turned bowl with an incision for a lid, *Fagus sylvatica*; 7, bowl turned on one side, *Fraxinus excelsior*; 8, lid of a vessel/float wooden disc/cart wheel?, *Pinus sylvestris*; 9, tub stave, *Taxus baccata*; 10, turned lid, *Salix* sp.; 11, ball, *Pinus sylvestris*; 12, sinker, *Carpinus betulus*; 13, fragment of plaited basket, birch bark; 14, furniture fragment, *Fraxinus excelsior*; 15, 16, parts of folded altars?, *Abies alba*; 17, torch, *Pinus sylvestris*; 18, rocker for making cheese, *Quercus* sp.; 19, spoon, *Taxus baccata*; 20, piece of latrine seat cover, *Quercus* sp.; 21, part of folded altar?, *Abies alba*; 22, hook, *Salix* sp.; 23, spoon, *Abies alba*; 24, peg for making rope, *Abies alba*; 25, carpenter's club hammer, *Quercus* sp.; 26, peg, *Viscum album*; 27, pricker, *Abies alba*; 28, shoe patten, *Salix* sp.; 29, piece of latrine cover (horizontal plank with an opening), *Pinus sylvestris* L.; 30, arrow shaft?, *Pinus sylvestris*; 31, needle for tying nets, *Euonymus* sp.; 32, hoe for fire, *Quercus* sp.; 33, tubular objects with openings, recorder or pipe?, *Sambucus* sp.; 34, beater, *Alnus* sp.; 35, object of unknown function, *Quercus* sp.; photos by K. Cywa

slightly less popular. The wood of these 13 taxa was used for over 90% of all analysed remains.

The use of the bark of eight taxa was also confirmed, *Abies alba* (fir) (0.03% of all remains), *Alnus* sp. (0.03%), *Betula* sp. (0.16%), *Larix* sp. (0.03%), *P. sylvestris* (1.73%), *Quercus* sp. (0.03%), *Salix* sp. (0.08%) and *Tilia* sp. (0.08%).

The survival of archaeological finds made of organic materials is determined by the preservation conditions of the site (Fejfer 2011). It is assumed that the amount, quality and proportions of materials found in medieval deposits depend on the type of site, type of object and type of sediment (Lityńska-Zajac and Wasylkowa 2005; Buko 2011). In the case of early urban centres, the poor state of stratification there is usually the result of centuries of rebuilding which has destroyed earlier buildings (Buko 2011). This is perhaps the main reason for not having published official data from Poland so far, which would indicate how many archaeological sites dating to the Middle Ages are characterized by very well-preserved organic materials. Assuming that sites with well-preserved archaeological wood are likely to exhibit a low degree of wood degradation as well as a large number of surviving wooden objects, it was found that in the case of the analysed sites, most of the items were relatively well preserved. This is shown by the very low percentage of unidentified objects (0.21% of all remains), as well as ones identified only as deciduous (1.7%) or coniferous (1.6%). Among 48 analysed sites, 21 (44%) only had a few wood remains (< 20 artefacts), 15 (31%) were in the range between 28 and 100 items and 12 sites (25%) are in a group of plentiful finds, where more than 100 objects have survived (Tables 1, 2). It should be borne in mind that the size of a settlement, as well as the amount of woodworking there, may also have had an impact on the number of objects found.

Technological aspect

Listing of the objects according to their functions (Fig. 5) indicates that parts of furniture, timber structures including those for building boats and sledges, various wooden structures, maces (wooden clubs used as weapons and also ceremonially), staves, large stave-built vessels, and large tools such as spades and club hammers were made mainly of *Quercus*, *Pinus* and more rarely of *Fraxinus*. *Taxus* wood (11.4%) was an important material which was used for making big stave-built vessels, but most often for small and medium sized buckets.

Various kinds of walking sticks, rods and poles were mainly made of *Quercus* (29.4%), *Taxus* (17.7%), *Pinus* (9.8%) and *Abies* (9.8%). Spear shafts and axe handles as well as maces (clubs) were usually made of *Fraxinus*. Also, for large handles, *Quercus* (25%) and *Alnus* (20.8%) were often used. For arrow shafts, only the wood of *P. sylvestris* was recorded, and the only crossbow bolt was made of *Fraxinus*. All of the bows were made of *Taxus*, and the only shield found, at Podzamcze in Szczecin, was made of *Alnus* wood.

Small tools and their parts including punches, needles and spindles, as well as knife handles, were made of *Pinus* (16.1%), *Quercus* (8%), *Euonymus* (23.7%), *Taxus* (13%), *Sambucus* (6.3%) and *Juniperus* (0.5%). The material used for making small table spoons was the wood of *Acer* (26.4%), *Fraxinus* (4.7%), *Betula* (7.6%), *Alnus* (8.5%), *Salix* (3.8%), *Taxus* (7.6%), *Euonymus* (7.6%), *Sambucus* (2.8%), *Juniperus* (7.6%), *Abies* (2.8%) and of some trees and shrubs from the Rosaceae (7.6%).

For making turned objects, besides hollowed and carved ones such as scoops, ladles and beaters, *Fraxinus*, *Quercus*, *Alnus* and *Acer* were selected most often. Nearly 70% of turned bowls and plates as well as 36% of hollow and carved vessels were made of *Fraxinus*.

The parts of small stave-built bowls were made of *Pinus*, *Picea/Larix* and *Abies*. The hoops of small stave-built bowls were made exclusively from *Salix* branches, while those of big buckets or tubs with narrower tops and wider bases were of *Taxus* (30.8%), *Fraxinus* (23.1%), *Corylus* (7.7%), *Abies* (7.7%) or *Picea/Larix* (7.7%).

Objects of unknown function were made of *Alnus* (20.5%), *Pinus* (12.8%), *Quercus* (10.3%) and *Fraxinus* (7.7%).

Torches were usually made of *Pinus* (61.6%), but sometimes of *Picea/Larix* (36.6%). The musical instruments were mainly recorders and pipes which were most often made from *Sambucus*. The wood of *Pinus*, *Fraxinus* and *Quercus* was the usual material for pegs, pins and bungs.

Carved objects (Fig. 5, column: art and cult) were usually made of *Abies* (23.1%), *Alnus* (23.1%), *Taxus* (15.4%) and *Acer* (15.4%). Children's toys, which were mainly miniatures

Fig. 4 Locations of the find sites and numbers of medieval wood finds. Abbreviations of site names as in Table 2

of other articles and also pieces used in games were made mostly of *Pinus* (23.3%). The few fragments of ropes and plaited woodwork were made of *Salix* branches (85.7%) and phloem (14.3%).

Medieval baskets and containers were woven from various materials, such as thin *Pinus* (mostly) and *Quercus* twigs, *Betula* bark and phloem. The floats for fishing nets were usually cut out of *Pinus* bark (87.9%).

Geographical aspect

The list of wood identifications from individual sites shows that the most important raw materials in northern (particularly north-western) Poland were *Pinus*, *Quercus*, *Fagus* and *Fraxinus* (Fig. 10). *Quercus* was a significant component in the majority of the examined sites. The proportions of *Pinus* were also marked in almost all sites but were rather low in the south of the country, as in Wrocław and Kraków. The use of *Taxus* is also evident in the whole of Poland, but the highest proportions in wood composition were noted from the island of Wolin. The significance of *Picea/Larix* distinctly increases from the north to the south, especially for making stave-built bowls etc. In the south, *Picea/Larix* is the first or second most important component of the wood spectra.

The number of objects made of *Pinus* was average or above average in 10 sites, and of *Quercus* in 11, and *Fraxinus* in several (Fig. 6, ESM 3).

The pattern of intensive use of *Abies alba* in the past agrees with the modern distribution of fir in Poland. The sites with the greatest number of objects made of *Fagus* are also only within its modern distribution range.

The distribution map of the use of *Carpinus betulus* shows that it exceeds the average value in three sites.

The number of objects made of *Betula* sp. is above average in two sites only, Opole Ostrówek I–IV and Kraków Wawel X, and the numbers of items made of *Taxus baccata* reach the mean value in four sites which were scattered over the whole of Poland.

Chronological aspect

The chronological aspect of the wood analyses shows that there are no items dating from the early Slavonic period (Figs. 7, 8). Five objects belong to the early tribal period, a scoop, the end of a barrel, two paddles and a stave of a small bucket made of *Taxus*. There are 1,710 objects from 14 sites of the state period in the early Middle Ages (Period III) and 1,557 objects from 30 sites of the late Middle Ages (Period IV) (Table 3). Among the items representing Period IV, there are ones characterised by a smaller functional diversity than those in Period III, with a predominance of coopers' wares, turned objects, pegs and tools. No distinct qualitative difference has been observed in the use of raw materials between the early and late Middle Ages, and the range of woods that

Fig. 5 Identified medieval wood and bark taxa, according to object type and function

Euonymus, while *Abies* and *Picea/Larix* increase. It seems, however, that the differences visible in such a general comparison are first of all connected with the slightly different kinds of wooden objects identified from each period, as well as with the locations of the sites and the local taxonomic composition of the finds from a given chronological phase.

Fig. 6 Distribution of sites in which the number of wooden objects made from a particular wood was average or above the average from all sites. The northern limit of *Abies alba* Mill. and the north-eastern limit of *Fagus sylvatica* L. are shown as dotted lines (after Konopski 2016)

The comparison of wood spectra in Periods III and IV could be done separately for individual sites only for four sites: Szczecin-Podzamcze V/VI, Gdańsk 1, Gdańsk 2, Kraków Wawel X and Kruszwica 4 (Fig. 7). In each site there is a strong decrease in the diversity of wood types in the material from the late Middle Ages, when compared to the state period of the early Middle Ages. This change

is associated, however, mainly with a considerable disproportion in the number of items belonging to individual chronological phases. In some cases, as at Szczecin-Podzamcze V/VI and Gdańsk 1, the fewer taxa in Period IV are also influenced by the functional composition of the objects from that period, for instance, when they mainly consisted of turned or stave-built wares.

Type of raw material	Taxa	Chronological period															
		Szpo VII		Szpo VIII		Gdsk I		Gdsk II		Gdsk III		Krsz IV		Krsz V		Krw Wa X	
		III	IV	III	IV	III	IV	III	IV	III	IV	III	IV	III	IV	III	IV
Deciduous	Wood																
	Acer sp. maple	1.62%															
	Alnus sp. alder	1.00%	2.60%														
	Betula sp. birch	0.46%		0.89%													
	Betulaceae birch family																
	Carpinus betulus hornbeam	0.23%															
	Cornus sp. dogwood																
	Corylus avellana hazel	2.55%															
	Crataegus sp. hawthorn																
	Euonymus sp. spindle	1.21%															
	Fagus sylvatica beech	1.39%	7.79%														
	Fraxinus excelsior ash	3.71%	44.16%														
	Juglans regia walnut																
	Populus sp. poplar	0.46%															
	Quercus sp. oak	12.53%	14.29%	5.36%													
	Rosaceae rose family	0.70%															
	Salix sp. willow	2.78%	2.60%														
	Salicaceae willow family																
	Sambucus sp. elder	3.71%	1.30%														
	Tilia sp. lime			0.89%													
	Ulmus sp. elm		1.30%														
	Viburnum sp. viburnum	0.23%															
Coniferous	Bark																
	Alnus sp. bark																
	Betula sp. bark																
	Salix sp. bark																
	Tilia sp. bark																
	Phloem																
	indet. deciduous	0.23%		12.38%	6.67%												
	indet. coniferous	0.23%															
	Wood																
	Abies alba silver fir	0.23%															
	Juniperus communis common juniper	0.23%															
	Picea/Larix spruce/larch	0.23%	2.60%														
	Pinus sylvestris Scots pine	42.00%	22.00%	41.86%	33.33%	100.00%	100.00%	38.46%	100.00%	100.00%	12.86%						
	Taxus baccata yew	5.10%	1.30%														
	Bark																
	Abies alba bark																
	Larix sp. bark																
	Pinus sylvestris bark	0.46%															
	indet. coniferous			38.39%	60.00%												
	indet.																
Sum		431	77	112	15	3	8	26	4	54	3						

Fig. 7 Identified medieval wood and bark taxa from sites covering chronological periods I and II

Discussion

The use of different types of wood in medieval Poland, selected aspects

This research has confirmed the use of various timbers in medieval Poland. The most important material was the wood of *Pinus sylvestris*. It represented a much valued timber which was used for various purposes due to its lightness and ease of working, as well as its useful qualities such as durability and strength. Pine wood, due to its high content of resinous substances, is durable in air and water (Warywoda 1957; Kocięcki et al. 1991; Szczuka and Żurowski 1999; Kokociński 2004). On the other hand, the high proportion of *Pinus* in the studied material could also be connected with the occurrence of very many small stave-built vessels or hollow ware made from pine (Fig. 9b). It is interesting that among the objects made of bark, those made of *P. sylvestris* were the most numerous, 81% of all identifications of bark.

An insignificant occurrence of *Tilia* (13 objects) and *Carpinus* (14 objects) among useful medieval wood seems striking, because both taxa are common in the Polish lowlands and foothills (Danielewicz 2012a). These days, *Tilia*

Chronological period		Historical regions																
		II	NW		III				SE		NW		IV				SE	
Taxa		Pomorze Zachodnie (Western Pomerania)	Pomorze Zachodnie (Western Pomerania)	Pomorze Gdańskie (Gdańsk Pomerania)	Kujawy (Kujavia)	Wielkopolska (Great Poland)	Śląsk (Silesia)	Małopolska (Little Poland)	Pomorze Zachodnie (Western Pomerania)	Pomorze Gdańskie (Gdańsk Pomerania)	Ziemia chełmińsko-dobrzyńska (Chełmno & Dobrzyń Region)	Kujawy (Kujavia)	Wielkopolska (Great Poland)	Podlasie (Podlachia)	Mazovia (Mazovia)	Śląsk (Silesia)	Małopolska (Little Poland)	
Deciduous	Wood	Acer sp. maple	4.70%			8.82%	2.88%	1.46%	1.87%	3.70%	2.36%					3.31%	2.67%	
		Alnus sp. alder	10.50%			3.85%	7.84%	3.05%	5.11%	1.33%		0.94%				1.24%	2.67%	
		Betula sp. birch	1.10%	0.87%			0.49%	5.93%	13.14%	0.80%	3.70%					11.29%		
		Betulaceae birch family							0.73%									
		Carpinus betulus hornbeam		0.16%			2.94%	0.34%	0.73%			1.42%					0.83%	
		Cornus sp. dogwood										0.47%					0.41%	1.60%
		Corylus avellana hazel		1.72%				0.68%	1.46%			0.94%					0.41%	
		Crataegus sp. hawthorn															0.41%	
		Euonymus sp. spindle		6.90%				2.71%							100.00%		0.41%	
		Fagus sylvatica beech		1.25%		3.85%	1.47%	0.85%	0.73%	3.47%							0.41%	1.07%
		Fraxinus excelsior ash		5.33%		3.85%	19.12%	8.98%	5.84%	23.17%		7.55%	3.21%	28.57%		11.29%	12.40%	5.35%
		Juglans regia walnut					0.17%	0.17%										
		Populus sp. poplar		0.31%			0.98%	0.17%										
		Quercus sp. oak	80.00%	3.48%	5.22%	42.31%	18.14%	14.51%	13.14%	12.80%		7.08%	4.49%			42.86%	1.65%	4.81%
		Rosaceae rose family		0.47%				1.36%									0.41%	
		Salix sp. willow		3.13%			1.96%	1.86%	2.19%	0.80%		5.19%	1.28%					
		Salicaceae willow family						0.34%										
		Sambucus sp. elder		2.82%			0.49%	4.58%		0.27%						11.29%	0.83%	0.53%
		Tilia sp. lime			0.87%		1.36%	1.19%	3.65%	0.27%		0.47%	1.28%				0.41%	
	Ulmus sp. elm					3.92%	1.19%	3.65%	0.27%		0.47%	0.64%						
	Viburnum sp. viburnum		0.16%															
	Bark	Alnus sp. bark		0.16%														
		Betula sp. bark										0.47%						
		Salix sp. bark								0.27%		0.47%						
		Tilia sp. bark							0.73%									
	Phloem	phloem						0.17%		0.27%								
		indet. deciduous		1.25%	12.17%		10.78%	0.51%	3.65%		3.70%		0.64%					1.07%
	Coniferous	Wood	Abies alba silver fir	0.16%				3.39%	7.30%	0.53%							4.13%	33.69%
			Juniperus communis common juniper	0.16%				0.34%	0.27%								3.31%	
Picea/Larix spruce/larch			0.78%		7.69%	0.49%	4.92%	3.65%	6.67%	7.41%	2.36%	39.10%			62.40%	37.43%		
Pinus sylvestris Scots pine			37.93%	43.48%	38.46%	19.61%	22.03%	24.09%	43.47%	48.15%	69.81%	49.36%	71.43%		11.29%	6.61%	5.88%	
Taxus baccata yew			20.00%	7.21%		2.94%	12.10%	6.57%	2.67%							0.83%	0.53%	
Abies alba bark								0.17%										
Bark		Larix sp. bark						0.17%										
		Pinus sylvestris		0.31%				4.41%		0.80%								
		indet. coniferous			37.39%			0.68%			33.33%							2.67%
		Indet.	Indet.	indet.					5.84%									
Sum		2	638	115	26	204	590	137	375	27	212	156	350	1	7	242	187	
Number of wood taxa		2	19	5	6	14	22	15	14	4	12	7	2	1	5	17	11	

Fig. 8 Identified wood and bark finds from chronological periods III and IV, according to the locations of the sites in historical regions

Table 3 Taxonomic composition of wooden objects from Periods III and IV of the Middle Ages in Poland

Taxa	Counts III	Counts IV
<i>Abies alba</i> (bark)	31 (1)	75
<i>Acer</i> sp.	67	26
<i>Alnus</i> sp. (bark)	109 (1)	15
<i>Betula</i> sp. (bark)	62	5 (1)
Betulaceae	1	
<i>Carpinus betulus</i>	10	3
<i>Cornus</i> sp.		3
<i>Corylus avellana</i>	17	6
<i>Crataegus</i> sp.		1
<i>Euonymus</i> sp.	60	2
<i>Fagus sylvatica</i>	18	16
<i>Fraxinus excelsior</i>	135	250
<i>Juglans regia</i>	1	
<i>Juniperus communis</i>	3	9
<i>Larix</i> sp., bark	1	
Phloem	1	1
<i>Picea/Larix</i>	42	314
<i>Pinus sylvestris</i> (bark)	505 (28)	679 (3)
<i>Populus</i> sp.	5	
<i>Quercus</i> sp.	244	86
Rosaceae	11	1
Salicaceae	2	
<i>Salix</i> sp. (bark)	38	16 (2)
<i>Sambucus</i> sp.	46	5
<i>Taxus baccata</i>	133	13
<i>Tilia</i> sp. (bark)	9 (1)	4
<i>Ulmus</i> sp.	20	3
Undet	8	
Undet. coniferous	47	14
Undet. deciduous	52	4
<i>Viscum album</i>	1	
Total	1,710	1,557

wood is a very popular material which is used in Poland in wood turning, wood carving, sculpture and the production of fancy goods. It is soft, easy to work and cut, and shows a low tendency to warp or crack (Serwa 1986; Surmiński 1991; Samojlik 2005). *Carpinus*, on the other hand, has a heavy and hard wood which is resistant to abrasion (Serwa 1986; Surmiński 1993), thus making it an excellent timber for applications needing strength. One might also wonder whether the low natural durability of *Tilia* and *Carpinus* wood might not be the cause of their poor representation among the medieval archaeological finds. However, *Fagus* has similar physical properties to *Carpinus*, and is equally susceptible to damp (Surmiński 1990), yet it was found much more often (43 objects). In an old Polish botanical work from the time of the enlightenment (Kluk 1805), *Carpinus* was renowned as firewood and its charcoal was considered second only to *Fagus*. Perhaps *Carpinus* was used mainly for such purposes in the Middle Ages. A similar suggestion was put forward by Makohonienko (2000) in his analysis of the medieval history of woodland communities in the surroundings of Gniezno. Pollen investigations have shown that a massive expansion of *Carpinus* in central Wielkopolska took place before the early medieval settlement expansion, and its later decrease was evidently connected with the pressure from human occupation (Makohonienko 2000). Meanwhile, wooden objects made of *Carpinus* discovered at the site of Ostrów Lednicki, Wielkopolska, amounted to less than 3% of the wood used there, perhaps due to use of its wood for fuel.

In the case of *Tilia*, the decrease of its pollen values to below 0.5% was recorded in the whole country at the time of the Polish state formation (Kupryjanowicz et al. 2004; Wacnik et al. 2013). It is possible, however, that *Tilia* was mainly used for its bast fibres, for the oldest *Tilia* names in several languages are similar to the names of phloem or bast made of *Tilia* (Boratyńska and Dolatowski 1991). In a way, this conclusion is confirmed by the historical and ethnographic data from the neighbourhood of the Puszcza

Fig. 9 Medieval wood finds from Polish archaeological sites ($\Sigma = 3,867$); **a** taxonomic composition of the analysed assemblage of objects; **b** functional composition

Type of raw material	Locality: NW — SE		Wolin														Szczecin		Stargard Szczeciński	Kolobrzeg		Puck	Gdańsk	Elbląg	Toruń	Płock	Inowrocław 19	Kruszwica 4	Ostrów Lednicki	Miedzyrzecz Wielkopolski			
	Taxa	Sites	NW														SzRW	Stargd	Kolb Ra	Kolb AK	Kolb EG	Puck	Gdańsk 1	Gdańsk 2	Elbg SR 38	Toru Ba	PloGr 14	PloGr 6	Inow 19	Kisz 4	OstrLed	OstrLed	MiedzW
			Wolin 1, 4	Wolin 3	SzPd 1	SzWZ V	SzPo II, III	SzPo V/IV	SzPo V/V	SzPo V/VI	SzRW	SzRW	Kolb Ra	Kolb AK	Kolb EG	Puck																	
Deciduous	Wood	Acer sp. maple	16.54%	3.08%	100.00%	5.88%	1.12%			1.16%	6.06%	3.33%	19.85%	5.45%	3.23%			50.00%	2.34%														
		Alnus sp. alder	9.77%	4.62%	100.00%	6.74%	3.37%			8.10%	15.51%		6.67%				0.61%		50.00%	1.40%	25.00%												
		Betula sp. birch	1.50%							0.33%	4.55%																						
		Betulaceae birch family																															
		Carpinus betulus hornbeam					1.12%			0.17%																							
		Cornus sp. dogwood																															
		Corylus avellana hazel								4.76%	1.82%																						
		Crataegus sp. hawthorn																															
		Euonymus sp. spindle																															
		Fagus sylvatica beech	1.50%	1.54%		5.88%		3.00%	2.38%	1.98%	3.06%		6.67%		6.45%																		
		Fraxinus excelsior ash	11.20%			11.76%	3.37%	7.00%		8.93%	4.55%	23.15%	6.67%		22.53%																		
		Juglans regia walnut																															
		Populus sp. poplar									0.33%	3.03%																					
		Quercus sp. oak	20.30%	7.69%		23.51%	6.74%	15.00%	2.38%	1.24%	2.12%	1.11%	6.67%		16.11%		1.52%																
		Rosaceae rose family		1.54%		35.29%	1.12%			0.50%	4.55%																						
		Salix sp. willow	0.75%	1.54%		35.29%	1.12%			3.97%																							
		Salicaceae willow family																															
		Sambucus sp. elder	1.50%								2.98%																						
		Tilia sp. lime																															
		Ulmus sp. elm									0.17%	3.03%																					
		Viburnum sp. viburnum										1.52%																					
		Viscum album mistletoe				5.88%					0.17%																						
		Coniferous	Bark	Alnus sp. bark																													
				Betula sp. bark		1.54%																											
				Quercus sp. bark										1.52%																			
				Salix sp. bark						1.00%																							
				Tilia sp. bark																													
				phloem																													
indet. deciduous	2.26%						4.49%			0.33%						3.23%																	
Abies alba silver fir									2.00%		0.17%	1.52%																					
Juniperus communis				1.54%					1.00%		0.17%																						
Picea/Larix spruce/larch	2.26%						6.74%	1.00%		4.46%	3.03%	2.22%	20.00%																				
Pinus sylvestris Scots pine	15.74%			12.31%		5.88%	6.74%	5.00%	7.61%	11.82%	8.9%	53.52%	50.00%																				
Taxus baccata yew	16.54%			11.85%		5.88%	2.25%	5.00%	7.14%	3.97%	9.09%		100.00%																				
Abies alba bark																																	
Larix sp. bark																																	
Pinus sylvestris bark																																	
indet. coniferous	50.77%									2.38%	0.33%	1.52%				9.18%																	
indet.																																	
Sum					133	65	1	17	89	100	42	605	66	135	30	1	31	2	165	29	2	214	4	3	152	30	148	56	353				

Type of raw material	Locality: NW — SE		Wrocław														Kraków		Czeremo								
	Taxa	Sites																									
			Drohiczyn	Wawa BS 2	Radom 2	WrOstr	WrWle	WrRyn	WrScol	Breg	Nysa fl	OpOstr I-V	Krkw SI 17	Krkw SI 14	Krkw MI	Krkw RG	Krkw RGR	Krkw MR	Krkw Gr	Krkw Wa la	Krkw Wa VII in.	Krkw Wa X	Krkw Kz	Krkw Za	Czmn 2	Czmn 70	
Deciduous	Wood	Acer sp. maple		2.48%	6.45%	1.32%	6.74%					2.57%	7.69%	100.00%				5.00%				2.33%	6.33%				
		Alnus sp. alder		3.11%	4.35%	3.37%						2.94%										2.33%					
		Betula sp. birch		38.63%	2.48%	4.35%						0.07%										2.33%					
		Betulaceae birch family																									
		Carpinus betulus hornbeam			0.62%	4.35%		2.25%																			
		Cornus sp. dogwood																									
		Corylus avellana hazel			1.86%	2.17%	0.66%					0.55%	15.38%														
		Crataegus sp. hawthorn																									
		Euonymus sp. spindle	100.00%																								
		Fagus sylvatica beech		2.48%	2.17%		1.12%					2.76%															
		Fraxinus excelsior ash	38.63%	14.29%	15.22%	7.95%	20.2%	10.45%				8.46%	38.46%														
		Juglans regia walnut																									
		Populus sp. poplar																									
		Quercus sp. oak		9.32%	15.22%		4.49%					1.45%							3.33%			4.65%	25.32%	100.00%	14.3%	2.50%	
		Rosaceae rose family																									
		Salix sp. willow		1.24%	4.35%																						
		Salicaceae willow family																									
		Sambucus sp. elder										100.00%	4.78%														
		Tilia sp. lime											1.47%														
		Ulmus sp. elm		1.86%	2.17%								1.10%														
		Viburnum sp. viburnum																									
		Viscum album mistletoe																									
		Coniferous	Bark	Alnus sp. bark																							
				Betula sp. bark		38.63%	0.62%																				
				Quercus sp. bark																							
				Salix sp. bark			1.24%																				
				Tilia sp. bark																							
				phloem																							
indet. deciduous				1.86%					4.48%			0.55%						3.33%									
Abies alba silver fir				7.45%	2.17%							3.49%	15.38%						38.33%								
Juniperus communis												0.37%															
Picea/Larix spruce/larch				2.48%			80.76%	7.45%	8.65%			5.33%															
Pinus sylvestris Scots pine	37.63%			17.63%	6.61%	3.37%	1.49%					22.43%	7.69%														
Taxus baccata yew				8.07%	4.35%							0.18%															
Abies alba bark												0.18%															
Larix sp. bark												0.18%															
Pinus sylvestris bark												4.78%															
indet. coniferous	0.62%											0.74%															
indet.																											
Sum					1	3	161	46	151	89	67	1	1	544	13	1	2	2	2	60	2	2	129	79	1	28	8

The relationship between the kind of wood used and object type and function

Large objects

Relatively large objects, which for their intended uses should be considerably strong and durable, such as architectural elements, pieces of furniture, structures of unknown uses and large tools, were made mainly of *Quercus*, *Pinus* and more rarely of *Fraxinus*. These timbers are characterised by considerable density, weight and hardness in the case of *Quercus* and *Fraxinus*, or durability and ease of being split, such as *Pinus*, *Quercus* and *Fraxinus* (Krzysik 1957; Surmiński 1995). Also, big timbers can be obtained for making large objects. The advantage of *Quercus* as a timber for making staved containers is the presence of tyloses within the vessels which lessen the permeability of its wood. Due to this property, oaken barrels are water- and airtight, which is particularly significant for the storage of various types of foods (Świdorski 1966). *Taxus* wood was important for making big stave-built vessels, but was most often used for small and medium size buckets (Figs. 3, 9). Very hard *Taxus* wood (Amann 2009) could be an attractive timber for making household goods. Using *Taxus* wood for containers used mainly for transporting and storing food may seem surprising. The majority of papers on *T. baccata* have emphasized its toxic properties. In general, it has been claimed that all parts of the *Taxus* tree are poisonous except the arils enveloping the seeds (Wilson et al. 2001; Falencka-Jabłońska 2004; Berny et al. 2010; Kite et al. 2013). The poisonous properties of *Taxus* were already known in antiquity. “Celts committed ritual suicide by drinking extracts from yew foliage and used the sap to poison the tips of their arrows during the Gallic Wars” (Wilson et al. 2001). According to Julius Caesar, the king of the Eburones tribe which was conquered by the Romans also poisoned himself with yew “juice” (Wilson et al. 2001). Clearly, not only the leaves had a bad reputation then, as “wine was served in a jar made of yew wood to get rid of an inconvenient person” (Falencka-Jabłońska 2004). Information on the unsuitability of *Taxus* for drinking vessels can also be found in a medieval and renaissance textbook on agriculture (Crescenzi 1571). A mixture of alkaloids is responsible for the poisonous characteristics of *Taxus*, taxines which were first found in the leaf-needles of this tree (Theodoridis and Verpoorte 1996). Taxine B is considered the most cardiotoxic (Grobosch et al. 2012; Arens et al. 2016). Because of the wide use of *Taxus* wood for making pails and buckets in medieval Poland it is noteworthy that the few studies on the toxin content in *Taxus* wood do not indicate the presence of this taxine in branch heartwood (Kite et al. 2013) nor in the twigs (Ray 2017). Simultaneously, the presence of other types of taxines of unknown toxicity in *Taxus* wood has been revealed (Kite et al. 2013).

Weapons The shield from Podzamcze in Szczecin was made of *Alnus*. The lightness of this wood together with its resistance to splitting and cracking could have been an advantage of using this timber.

Among a few objects that could be interpreted as remains of arrow shafts (Fig. 3, 30), or perhaps rather as semi-finished products, because no traces of a binder or twist fastening flight feathers were found (S. Słowiński, pers. comm.), only the wood of *P. sylvestris* was identified, just as in the material from Novgorod (Brisbane and Hather 2007). In this case, the lightness of the material together with its considerable hardness would have been of great significance (Jankowski 2008).

Bows found in Poland were made of *Taxus*, which is consistent with historical records about the use of yew wood (Marcin z Urzędowa 1595). *Taxus* wood is remarkably elastic and therefore does not crack or warp while drying (Kłosiewicz and Kłosiewicz 2011). Sapwood has a high tensile strength while heartwood withstands compression, qualities which are particularly relevant for longbows (Gale and Cutler 2000). *Taxus* wood was not only used by local craftsmen but was also exported. The first information about Poland’s trade in yew wood with the Netherlands comes from 1287 (Czartoryski 1975). According to historical sources, *Taxus* almost completely disappeared from Polish woods and for that reason became the basis of a royal law of 1423 that prohibited its felling (Czartoryski 1975; Cedro 2004; Pawelec 2010).

Small tools In medieval deposits, various types of small tools have often been found, such as punches, needles and spindles, as well as handles for knives, borers or other small tools, which in accordance with their function should have great strength. Interestingly, such objects were very often made from the wood of small trees or shrubs, including *Euonymus*, *Taxus* and *Sambucus*, as well as *Pinus* and *Quercus*. Such wood has an exceptional hardness and density, exceeding that of *Quercus*. The frequent use of *Taxus* wood for making handles could be connected with its outstanding suitability for polishing, rendering it perfect for creating very smooth surfaces on objects. *Euonymus*, with its heavy and slightly flexible wood was used, among other things, as the main material for making spindles, hence its name, “spindle tree”. This means that the choice of wood for making these particular objects was not made by chance (Cywa 2016). Such uses of *Euonymus* sp. are consistent with the records of the use of this shrub in other parts of medieval Europe, such as at Dolny Zamek in Vilnius, Lithuania (Pukienė 2008), and at the Danish site of Svendborg (Müller 2008 and references). *Euonymus* was also used for making fork-shaped shuttles and needles used for tying and repairing fishing nets (Fig. 3, 31). Added to the group of relatively

small articles which require hardness and strength are also a hammer handle from Wawel hill (Fig. 5, column: big tools) and a comb discovered in the Rynek (market square) in Wrocław (Fig. 5, column: outfit and hygiene). These objects were made of *Cornus*, which is very heavy and as hard as *Euonymus* (Krzysik 1957). The fact that the hard wood of shrubs was not used for making larger objects may be because their branches were too small.

Spoons The material used for making small table spoons was fairly varied. *Acer* wood was the most common one, then *Fraxinus*, *Betula*, *Alnus* and *Salix*, which are all easy to work (Krzysik 1957; Serwa 1986), as well as the very hard woods of *Taxus*, *Euonymus*, *Sambucus*, *Juniperus*, *Abies* and of some rosaceous trees and shrubs. Evidently, both the ease and speed of working (more often) as well as the hardness and durability of the products were taken into consideration. It cannot be overlooked that the aesthetic values of *Taxus*, *Euonymus* and *Juniperus* woods, such as smoothness and colour, as well as the easy shaping of woodcarving details, favoured their use. This suggestion is confirmed by the wood identifications of well worked and decorated spoons that were mostly made of *Taxus*. It is worth mentioning that according to old Polish customs, spoons were generally carried under a belt (Gołębiowski 1830). In a sense, they were treated like personal equipment with an exceptional and individual character, which was constantly exposed to damage.

Turned, carved and drilled kitchen utensils The choice of raw material for making turned objects, in addition to carved and planed ones, depended not only on attributes connected with their function but also on the kind of woodwork involved. *Fraxinus*, *Alnus* and *Acer* were selected most often. The wood of these trees is fairly homogenous, straight grained and durable, but soft enough to be easily worked. These are also fairly large trees, which makes it possible to make relatively large objects from single pieces of wood. The narrow growth rings of *Fraxinus* timber make it usually considered to be soft enough to work easily, both cutting it into planks and turning (Krzysik 1957; Surmiński 1995). In the book about farming by P. Crescenzi (1571), there is a statement that *Fraxinus* was a wood used first of all for making various domestic dishes. One- and two-sided turned dishes were made of it, but the latter were also made of *Acer* timber. Also, as a result of turning wood to make bowls, etc. on a lathe, there are waste cores from the middle of the turned wood pieces. In this group of “objects” only *Fraxinus* and *Acer* were identified.

The use of *Alnus* as the main wood for making scoops and most of the beaters, used for washing cloth among other things, could be because of its exceptional durability when in permanent contact with water. It must be added that *Alnus* wood becomes mineralized when soaked in water, which

improves its strength, hardness and durability. This process is due to the precipitation of water soluble calcium and magnesium bicarbonates, which upon converting into inert salts, deposit on the cell walls of *Alnus* wood. This phenomenon is fastest in shallow standing water which warms up easily (Surmiński 1980). In the old Polish economic and technical herbarium of Gerald-Wyżycki (1845) there is a guide on how to prepare *Alnus* wood for a turner and a carpenter, according to which the wood should be put in water for 3 years in order to reach its proper hardness and durability.

Small stave-built bowls and other coopers’ goods Small stave-built bowls (Fig. 3, 5), which most probably were used mainly for eating from (Polak 1996; Wysocka 2001), were only made of softwoods, namely *Pinus*, *Picea*/*Larix* and *Abies*, which are not as strong as, for instance, *Taxus*. These woods have great (*Larix*), medium (*Pinus*) or little (*Picea*, *Abies*) hardness but are both light and easy to split, particularly *Picea* and *Pinus* (Krzysik 1957), allowing craftsmen to make thin staves from them. Interestingly, the end discs of these bowl types were made mostly from *Pinus*, while their staves were *Picea*/*Larix*. This may be explained by the rules in coopers’ craft handbooks, whereby the use of pine wood for making containers used for food storage was limited due to the strong smell. *Picea* can be used for food storage purposes because its wood has a small number of resin canals (Świdorski 1966). The use of *Picea*/*Larix* for making the side staves of containers, which have a much larger surface area than the end disc, could have reduced the influence of resin on food. No information was found about the influence of *Larix* wood on food.

Wooden hoops, used for fastening the sides of stave-built vessels, were made by hoopers. Wood analyses have shown that in order to make hoops for small stave-built bowls, thin *Salix* (willow) branches were split longitudinally (Fig. 11, 1a, b).

Ambiguous function The group of objects of undefined function includes wooden balls (Fig. 3, 11) and discs with a hole in the centre (Fig. 3, 8), which are interpreted by archaeologists as fishing equipment, such as floats and net sinkers, dish lids or items used for games and toys such as balls or rattle-boxes or wheels from baby carriages (Dziekoński and Kóčka 1939; Ostrowska 1962; Świętek 1999). In the case of these object types, wood analysis does not offer an unequivocal answer as to their use. Some balls and rings were made from heavy, hard and strong kinds of wood, such as *Quercus* and *Fraxinus* (toys?), while the others were from much lighter and more water-resistant timbers, such as *Alnus* and *Pinus* (floats?). However, the fact that these objects were most often made out of alder points to a close connection with fishing.

Fig. 11 Selected everyday objects from Polish archaeological sites; 1a, stave of a small stave-built bowl, *Pinus sylvestris* with remains of hoop made of *Salix* sp. (Szczecin-Podzamcze V/VI, inv. no. 1288, collections of the National Museum in Szczecin); 1b, transversal section of the hoop, half of the branch; 2, the structure of a peg (after Molski 1968), which joined planks of a clinker-built boat (Szczecin-Podzamcze V/VI, inv. no. 7661); 3a, wooden end disc of a basket, *Pinus sylvestris* (Szczecin-Podzamcze V/VI, inv. no. 8549, collections of the National Museum in Szczecin); 3b, sharpened end of a vertical piece of plaited woodwork, *Pinus sylvestris* (photos by K. Cywa)

Torches Torches were made of *Pinus* and *Picea/Larix* (Fig. 3, 17). The main reason for this choice was that this wood can catch fire quickly and burn with a large flame, because of the considerable quantity of resinous substances in the wood (Surmiński 1970, 1986). Highly resinous wood absorbs less water and can catch fire more easily, which could have been important, especially in rainy weather.

Musical instruments Among the items interpreted as musical instruments, the most common are tubular objects with openings (Fig. 3, 33), which according to archaeologists could be fragments of pipes or recorders. All objects of that kind, as well as tubular objects without openings, were made of thin *Sambucus* branches, which have an easily removable, exceptionally broad and spongy pith. It is interesting that the name *Sambucus* is a Latinized form of the Greek word, “sambuke”, meaning “pipe”. According to the ethnographic information about ancient Poland, in order to repel evil powers from huts and farmyards, village musicians played on pipes made of *Sambucus* (Kłosiewicz and Kłosiewicz 2011). The parts of medieval sounding boards and bodies of stringed instrument were made of various wood types, *Tilia*, *Pinus*, and *Quercus*. On the other hand, the mouthpieces of musical instruments were cut from thin *Salix* twigs or from *Picea/Larix* and *Betula*.

Pegs, pins and wedges With respect to wood types used, the most varied group was composed of pegs, pins and wedges, which were made from all available wood types, but largely from *Pinus*, *Quercus*, *Fraxinus* and *Abies*. Thin and sharpened pegs of unknown uses were made mainly of pine. Much larger items, often used in architectural elements, as well as pin-type pegs which joined, for instance, two parts of barrel lids composed of many segments, were produced from *Fraxinus* and less often *Quercus*. Dowels joining the staves of plank-built boats had a particularly interesting and complex structure. Their outer part was made of relatively soft pine wood while in the inner was a wedge of hard oak wood (Fig. 11, 2). The use of two types of wood is explained in the following way: the wedging of pegs in the planks had to be done very tightly, which could smash pine pegs (Molski 1968).

Footware A wooden patten found at the Toruń Bankowa 14/16 site represents an interesting object (Fig. 3, 28). It is a sort of wedge-heeled sole which was put on shoes for protection against street dirt (R. Uziembło, personal communication). The specimen examined was made of *Salix* sp.

Fun and entertainment On Polish archaeological sites toy boats made of pine bark have been found very often, which could easily float, just like real boats, due to the properties of the material used. Bark is a very simple material to work, and thanks to that, an attractive toy could be made of it quickly and without much work.

Baskets Some medieval baskets were wholly woven from *Pinus* and *Quercus* twigs or *Betula* bark (Fig. 3, 13), while others had wooden end discs of pine with holes around the circumference into which the ends of the basket-work were inserted (Fig. 11, 3a, b).

Floats Most floats for fishing nets (Fig. 3, 3) were cut out of pine bark. Sometimes, thick *Salix* or *Betula* bark from the lower part of the trunk was used for this purpose.

Insulation *Betula* bark was also used as a water repellant insulation. A complete chest lined with birch bark fragments for keeping cereals was found at the site of Bródno Stare (Ruszkowska et al. 2011).

Regional differences in the timbers used for making wooden articles

The pattern of wood use according to the intended function and purpose of the particular wooden articles, as mentioned above, is generally similar in all regions of Poland. However, there are some differences in composition of the

wood used in certain areas, connected with the local availability of particular trees and shrubs (Fig. 10). When considering the geobotanical variation of Polish vegetation and the limitations of the wood identification methods, one can see that regional differences in the selection of wood are best expressed in the use of *Abies*, which was an important resource, but only in southern Poland. The use of *Abies* coincides with the distribution of fir in Poland, which is mainly in mountainous areas. The northern limit of the range of *A. alba* is in central Poland (Danielewicz 2012a). *Abies* wood was found at Radom 2, Wrocław Ostrów Tumski, Wrocław Rynek, Wrocław Szewska and Oławska, Opole Ostrówek I–IV and in most sites in Kraków. According to the wood identifications, *Abies*, in addition to *Picea/Larix*, was the most frequently used kind of wood there, while in sites in Wielkopolska and Pomorze, northern Poland (Pomerania) it occurred sporadically or was totally absent. A few examples of the use of *Abies* in Pomorze Zachodnie (western Pomerania) are a spoon from Szczecin Rynek Warzywny and three objects of unknown function from Szczecin-Podzamcze V/IV and V/VI, which are conventionally described by archaeologists as icons or portable altars (Fig. 3, 15, 16, 21). Images of saints could have been placed on oval depressions in these objects (S. Słowiński, personal communication). In their general scheme these artefacts, a thin plate with a depression, are like objects discovered in the medieval cultural layers in Novgorod, which are described as mirror cases and they were also made of *Pinus* sp. (Brisbane and Hather 2007). Altars and mirrors were luxury goods and therefore they could have come from long distance trade, which developed widely in Poland as late as the 13th century (Małowist 1938; Samsonowicz 1973). The dating of the Szczecin icons/altars, from the second quarter of the 13th and third quarter of the 13th century to the end of the 14th century, fits this time period. Consequently, these objects could be evidence of the early medieval importing of *Abies* timber from southern areas.

In the case of *P. sylvestris*, *Quercus* sp., *Fraxinus excelsior*, *A. alba*, *Fagus sylvatica* and *Carpinus betulus*, a distinct correlation was observed between the distribution of sites where their wood was most intensively used and the modern distributions of these trees in Poland (Fig. 6). The number of objects made of pine or oak wood reached the mean value in several of the analysed sites, thus confirming that these timbers were widely used and easily accessible there (Ralska-Jasiewiczowa et al. 2004). A similar tendency can be seen on the map showing the use of *Fraxinus*. It is worth noting that among wood deposits which contain a large number of objects, only those from Kraków are not marked on this map, which may be explained by the fact that turned objects, which are the main products of *Fraxinus* wood working, are very rare in these deposits.

The evidence of intensive use of *A. alba* and *F. sylvatica* wood agrees with the modern distributions of fir and beech in Poland (Fig. 6). It should be mentioned that north-eastern parts of Poland, which were at least partially beyond the range of *Fagus* during medieval times (Wacnik et al. 2016), also provided the smallest number of archaeological sites and the fewest wood finds.

It is interesting that the map showing the use of *Carpinus betulus* wood, a species very poorly represented among the archaeological finds, shows that it exceeds the mean values in three sites: Ostrów Tumski in Wrocław, Ostrów Lednicki and Toruń Bankowa 14–16 (Fig. 6). This coincides with pollen investigations which indicate that there were woodlands with much hornbeam in those areas before the spread of medieval settlement (Makohonienko 2000).

The number of objects made of *Betula* sp. exceeds the mean value in two sites only. Birch is a very common tree in Poland (Danielewicz 2012a). It includes pioneer trees that spread easily on land previously cleared by human activities (Wacnik et al. 2014; Bronisz et al. 2016; Jagodziński et al. 2017), which makes access to the timber easy. Taking into consideration the fact that *Betula* wood is easy to work and hardly warps (Surmiński 1979), it was probably used by medieval craftsmen. Low representation of this wood among the everyday medieval objects may thus be connected with its poor natural durability (Surmiński 1979).

The number of items made of *Taxus baccata* wood reached the mean value only in four sites. It is worth observing that the mean number of objects of yew wood is strikingly high compared to some larger trees, such as *Fagus* or *Abies* (ESM 3), which combined with its scarcity in woodland communities (Iszkuło et al. 2016) additionally emphasises the intensive use of *Taxus* in the Middle Ages.

The information based on analysis of the relationship between the taxonomic composition of medieval wood deposits and locations of the archaeological sites indicates that in most cases the wood spectra reflect the local availability of trees and shrubs in the surroundings. These conclusions agree with the opinions of archaeologists and historians about the great importance of local production, exchange and trade in medieval Poland (Samsonowicz 1973).

Relationship between the age of the material and taxonomic diversity of the wood

Wooden objects found in medieval archaeological sites show a typological similarity, so that articles have universal forms over extended periods of time, and undergo no distinct changes (Barnycz-Gupieniec 1959; Wysocka 1999; Łosiński et al. 2003; Müller 2008). Studying medieval artefacts can lead to the question whether there were any changes in the use of timbers due to changes in the woodlands around the

sites from human activities, or to developments in wood-working crafts.

In order to compare archaeological finds from chronological periods II, III and IV, all of the objects were grouped according to the historical regions of medieval Poland (Figs. 2a, 8). This arrangement shows that in the late Middle Ages, in all regions of Poland, the number of objects made of deciduous tree and shrub wood decreased, except for *Quercus* and *Fraxinus*, whereas the use of coniferous wood remained at a similar level in the early and late Middle Ages. The composition of coniferous taxa used in the individual regions, however, changed distinctly. During the Piast period in the early Middle Ages, pine wood was most often used in Małopolska (Little Poland) and Śląsk (Silesia, southern Poland), as in other parts of the country. By the late Middle Ages the use of this wood in southern regions distinctly decreased, while that of *Picea/Larix* and *Abies* increased. In other regions of Poland, the proportion of *P. sylvestris* wood in the wood spectra did not change. Historical sources indicate that in the late Middle Ages, pine timber from Małopolska was probably exported and that this trade developed on a large scale in Poland as late as the 14th century (Danielewicz 2012b). Pine wood with narrow growth rings grown in southern Poland, as well as from Russia and Lithuania, was highly appreciated for boat building (Gerlach 2011), although the best pine timber, known as mast pine, came from Puszcza Knyszyńska, northeast Poland (Kłosiewicz and Kłosiewicz 2011).

Among the coniferous taxa, only the wood of *Taxus baccata* was poorly represented in the late Middle Ages in the whole of Poland. This agrees with historical and pollen data according to which a decline of *Taxus* took place as early as the early Middle Ages (Czartoryski 1975; Cedro 2004; Pawelec 2010; Iszkuło et al. 2016).

The use of wood in medieval Poland in relation to the other countries in eastern and central Europe

The results of the identifications of medieval archaeological wood from Polish archaeological sites show several similarities with those obtained on the past uses of wood in other parts of eastern and central Europe. In Novgorod, Russia (Brisbane and Hather 2007), about 710 km from the eastern border of Poland, the wood of *Pinus*, *Quercus* and *Fraxinus* was also used very often. *Taxus*, *Alnus* and *Picea* were present too. *Fraxinus* wood, just as in Poland, was an important timber there for making turned vessels, while *Pinus* and *Taxus* were used for making stave-built containers. *Alnus* was used for making carved and hollowed vessels, and a spade for removing snow, suggesting that this wood was used in wet conditions, just as in Polish sites. On the Žemutinė Pilie (Lower Castle) site in Vilnius, Lithuania, *Acer* was frequently used for making scoops and spoons

(Pukienė 2008). In Poland this wood was also one of the main ones used for making spoons and it was also used for plates and bowls turned on both sides. In the Žemutinė Pilie site at Vilnius, pine wood was mainly used for making parts of architectural structures, furniture and other things as well as large tools like spades. In contrast to Poland, Lithuanian craftsmen seldom used *Quercus* and *Fraxinus*, yet frequently used *Betula*. *Tilia* was found there more often than in Poland. In the Mikulčice site, Czech Republic, *Quercus*, *Acer* and *Fraxinus* were the main timbers used (Poláček et al. 2000). As in Poland, oak was used there mainly for making building structures and cooperage (barrels etc.), and *Acer* and *Fraxinus* for scoops and axe handles. Interestingly, in two cases axe handles were also made from *Tilia*. The staves of buckets were made of *Taxus* and yew was also used for these at the Devínska Nová site, Slovak Republic (Eisner 1952; Gluza 1977). The comparison of the results of wood analyses from Poland and southern Germany shows certain similarities, first of all in woodworking and object functions. For instance, in the medieval cemetery in Oberflacht (Filzer 1992), *Acer* and *Fraxinus* predominated among the turned objects, while *Quercus* was mainly used in architectural pieces, mostly planks of burial chambers. In the material from Elisenhof, the main timber used was *Quercus*, while *Taxus* and *Sambucus* appeared very often, which are two small trees or shrubs with strong wood (Müller 2008 and references).

Conclusions

Identifications of 3,867 wooden artefacts recovered from 48 archaeological sites in Poland make it possible to conclude that in the Middle Ages the choice of timber for the needs of handicrafts was deliberate and was motivated by the technological and working properties of particular kinds of wood. In each case, however, the possibility of obtaining the preferred timber was limited by its availability in the local woodlands.

Wood analyses have shown a great diversity of wood material used for making everyday objects in medieval Poland, but only some of the identified taxa were used on a large scale. Over 90% of the examined items were made of *Pinus*, *Picea/Larix*, *Fraxinus*, *Quercus*, *Taxus*, *Alnus*, *Abies*, *Acer*, *Betula*, *Salix*, *Euonymus*, *Sambucus* and *Fagus*.

The most frequently used wood was *P. sylvestris*, a widespread tree in the Polish flora, which was readily available. In addition to lightness, other useful properties such as its strength and ease of splitting, as well as its durability and ease of working, would have favoured it as a fairly universal timber. Staved vessels, both big buckets and small bowls, and also torches, were mainly made from pine. The articles which required durability and

strength were made of *Quercus*, such as furniture, barrels, architectural elements, parts of wheels and axles, spades and carpenters' club hammers. *Picea/Larix* was used for small stave-built bowls and for torches. Plates and bowls were turned from *Fraxinus*, and *Alnus* was used for making items to be exposed to prolonged contact with water, including net rings/floats, beaters, ladles and scoops.

Contrary to the common belief in the toxicity of *Taxus baccata*, it has been found that yew wood was frequently used for making big stave-built vessels. As yew wood was also used at various sites in Poland, as well as in other regions of central and eastern Europe as at Novgorod and Mikulčice, the issue of the toxicity of the wood of *T. baccata* to humans and animals requires further toxicological studies which take account of the content of various alkaloids in the wood.

It is particularly interesting that besides large trees, which nowadays play a leading role in the modern forestry industry, the wood of shrubs was fairly frequently used in the Middle Ages, such as *Euonymus* and *Sambucus*, which are not presently used either on an industrial scale or in small crafts. *Euonymus* sp. was the main wood for making spindles and *Sambucus* sp. for whistles or recorders.

The analysis of wood use, according to the locations of the sites, indicates a regional differentiation connected with the availability of particular trees and shrubs in the neighbourhoods of the sites, which were in strongholds and early urban centres. This can most clearly be seen in the use of *Abies*, which was used mainly in the parts of southern Poland which lie within the range of natural fir distribution. A few objects made of *Abies* discovered further away, in Szczecin, could be examples of trade in wooden objects or sporadic imports from distant places.

The studies have shown that the number of items made of the wood of deciduous trees and shrubs decreased in the late Middle Ages compared to the Piast period of the early Middle Ages in all of the historical regions of medieval Poland. Wood analyses also confirm historical information about the intensive use of *Taxus* in the early Middle Ages, which brought about a significant decrease of yew trees in medieval woodlands.

Similarities between Poland and other countries in central and eastern Europe are shown by the particular use of some wood taxa such as *Acer* for making spoons as in Lower Castle, Vilnius, *Taxus* for stave-built vessels, as in Novgorod, Mikulčice and Devínska Nová, *Euonymus* for making spindles, as in Žemutinė Pilie, Vilnius and in Svendborg, and *Fraxinus* as the material for making turned vessels as in Oberflacht.

Acknowledgements The paper is part of a doctoral thesis carried out under the supervision of A. Wacnik of the W. Szafer Institute of Botany, Polish Academy of Sciences (advisor) and M. Lityńska-Zajac

of the Centre for Archaeology of Hills and Uplands of the Institute of Archaeology and Ethnology, Polish Academy of Sciences (co-advisor). I warmly thank K. Wasylkowa for help during preparation of this manuscript, Z. Tomczyńska for helpful discussions about wood anatomy, S. Jędrzejewska and B.S. Szmoniewski for consultations on the chronology of the Middle Ages in Poland. I am also grateful to the anonymous reviewers for constructive comments, suggestions and amendments. The investigations were financed from the funds of the National Science Centre, Poland, conferred by decision No. DEC-2014/13/N/ST10/04881 (Grant no. 2014/13/N/ST10/04881) and partially supported by statutory funds of the W. Szafer Institute of Botany, Polish Academy of Sciences. I wish to express my gratitude to all who kindly allowed me to carry out investigations of wooden items stored in various institutions under their supervision: M. Cieślak-Kopyt, Head of Dział Archeologii Muzeum im. Jacka Malczewskiego w Radomiu (Archaeological division, Jacek Malczewski Museum in Radom); J. Górski, Director of Muzeum Archeologiczne w Krakowie (Archaeological Museum in Kraków); A. Janowski of Ośrodek Archeologii Średniowiecza Krajów Nadbałtyckich Instytutu Archeologii i Etnologii Polskiej Akademii Nauk w Szczecinie (Centre for Medieval Archaeology of the Baltic Region of the Institute of Archaeology and Ethnology, Polish Academy of Sciences, in Szczecin); L. Karwowski, Director of Muzeum Narodowe w Szczecinie (National Museum in Szczecin); J.K. Ostrowski, Director of Zamek Królewski na Wawelu (Wawel Royal Castle); M. Rubnikowicz, Director of Muzeum Okręgowego w Toruniu (District Museum in Toruń) and to M. Wołoszyn of Ośrodek Archeologii Gór i Wyżyn Instytutu Archeologii i Etnologii Polskiej Akademii Nauk w Krakowie (Centre for Archaeology of Hills and Uplands of the Institute of Archaeology and Ethnology, Polish Academy of Sciences, in Kraków). I thank also the following people for rendering accessible the archaeological documentation of the items studied, J. Firlet, P. Kajfasz, A.B. Kowalska, A. Kowalówka, E. Skubicha, S. Słowiński, M. Szewczyk-Wojtasiewicz, A. Tyniec, A. Uciechowska-Gawron and R. Uziębło.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

- Amann G (2009) Drzewa i krzewy, Kieszonkowy atlas, Seria flora i fauna lasów [Trees and shrubs, pocket atlas, a series on the flora and fauna of woodlands, in Polish]. Multico Oficyna Wydawnicza, Warszawa
- Anagnost SA, Meyer RW, De Zeeuw C (1994) Confirmation and significance of Bartholin's method for the identification of the wood of *Picea* and *Larix*. IAWA J 15:171–184
- Arens AM, Anaebere TC, Horng H, Olson K (2016) Fatal *Taxus baccata* ingestion with perimortem serum taxine B quantification. Clin Toxicol 54:878–880
- Barnycz-Gupieniec R (1959) Naczynia drewniane z Gdańska z X–XIII wieku [10th–13th century wooden vessels from Gdańsk, in Polish, with French summary]. Acta Archaeologica Universitatis Lodziensis 8:1–109
- Barnycz-Gupieniec R (1961) Tokarstwo i bednarstwo z XIII–XIV wieku w osadzie miejskiej w Gdańsku. [The turnery and coopers in the town of Gdańsk in the 13th–15th centuries, in Polish, with English summary]. Materiały Zachodnio-Pomorskie 7:391–434

- Benkova VE, Schweingruber FH (2004) Anatomy of Russian woods. Haupt, Wien
- Berny P, Caloni F, Croubels S, Sachana M, Vandenbroucke V, Davanzo F, Guitart R (2010) Animal poisoning in Europe. Part 2: companion animals. *Vet J* 183:255–259
- Bobik I (2012) Zabytki drewniane z późnośredniowiecznej latryny [Wooden artefacts from a late medieval latrine, in Polish, with German summary]. *Archeologia Stargardu* 1:185–195
- Boratyńska K, Dolatowski J (1991) Systematyka i geograficzne rozmieszczenie [Systematics and geographical distribution, in Polish, with English summary]. In: Białobok S (ed) *Lipy Tilia cordata* Mill *Tilia platyphyllos* Scop. Nasze Drzewa Leśne XV. Polska Akademia Nauk, Instytut Dendrologii, Arkadia, Poznań, pp 21–55
- Brisbane M, Hather J (eds) (2007) Wood use in medieval Novgorod. (The archaeology of medieval Novgorod 2. Oxbow Books, Oxford
- Bronisz K, Strub M, Cieszewski C, Bijak S, Bronisz A, Tomusiak R, Wojtan R, Zasada M (2016) Empirical equations for estimating aboveground biomass of *Betula pendula* growing on former farmland in central Poland. *Silva Fenn.* <https://doi.org/10.14214/sf1559>
- Buko A (2011) Archeologia Polski wczesnośredniowiecznej. Odkrycia—hipotezy—interpretacje. [The archaeology of early medieval Poland. Discoveries—hypotheses—interpretations, in Polish with English summary]. Wydawnictwo TRIO, Warszawa
- Bukowska-Gedigowa J, Gediga B (1986) Wczesnośredniowieczny gród na Ostrówku w Opolu. [Early medieval stronghold in Ostrówek in Opole, in Polish, with German summary]. (Polskie Badania Archeologiczne 25) Zakład Narodowy im Ossolińskich, Wydawnictwo Polskiej Akademii Nauk, Instytutu Historii Kultury Materialnej, Wrocław
- Cedro A (2004) Wpływ warunków klimatycznych na kształtowanie się przyrostów radialnych cisa pospolitego (*Taxus baccata* L.) w rezerwacie Cisy staropolskie w Wierchlesie [Influence of climatic conditions on the radial increments of yew (*Taxus baccata* L.) from Cisy Staropolskie Reserve in Wierchles, in Polish, with English summary]. *Prace Geograficzne IGiPZ PAN* 200:47–57
- Cnotliwy E, Leciejewicz L, Łosiński W (eds) (1983) Szczecin we wczesnym średniowieczu, Wzgórze Zamkowe. [Szczecin in the Early Middle Ages, Castle Hill (Wzgórze Zamkowe), in Polish]. (Polskie Badania Archeologiczne 23) Zakład Narodowy im Ossolińskich, Wydawnictwo Polskiej Akademii Nauk, Wrocław
- Crescenzi P (1571) Piotra Crescentyna, O pomnożeniu i rozkrzewieniu wszelkich Pożytkow Książ Dwoienaście: Ludziom Stanu każdego/którzyby się gospodarstwem bawili/wielce potrzebne i użyteczne [Twelve volumes on the multiplication and spreading of any yield: Greatly needed by and useful for people of all classes who try their hand at farming, in Polish]. Wydawnictwo Stanisława Szarfenberga, Kraków
- Cywa K (2016) Znaczenie użytkowe drewna *Euonymus* sp. w średniowiecznej Polsce [Uses of spindle tree *Euonymus* sp. wood in medieval Poland (in Polish, English summary)]. *Fragmenta Floristica et Geobotanica Polonica* 23:321–347
- Cywa K (2017) Analysis of wood and bark remains from the site in Czermino [Analiza pozostałości drewna i kory ze stanowiska w Czerminie]. In: Florek M, Wołoszyn M (eds) The early medieval settlement complex at Czermino in the light of results from past research (up to 2010). Material evidence 1. Wczesnośredniowieczny zespół osadniczy w Czerminie w świetle wyników badań dawnych (do 2010). Podstawy źródłowe, vol 1]. *U źródeł Europy Środkowo-Wschodniej/Frühzeit Ostmitteleuropas*, Tom 2, część 1/Band 2, Teil 1, Kraków-Leipzig-Rzeszów-Warszawa, pp 499–509 (in press)
- Czartoryski A (1975) Z przeszłości cisa [Yew in the past, in Polish]. In: Białobok S (ed) *Cis pospolity Taxus baccata* L. Nasze Drzewa Leśne III. Polska Akademia Nauk, Instytut Dendrologii, Państwowe Wydawnictwo Naukowe, Warszawa-Poznań, pp 134–140
- Danielewicz W (2012a) Drzewa leśne Polski [Polish woodland trees, in Polish]. In: Matuszkiewicz W, Sikorski P, Szwed W, Wierzba M (eds) *Zbiorowiska roślinne Polski, Lasy i zarośla, Ilustrowany przewodnik* [Polish plant communities, woodland and thickets, illustrated guide, in Polish]. Wydawnictwo Naukowe PWN, Warszawa, pp 21–61
- Danielewicz W (2012b) Zagrożenia i ochrona zbiorowisk leśnych [Threats to and protection of woodland communities, in Polish]. In: Matuszkiewicz W, Sikorski P, Szwed W, Wierzba M (eds) *Zbiorowiska roślinne Polski, Lasy i zarośla, Ilustrowany przewodnik* [Polish plant communities, woodland and thickets, illustrated guide, in Polish]. Wydawnictwo Naukowe PWN, Warszawa, pp 74–86
- Dzieduszycki W (1976) Wykorzystywanie surowca drzewnego we wczesnośredniowiecznej i średniowiecznej Kruszwicy [The use of timber in early medieval and medieval Kruszwica, in Polish, with German summary]. *Kwartalnik Historii Kultury Materialnej* 24:35–54
- Dziekoński T, Kóčka W (1939) Przedmioty drewniane z grodu gnieźnieńskiego [Wooden artefacts from Gniezno stronghold, in Polish]. In: Kostrzewski J (ed) *Gniezno w zarysie dziejów (od VIII–XII wieku) w świetle wykopalisk* [Gniezno at the dawn of history (from 8th to 12th centuries) in the light of excavations, in Polish]. (Biblioteka Prehistoryczna 4) Polskie Towarzystwo Prehistoryczne, Poznań, pp 136–145
- Earwood C (2002/2003) Wooden artefacts from the medieval town of Dawidgródek. *Belarus Wiadomości Archeologiczne* 56:393–430
- Eisner J (1952) *Devínska Nová Ves* [Devínska Nová Ves, in Czech]. Nakl Slovenskej akademie vied a umení, Bratislava
- Falencka-Jabłońska M (2004) Conservation of common yew (*Taxus baccata* L.) in Poland. In: Vančura K, Fady B, Koskela J, Mátyás C (eds) *Conifers network, Report of the second (20–22 September 2001, Valsáfn, Spain) and third (17–19 October 2002, Kostrzyca, Poland) meetings*. International Plant Genetic Resources Institute, Rome, pp 31–34
- Fejfer M (2011) Monitorowanie warunków zalegania pozostałości osady kultury łużyckiej w Biskupinie jako przykład ochrony zabytków drewnianych na mokrym stanowisku archeologicznym [Monitoring of depositional conditions of the Lusatian Culture settlement finds in Biskupin as an example of timber monuments protection in a wet archaeological site, in Polish, with English summary]. In: Pelczyk A, Wyrwa AW (eds) *Konserwacja drewna zabytkowego między teorią a praktyką*. Biblioteka Studiów Ledenickich 23. Muzeum Pierwszych Piastów na Lenicy, Dziekanowice-Lednica, 65–77
- Filzer P (1992) Die Holzproben von Oberflacht. In: Schick S (ed) *Das Gräberfeld der Merowingerzeit bei Oberflacht (Gemeinde Seitingen, Lkr. Tuttlingen)*. Theiss, Stuttgart, pp 121–127
- Gale R, Cutler D (2000) *Plants in archaeology: identification manual of vegetative plant materials used in Europe and the Southern Mediterranean to c. 1500*. Westbury Publishing and the Royal Botanic Gardens, Kew, Otley
- Gerald-Wyżycki J (1845) *Zielnik ekonomiczno-techniczny, czyli opisanie drzew, krzewów i roślin dziko rosnących w kraju, jako też przyswojonych, z pokazaniem użytku ich w ekonomice, rękodzielnictwie, fabrykach i medycynie domowej, z wyszczególnieniem jadowitych i szkodliwych, oraz mogących służyć ku ozdobie ogrodów i mieszkań wiejskich ułożony dla gospodarzy i gospodyń* [An economic and technical herbarium describing the trees, bushes and plants growing wild in the country as well as those assimilated, demonstrating their use in economy, handicraft, factories and home medicine, detailing poisonous and

- harmful species, and those that can be used as decoration of gardens and rural dwellings; arranged for hosts and hostesses, in Polish], vol 1. Drukiem Józefa Zawadzkiego, Wilno
- Gerlach K (2011) Drewno szkatułnicze do końca epoki żagla [Boatbuilding timber until the culmination of the 'Era of Sail', in Polish]. Warszawa Firma Wydawnicza, Warszawa
- Gluz I (1977) Szczątki drewna z wczesnośredniowiecznego cmentarzyska w Krakowie na Zakrzówku. [Wood remains from an early medieval cemetery in Zakrzówek, Krakow, in Polish, with French summary]. *Materiały Archeologiczne* 17:201–203
- Gluz I (2009) Zabytki drewniane z badań archeologicznych prowadzonych na Małym Rynku w Krakowie w 2007 roku—analiza paleobotaniczna. [Palaeobotanical analysis of wooden artefacts from archaeological research conducted in Mały Rynek in Krakow in 2007, Polish, with English summary]. *Materiały Archeologiczne* 37:103–105
- Gorczyński T, Molski B, Pogorzelska I (1969) Struktura drewna z wykopaliska "Rynek Warzywny" w Szczecinie [Wood structure from the archaeological excavation "Vegetable Market" in Szczecin in Poland, in Polish, with English summary]. *Rocznik Dendrologiczny* 23:5–38
- Gostwicka J (1965) Dawne meble Polskie [Old Polish furniture, in Polish, with French summary]. Wydawnictwo Arkady, Warszawa
- Gołębowski Ł (1830) Domy i dwory, przy tym opisanie apteczki, kuchni, stołów, uczt, biesiad, trunków i pijatyki; łóżek, pościeli, ogrodów, powozów i koni; błaznów, karłów, wszelkich zwyczajów dworskich i różnych obyczajowych szczegółów [Houses and mansions, including the description of the first-aid kit, kitchen, tables, feasts and banquets, liquors and carousals; beds, bedding, gardens, carriages and horses; clowns, dwarves, all types of courtly customs and various societal curiosities, in Polish]. Druk N. Glücksberga, Warszawa
- Grabska M (1979) Przedmioty drewniane [Wooden objects, in Polish]. In: Cofta-Broniewska A (ed) *Zaplecze gospodarcze Konwentu OO. Franciszkanów w Inowrocławiu od połowy 14 w* [The base of supplies of the monastery of the Franciscan order in Inowrocław, in Polish]. Wydawnictwo Naukowe Uniwersytetu im Adama Mickiewicza w Poznaniu, Poznań, pp 117–144
- Greguss P (1945) Bestimmung der mitteleuropäischen Laubhölzer und Sträucher auf xylotomischer Grundlage. Ungarisches Naturwissenschaftliches Museum, Hungarian Museum of Natural History, Budapest
- Grobosch T, Schwarze B, Stoecklein D, Binscheck T (2012) Fatal poisoning with *Taxus baccata*. Quantification of paclitaxel (taxol A), 10-Deacetyl taxol, baccatin III, 10-deacetyl baccatin III, cephalomannine (taxol B), and 3,5-dimethoxyphenol in body fluids by liquid chromatography–tandem mass spectrometry. *J Anal Toxicol* 36:36–43
- Grupa M (2000) Sprzęt i wyposażenie gospodarstwa domowego [Household inventory and equipment, in Polish, with English summary]. In: Kurnatowska Z (ed) *Wczesnośredniowieczne mosty przy Ostrowie Lednickim* [Early medieval bridges at Ostrów Lednicki, in Polish], *Mosty traktatu gnieźnieńskiego. Biblioteka Studiów Lednickich* 5, vol 1. Muzeum Pierwszych Piastów na Lednicy, Lednica-Toruń, pp 139–162
- Gärtner H, Schweingruber FH (2013) Microscopic preparation techniques for plant stem analysis. Kessel, Remagen-Oberwinter
- Gędek M (2015) Atlas historii Polski [Atlas of Polish history, in Polish]. Bellona, Warszawa
- Głosek M, Kajzer L (1977) Łuk średniowieczny znaleziony w Brzegu [Medieval bow discovered in Brzeg, in Polish]. *Silesia Antiqua* 19:241–250
- Głosek M, Uciechowska-Gawron A (2009/2010) Wczesnośredniowieczna tarcza z podgrodzia w Szczecinie. [An early medieval shield from the borough in Szczecin (Polish, with English summary)] *Materiały. Zachodniopomorskie Nowa Seria* 6/7:269–284
- Iszkuło G, Pers-Kamczyc E, Nalepka D, Rabska M, Walas Ł, Dering M (2016) Postglacial migration dynamics helps to explain current scattered distribution of *Taxus baccata*. *Dendrobiology* 76:81–89
- Iwaszczuk U (2014) Animal husbandry on the Polish territory in the Early Middle Ages. *Quat Int* 346:69–101
- Jagielska I (2009/2010) Badania i konserwacja drewnianej tarczy ze szczecińskiego Podzamcza [The study and conservation of a wooden shield from Podzamcze in Szczecin, in Polish]. (Materiały Zachodniopomorskie Nowa Seria, z. 1. *Archeologia* 6/7:285–297
- Jagodziński AM, Zasada M, Bronisz K, Bronisz A, Bijak S (2017) Biomass conversion and expansion factors for a chronosequence of young naturally regenerated silver birch (*Betula pendula* Roth) stands growing on post-agricultural sites. *For Ecol Manage* 384:208–220
- Jankowski J (2008) Kusza i łuk, rzemiosło średniowieczne i współczesne [Crossbow and bow, medieval and contemporary crafts, in Polish]. Wydawnictwo Replika, Zakrzewo
- Kite GC, Rowe ER, Veitch NC, Turner JE, Dauncey EA (2013) Generic detection of basic taxoids in wood of European Yew (*Taxus baccata*) by liquid chromatography–ion trap mass spectrometry. *J Chromatogr B* 915–916:21–27
- Kluk JK (1805) Dykcjonarz roślinny, w którym podług układu Linneusza są opisane rośliny nie tylko krajowe, dzikie, pożyteczne albo szkodliwe: na roli, w ogrodach, oranżeryach utrzymywane: ale oraz y cudzoziemskie, któreby w kraju pożyteczne bydź mogły: albo z których mamy lekarstwa, korzenie, farby, etc albo które jakową nadzwyczajność w sobie mają: ich zdatności lekarskie, ekonomiczne, dla ludzi, koni, bydła, owiec, pszczoł, etc utrzymywanie, etc Z poprzedzającym wykładem słów Botanicznych i kilkorakim na końcu Reiestrem [A lexicon of plants where plants are described using the Linnaean taxonomy, not only those in the country, wild, beneficial or harmful, growing in the field the garden or kept in orangeries, but also foreign ones, which could be put to good use in the country or can be used to make medicine, roots, paint, etc, or which contain some special properties: medical, economic, for people, horses, cattle, sheep, bees, etc, preceded by a list of botanical terms and with a register added at the end, Polish, vol 1. Drukarnia Xieży Piarów, Warszawa
- Kocięcki S, Zdanowski A, Kolk A, Rządowski S, Sobczak R (eds) (1991) *Mała encyklopedia leśna* A little encyclopaedia of the forest, in Polish]. PWN, Warszawa
- Kokociński W (2004) Drewno pomiary właściwości fizycznych i mechanicznych [Wood—measurements of physical and mechanical properties, in Polish]. Prodrak, Poznań
- Kondracki J (2009) Geografia regionalna Polski [Regional geography of Poland, in Polish]. Wydawnictwo Naukowe PWN, Warszawa
- Konopski M (2016) Środowisko przyrodnicze, Zasięgi wybranych gatunków drzew [Natural environment, the ranges of selected trees, in Polish]. In: Bański J (ed) *Atlas obszarów wiejskich w Polsce* [Atlas of rural areas in Poland, in Polish], IGI PAN, Warszawa. <https://www.igipzpan.pl/atlas-obszarow-wiejskich-rozdzial1.html>. Accessed 10 Oct 2016
- Kornaś (1972) Wpływ człowieka i jego gospodarki na szatę roślinną Polski. Flora synantropijna [The influence of man and his economy on Polish vegetation. Synanthropic flora, in Polish]. In: Szafer W, Zarzycki K (eds) *Szata Roślinna Polski* [The flora of Poland, in Polish], vol 1. Państwowe Wydawnictwo Naukowe, Warszawa, pp 95–127
- Kowalska AB, Dworaczek M (2011) Szczecin wczesnośredniowieczny, Nadodrzańskie centrum [Early medieval Szczecin, centre by the river Oder in Polish, with English summary]. (Seria *Origines Polonorum* 5) Fundacja na rzecz Nauki Polskiej. Instytut Archeologii i Etnologii PAN, Wydawnictwo TRIO, Warszawa

- the Vilnius Lower Castle, in Lithuanian, with English summary]. *Lietuvos pilys* 4:95–111
- Puziuk J, Tyniec A (2013) Buławy średniowieczne z ul Sławkowskiej 17 w Krakowie [Medieval maces from 17 Sławkowska St in Kraków, in Polish, with English summary]. *Materiały Archeologiczne* 39:33–53
- Pyszyński W (2001) Anatomiczna analiza oraz stan zachowania ścian komórkowych zabytków drewnianych [Anatomical analysis and preservation status of cell walls of wooden artefacts, in Polish]. *Wratislavia Antiqua* 3:211–221
- Ralska-Jasiewiczowa M, Latałowa M, Wasylukowa K, Tobolski K, Madeyska E, Wright HE Jr, Turner C (eds) (2004) Late Glacial and Holocene history of vegetation in Poland based on isopollen maps. W: Szafer Institute of Botany, Polish Academy of Sciences, Kraków
- Ray CD (2017) Toxicity of yew wood and roots. A case study of yew toxicity in fresh and aged yew roots and stem. In: Penn State Extension, The Pennsylvania State University 2017. <http://extension.psu.edu/natural-resources/forests/woodpro/tech-notes/toxicity-of-yew-wood-and-roots>. Accessed 2 Feb 2017
- Richling A (2009) Położenie fizycznogeograficzne [Physico-geographical location, in Polish]. In: Richling A, Ostaszewska K (eds) *Geografia fizyczna Polski* [Physical geography of Poland, in Polish]. Wydawnictwo Naukowe PWN, Warszawa
- Robak Z (2009) Wczesnośredniowieczny wóz w Polsce [An early medieval cart in Poland, in Polish, English summary]. *Zborník Filozofickej Fakulty Univerzity Komenského* 26:175–188
- Rulewicz M (1958) Wczesnośredniowieczne zabawki i przedmioty do gier z Pomorza Zachodniego (z badań prowadzonych w latach 1947–1958) [Early medieval toys and game-related objects from western Pomerania (research conducted in 1947–1958), in Polish]. *Materiały Zachodniopomorskie* 4:303–354
- Ruszkowska M, Szewczuk U, Wójcik A, Piotrowski A (2011) Zespół osadniczy na Bródnie: Wczesnośredniowieczny kompleks osadniczy na Bródnie w świetle badań archeologicznych [Settlement complex in the Bródno area: Early medieval settlement complex in Bródno in the light of archaeological research, in Polish]. <http://panoramavarsoviapl/varsovia/index.php-frame=main&mapa=0&item=140&top=48.htm>. Accessed 15 Apr 2016
- Salamon M, Waško A (2000) Encyklopedia historyczna świata vol 4: Średniowiecze. [The world's historical encyclopaedia, vol 4, The Middle Ages, in Polish] Agencja Publicystyczno-Wydawnicza Opres, Kraków
- Samojlik T (2005) Drzewo wielce użyteczne—historia lipy drobnolistnej (*Tilia cordata*) w Puszczy Białowieskiej [A tree of many uses—the history of small-leaved lime (*Tilia cordata*) in Białowieża Primeval Forest, in Polish]. *Rocznik Dendrologiczny* 53:55–64
- Samsonowicz H (1973) Przemiany osi drożnych w Polsce późnego średniowiecza (Road axis transformation in Poland in the late Middle Ages, in Polish, with French summary). *Przegląd Historyczny* 64:697–716
- Schweingruber FH (1978) *Mikroskopische Holzanatomie*. Zürcher AG, Zug
- Schweingruber FH, Börner A, Schulze ED (2011) *Atlas of stem anatomy in herbs, shrubs and trees*, vol 1. Springer, Berlin
- Serwa Z (1986) *Galanteria drzewna* [Wood-craft items, technology, in Polish]. Technologia. Wydawnictwa Szkolne i Pedagogiczne, Warszawa
- Sönke L (2000) Wald und Mensch im Mittelalter: Aspekte einer historischen Ökologie. In: Iwańczak W, Bracha K (eds) *Człowiek i przyroda w średniowieczu i we wczesnym okresie nowożytnym*. Wydawnictwo DIG, Warszawa, pp 161–171
- Słowiński S (2004) Wpływy skandynawskie w dekoracji drewnianych przedmiotów codziennego użytku ze szczecińskiego podzamcza [Scandinavian influence in the decoration of daily wooden objects from the Szczecin Podzamcze site, in Polish, with German summary]. In: Glińska M, Kroman K, Makala R (eds) *Terra Transoderana, Sztuka Pomorza nadodrzańskiego i dawnej Nowej Marchii w średniowieczu, Materiały z seminarium naukowego poświęconego jubileuszowi 50-lecia pracy w muzealnictwie szczecińskim Zofii Krzymuskiej-Fafius, 7–8 czerwca 2002* [Terra Transoderana, The art of Pomerania and the former Neumark in the Middle Ages; materials from a scientific seminar devoted to the celebration of 50 years' museum work of Zofia Krzymuska-Fafius, in Polish]. *Stowarzyszenie Historyków Sztuki, Oddział Szczeciński, Szczecin*, pp 189–202
- Stępnik T (1996) Średniowieczne wyroby drewniane z Ostrowa Lednickiego—analiza surowcowa [Medieval wooden objects from Ostrow Lednicki—raw material analysis, in Polish, with German summary]. *Studia Lednickie* 4:261–296
- Stępnik T (2013) Drewniane toporzyska w świetle analizy surowcowej [Wooden axe handles in the light of raw material analysis, in Polish]. In: Sankiewicz P, Wyrwa AM (eds) *Topory średniowieczne z Ostrowa Lednickiego i Gieczy* [Medieval axes from Ostrow Lednicki and Giecz, in Polish] (Biblioteka Studiów Lednickich Fontes 2). Muzeum Pierwszych Piastów na Lednicy, Lednogóra, pp 283–295
- Stępnik T (2014) Wczesnośredniowieczne zabytki drewniane z Wolina w świetle analizy surowcowej [Early medieval wooden artefacts from Wolin in the light of a raw material analysis, in Polish, with German summary]. In: Stanisławski B, Filipowiak W (eds) *Wolin wczesnośredniowieczny* [Early medieval Wolin, in Polish], vol 2. (Seria Origines Polonorum 7) Fundacja na rzecz Nauki Polskiej, Instytut Archeologii i Etnologii Polskiej Akademii Nauk, Wydawnictwo TRIO, Warszawa, pp 171–194
- Surmiński J (1970) Właściwości techniczne i możliwości użytkowania [Technical qualities and the possibilities of utilization, in Polish, with English summary]. In: Białobok S (ed) *Sosna zwyczajna Pinus sylvestris L. (Nasze Drzewa Leśne 1)* Polska Akademia Nauk, Instytut Dendrologii. Państwowe Wydawnictwo Naukowe, Warszawa-Poznań, pp 309–331
- Surmiński J (1979) Właściwości techniczne drewna brzozy i możliwości jego użytkowania [Technical properties of the wood, in Polish, with English summary]. In: Białobok S (ed) *Brzoza Betula L. (Nasze Drzewa Leśne 7)* Polska Akademia Nauk, Instytut Dendrologii. Państwowe Wydawnictwo Naukowe, Warszawa-Poznań, pp 355–379
- Surmiński J (1980) Właściwości techniczne drewna olszy i możliwości jego wykorzystania [Technical properties of alder wood and possibilities of its utilization, in Polish, with English summary]. In: Białobok S (ed) *Olsze Alnus Mill. (Nasze Drzewa Leśne 8)* Polska Akademia Nauk, Instytut Dendrologii. Państwowe Wydawnictwo Naukowe, Warszawa-Poznań, pp 325–341
- Surmiński J (1986) Właściwości techniczne i możliwości użytkowania drewna modrzewia [Technical properties and possibilities of use of larch, in Polish, with English summary] In: Białobok S (ed) *Modrzewie Larix Mill. (Nasze Drzewa Leśne 6)* Polska Akademia Nauk, Instytut Dendrologii, Państwowe Wydawnictwo Naukowe, Warszawa-Poznań, pp 562–576
- Surmiński J (1990) Właściwości techniczne i możliwości zastosowania drewna [Technical properties of beech wood and possibilities of its utilization, in Polish with English summary] In: Białobok S (ed) *Buk zwyczajny Fagus sylvatica L. (Nasze Drzewa Leśne 10)* Polska Akademia Nauk, Instytut Dendrologii, Państwowe Wydawnictwo Naukowe, Warszawa-Poznań, pp 598–613
- Surmiński J (1991) Właściwości techniczne i możliwości zastosowania drewna lipowego [Technical properties of wood and possibilities of use of the lime-tree wood, in Polish, with English summary]. In: Białobok S (ed) *Lipy Tilia cordata Mill Tilia platyphyllos*

- Scop. (Nasze Drzewa Leśne 15) Polska Akademia Nauk. Instytut Dendrologii, Arkadia, Poznań, pp 374–383
- Surmiński J (1993) Właściwości techniczne i możliwości zastosowania drewna [Technical properties of wood and possibilities of its utilization, Polish, with English summary] W. In: Bugała W (ed) Grab zwyczajny *Carpinus betulus* L. (Nasze Drzewa Leśne 9) Polska Akademia Nauk, Instytut Dendrologii, Sorus, Poznań-Kórnik, pp 326–330
- Surmiński J (1995) Właściwości techniczne i możliwości zastosowania drewna jesionowego [Technical properties of wood and possible uses of ash wood, in Polish, with English summary]. In: Bugała W (ed) Jesion wyniosły *Fraxinus excelsior* L. (Nasze Drzewa Leśne 17) Polska Akademia Nauk, Instytut Dendrologii. Sorus, Poznań-Kórnik, pp 469–480
- Świderski J (1995) Produkcja wyrobów bednarskich [Coopers' production craft, in Polish]. Wydawnictwo Przemysłu Lekkiego i Spożywczego, Warszawa
- Świątek K (1999) Naczynia i drobne przedmioty drewniane [Vessels and small wooden items, in Polish]. *Wratislavia Antiqua* 1:105–119
- Szczuka J, Żurowski J (1999) Materiałoznawstwo przemysłu drzewnego [Material science of the wood industry, in Polish]. Wydawnictwa Szkolne i Pedagogiczne, Warszawa
- Szulta W (2000) Narzędzia rolnicze i gospodarskie [Farming and household tools, in Polish, with English summary]. In: Kurnatowska Z (ed) Wczesnośredniowieczne mosty przy Ostrowie Lednickim. Mosty traktatu gnieźnieńskiego. (Biblioteka Studiów Lednickich 5), vol 1. Muzeum Pierwszych Piastów na Lednicy, Lednica-Toruń, pp 105–137
- Theodoridis G, Verpoorte R (1996) Taxol analysis by high performance liquid chromatography: a review. *Phytochem Anal* 7:169–184
- Tokarski W (2000) Militaria—broń miotająca, obuchowa i drzewcowa oraz elementy rzędu końskiego i oporządzenia jeździeckiego [Military equipment—projectile, flail and shaft, weapons, elements of harness and rider's equipment, in Polish, with English summary]. In: Kurnatowska Z (ed) Wczesnośredniowieczne mosty przy Ostrowie Lednickim. Mosty traktatu gnieźnieńskiego. (Biblioteka Studiów Lednickich 5), vol 1. Muzeum Pierwszych Piastów na Lednicy, Lednica-Toruń, pp 77–103
- Trzeciński M (2000) Kultura materialna średniowiecznego Płocka [Material culture of medieval Płock, in Polish]. In: Gołębniak A (ed) Historia Płocka w ziemi zapisana. Podsumowanie wyników dotychczasowych badań archeologicznych [The history of Płock written in the land. Summary of the results of archaeological research conducted thus far, in Polish]. Stowarzyszenie Starówka Płocka, Płock, pp 116–118
- Wacnik A, Kupryjanowicz M, Mueller-Bieniek A, Karczewski M, Cywa K (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. *Veget Hist Archaeobot* 23:439–459
- Wacnik A, Madeja J, Nalepka D (2013) *Tilia* L.—Lime. In: Obidowicz A, Madeyska E, Turner C (eds) Postglacial history of vegetation in the Polish part of the western Carpathians based on isopollen maps. W. Szafer Institute Of Botany, Polish Academy of Sciences, Kraków, pp 141–150
- Wacnik A, Tylmann W, Bonk A, Goslar T, Enters D, Meyer-Jacob C, Grosjean M (2016) Determining the responses of vegetation to natural processes and human impacts in north-eastern Poland during the last millennium: combined pollen, geochemical and historical data. *Veget Hist Archaeobot* 25:479–498
- Warywoda A (1957) Drzewa użytkowe w architekturze przestrzennej i przemyśle. Ważniejsze gatunki iglaste i liściaste produkujące drewno i inne surowce znane na międzynarodowych rynkach handlowych [Trees used in spatial architecture and industry; major species of coniferous and deciduous trees used for wood and other raw materials known in international markets, in Polish]. (Encyklopedia techniczna 1) Krakowskie Zakłady Graficzne, Kraków
- Wasylikowa K (1958) Szczątki roślinne ze średniowiecznego zabytku Krakowa [Plant remains from a medieval historical site in Krakow, in Polish, with English summary]. *Monographiae Botanicae* 7:135–155
- Wasylikowa K (1978) Plant remains from Early Medieval time found on the Wawel Hill in Kraków. *Acta Palaeobot* 19:115–200
- Wasylikowa K (1991) Roślinność wzgórza wawelskiego we wczesnym i późnym średniowieczu na podstawie badań paleobotanicznych [Vegetation of the Wawel Hill in early and late Middle Ages on the basis of palaeobotanical studies, in Polish, with English summary]. *Studia do Dziejów Wawelu* 5:93–131
- Wasylikowa K (2004) Present-day natural environment of Poland. In: Ralska-Jasiewiczowa M, Latałowa M, Wasylikowa K, Tobolski K, Madeyska E, Wright HE Jr, Turner C (eds) Late Glacial and Holocene history of vegetation in Poland based on isopollen maps. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, pp 13–18
- Wilgocki E (1995) Drewniany posążek ze szczecińskiego Podzamcza [A wooden figure from Szczecin-Podzamcze, in Polish, with English summary]. *Przegląd Archeologiczny* 43:187–190
- Wilson CR, Sauer J, Hooser SB (2001) Taxines: a review of the mechanism and toxicity of yew (*Taxus* spp.) alkaloids. *Toxicon* 39:175–185
- Wołkowyci D (2010) Zróżnicowanie szaty roślinnej pogranicza Europy środkowej i północno-wschodniej [Diversity of the flora at the border of central and north-eastern Europe, in Polish]. In: Obidziński A (ed) Z Mazowsza na Polesie i Wileńszczyznę: Zróżnicowanie i ochrona szaty roślinnej pogranicza Europy środkowej i północno-wschodniej [From Mazovia to Polesie and the Vilnius region: diversification and preservation of the flora at the border of central and north-eastern Europe, in Polish]. Monografia sesji terenowych LV zjazdu Polskiego Towarzystwa Botanicznego, Planta in vivo, in vitro et in silico. Polskie Towarzystwo Botaniczne, Warszawa
- Woźnicka Z (1961) Wyroby bednarskie i tokarskie średniowiecznego Międzyrzecza [Coopers' and turners' products from the medieval site of Międzyrzecz in Polish, with English summary]. Prace Komisji Archeologicznej (Poznańskie Towarzystwo Przyjaciół Nauk 5, Zeszyt 1). Państwowe Wydawnictwo Naukowe, Poznań
- Wysocka I (1999) Naczynia i drobne przedmioty drewniane z Wrocławskiego Rynku [Vessels and small wooden objects from the market square in Wrocław, in Polish, with English summary]. *Mediaevalia Archaeologia* 1:101–124
- Wysocka I (2001) Wyroby drewniane produkcja i dystrybucja. *Wratislavia Antiqua* 3:147–208
- Zaitz E (2006) Sprawozdanie z badań archeologicznych prowadzonych w Krakowie w 2004 r. przy przebudowie nawierzchni płyty Rynku Głównego po zachodniej stronie Sukiennic [Report from archaeological excavations conducted in Krakow in 2004 while rebuilding the surface of the main market square on the west side of the Cloth Hall, in Polish, with English summary]. *Materiały Archeologiczne* 36:79–142
- Zielski A (1993) Rodzaje drewna oznaczone na podstawie przedmiotów drewnianych i resztek mostów w Jeziorze Lednickim, woj. Poznańskie [Tree types determined on the basis of wooden artefacts and bridge remains from the Lednica lake, in Polish, with English summary]. *Nauki Humanistyczno-Społeczne* 249:135–137 (Acta Universitatis Nicolai Copernici, Archeologia 21)