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The proposal of a new provisional border of range of the acidophilous oak forest *Calamagrostio arundinaceae-Quercetum petraeae* Hartm. 1934 Scam. et Pass. 1959 in central Poland

Zaniewski Piotr T.[1] ✉, *Ciurzycki Wojciech*[1], *Zaniewska Ewa*[2]

[1] Warsaw University of Life Sciences – SGGW, Institute of Forest Sciences, Department of Forest Botany, Nowoursynowska 159, 02-776 Warszawa, Poland, e-mail: piotr_zaniewski@sggw.edu.pl

[2] Warsaw University of Life Sciences – SGGW, Institute of Horticultural Sciences, Department of Environmental Protection and Dendrology, Nowoursynowska 166, 02-787 Warszawa, Poland

Abstract

The range of acidophilous oak forest from *Quercetea robori-petraeae* Br-Bl. et Tx. ex Oberd. 1957 in Central Europe depends largely on the syntaxonomical concept used and is still provisional. The most continental association from this class occurring in Poland is *Calamagrostio arundinaceae-Quercetum petraeae* Hartm. 1934 Scam. et Pass. 1959. It is present in western and central Poland, but its eastern boundary is not well known. The aims of the study were to survey and document new patches of *Calamagrostio-Quercetum* in central Poland, to check the internal variation of the association and to summary the known distribution of it in lowlands of central-western and central Poland. 23 phytosociological relevés were made within new stands together with soil sampling. New relevé data was subjected to the numerical Wards classification together with acidophilous oak forests datasets from western Poland and oak-pine forests ones from eastern part of the Country. The new dataset was similar to *Calamagrostio-Quercetum*. Three subassociations were distinguished. Soil parameters and oak site index did not differ from acidophilous oak forest stands from other parts of Poland. The provisional range of *Calamagrostio-Quercetum* in central Poland was proposed to be moved by circa 60–90 km to the north-east (approximately as far as the Vistula river line) in order to include south-western part of Mazowsze.

Key words

forest association range border, *Quercetea-robori petraeae*, sessile oak, Mazowsze, Kujawy, Łódź, Wielkopolska

Introduction

The range of acidophilous oak forest from *Quercetea robori-petraeae* Br-Bl. et. Tx. ex Oberd. 1957 in Central Europe is not well known. It depends largely on the syntaxonomical concept used. According to many Polish authors acidophilous oak forest range finishes in central Poland and in the eastern part of the country they are replaced by oak-pine forest from *Dicrano-Pinion* alliance: *Querco-Pinetum* (W. Mat. 1981) J. Mat. 1988 and

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Serratulo-Pinetum (W. Mat. 1981) J. Mat. 1988 (i.e. Matuszkiewicz 1988; Matuszkiewicz and Matuszkiewicz 1996). According to other authors the acidophilous oak forests are present also in Eastern Europe (Mucina et al. 2016) and are reported for example from Ukraine (Goncharenko and Yatsenko 2020). According to polish authors, the acidophilous central European oak forest *Calamagrostio arundinaceae-Quercetum petraeae* (Hartm. 1934 Scam. et Pass. 1959) is the most continental association from *Quercetea robori-petraeae* class in Europe. Traditionally it was placed in *Quercion roboris* Malcuit 1929 (syn. *Quercion robori-petraeae* Br.-Bl. 1932) alliance (Matuszkiewicz 2008), but recently was moved to the *Agrostio-Quercion petraeae* Scamoni et Passarge 1959 (Kasprowicz 2010; Mucina et al. 2016), which gather the associations with most continental preferences. The knowledge about the distribution of *Calamagrostio-Quercetum* in central Poland is helpful in understanding the distribution of the acidophilous oak forests from *Quercetea robori-petraeae* class in Europe.

The acidophilous central European oak forests *Calamagrostio arundinaceae-Quercetum petraeae* was firstly reported from Germany (Hartmann 1934; Scamoni 1961) and later from western Poland (Fabiszewski and Faliński 1967). The knowledge on the distribution of it was reviewed by Matuszkiewicz (1988); Matuszkiewicz and Matuszkiewicz (1996), but the eastern border of the association was determined by the Authors only provisionally. Range of the association in western Poland was broadly reviewed by Kasprowicz (2010). In addition, new stands of *Calamagrostio-Quercetum* were recently found in central Poland (i.e. Jakubowska-Gabara 1999; Koba 2012, 2013; Zaniewski et al. 2020), outside the provisional border determined by Matuszkiewicz (1988); Matuszkiewicz and Matuszkiewicz (1996). According to the brief review of distribution of the association in this part of the Country conducted by Zaniewski et al. (2020) the *Calamagrostio-Quercetum* tend to be more widespread association there and its range is at least several dozen kilometers wider. However the newly gathered data was only contributory and large gaps in the assumed distribution of the association were present.

The aims of this study were to survey and document new patches of *Calamagrostio-Quercetum* in central Poland, especially outside the acidophilous oak forest provisional range, to check the lower syntaxonomical units of the association and to present (cartogram) the correction of its provisional range in central Poland.

Material and methods

The study was based on field inventory of *Calamagrostio-Quercetum* (23 relevés within 10 stands located in central Poland) and on published data (524 relevés of *Calamagrostio-Quercetum*, *Querco-Pinetum* and intermediate communities).

We have chosen 10 localities of oak forest in central Poland in order to document *Calamagrostio arundinaceae-Quercetum petraeae* phytocoenoses. The fieldwork was conducted mainly at the beginning of vegetation seasons of 2017, 2018 and 2020. In case of stands located in Kampinos National Park, the exact sites were previously checked for the presence of early forest floor species few weeks before the main sampling conducted in summer. A set of 23 phytosociological relevés (circular shape, 400 m^2 each) was prepared in accordance with the principles of the Braun-Blanquet (1964) school, using the Barkman et al. (1964) scale. Cover was used as the measure of abundance. The value 'rr' was assumed as the smallest cover of species within relevé (corresponding to an area of about 0.01%), while the limit value between 'r' and '+' was assumed to be a cover area of 0.5%. Species occurring outside the phytosociological relevé area were not recorded. Such a procedure was applied in order to obtain narrow cover-based intervals, characterized by relatively better behavior during numerical analysis (see Podani 2005, 2006; Maarel 2007).

Soil samples for laboratory analyses were collected from a depth from 0 to 20 cm measured from the top of the mineral organic matter horizon, from the central part of each phytosociological relevé. The soil samples were dried and divided. The skeletal and sand fractions were determined using the sieve method and compared using the divisions of Soil Science Society of Poland – PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009). The second part was sifted through a 1 mm diameter sieve. The content of organic matter was determined by the loss on ignition method at 600°C, pH was measured using an electronic pH-meter in a distilled water solution using a standard ratio of 10:25. The information about other stand parameters, i.e. age of stand and site index

of oak were obtained from Forest Data Bank – BDL (2020) Web Map Service (WMS).

The newly gathered phytosociological data was subjected to similarity analysis with typical *Calamagrostio-Quercetum* from Wielkopolska region (Kasprowicz 2010) and *Querco-Pinetum* and *Serratulo-Pinetum* from eastern Poland (Sokołowski 1963, 1976) phytocoenoses. Due to *Calamagrostio-Querceum* was also registered in the area of Kujawy region (Załuski 2011), the works by Kępczyński and Cyzman (1991, 1992) and Cyzman (1991) documenting the forest communities of *Querco-Pinetum* highly similar to communities from *Quercetea robori-petraeae* class were also taken into account. Only two relevés strongly dominated by *Quercus rubra* (Kępczyński and Cyzman 1992) were excluded from this dataset. The last datasets accounted in the analysis were *Calamagrostio-Quercetum* stands recently described from southern Mazowsze (Koba 2012, 2013; Zaniewski et al. 2020) and intermediate with *Querco-Pinetum* association from Puszcza Kozienicka forest (Zaręba 1971). Phytosociological data was arithmetically transformed (Tüxen and Ellenberg 1937) before numerical processing which allowed comparison of data collected using scales of varying accuracy. All of the relevés (547) from these datasets were classified using Ward's method. The average cover (Barkman's TCV) and Phi coefficients (as a measure of species fidelity to the groups) were calculated for each of distinguished groups of relevés. The significance of Phi coefficients of species was checked with Fisher's exact test, according to Chytrý et al. (2002). The obtained groups were assigned to associations on the basis of cover and fidelity of dominant and diagnostic species according to Matuszkiewicz (2008) and Kasprowicz (2010). The Ward's analysis was carried out using PAST

Table 1. Numerical relevé classification of 15 datasets (A, B – *Calamagrostio-Quercetum*, C – *Querco-Pinetum*), N – number of relevés, % – share of relevés from a specific dataset, *C-Q* – *Calamagrostio-Quercetum*, *Q-P* – *Querco-Pinetum*

No	Name of the dataset	Author of the dataset	A (n = 233)		B (n = 131)		C (n = 183)		A-C
			N	%	N	%	N	%	N
1	*C-Q molinietosum* (Wielkopolska)	Kasprowicz (2010)	8	14	38	68	10	18	56
2	*C-Q typicum* var. *typicum* (Wielkopolska)	Kasprowicz (2010)	25	69	7	19	4	11	36
3	*C-Q typicum* var. *Anemone nemorosa* (Wielkopolska)	Kasprowicz (2010)	14	33	24	56	5	12	43
4	*C-Q polygonatetosum* var. *typicum* (Wielkopolska)	Kasprowicz (2010)	72	92	3	4	3	4	78
5	*C-Q polygonatetosum* var. *Anemone nemorosa* (Wielkopolska)	Kasprowicz (2010)	54	59	30	33	7	8	91
6	*Q-P typicum* (S Mazowsze)	Zaręba (1971)	6	26	0	0	17	74	23
7	*Q-P berberidetosum* (S Mazowsze)	Zaręba (1971)	1	7	0	0	13	93	14
8	*Q-P populetosum* var. *typicum* (S Mazowsze)	Zaręba (1971)	0	0	1	11	8	89	9
9	*Q-P populetosum* var. *Abies alba* (S Mazowsze)	Zaręba (1971)	0	0	0	0	13	100	13
10	*Q-P serratuletosum* (E Mazowsze / S Podlasie / N Lubelszczyzna)	Sokołowski (1963)	4	8	2	4	43	88	49
11	*Q-P typicum* (E Mazowsze / S Podlasie / N Lubelszczyzna)	Sokołowski (1963, 1976)	0	0	6	27	16	73	22
12	*Q-P populetosum* (E Mazowsze / S Podlasie / N Lubelszczyzna)	Sokołowski (1963, 1976)	4	8	4	8	41	84	49
13	*Q-P* (SE Kujawy / NW Mazowsze)	Cyzman (1991); Kępczyński and Cyzman (1991, 1992)	10	36	15	54	3	11	28
14	*C-Q* (S Mazowsze)	Koba (2012, 2013); Zaniewski et al. (2020)	13	100	0	0	0	0	13
15	*C-Q* (central Poland)	this study	22	96	1	4	0	0	23
	Total		233		131		183		547

4 software (Hammer et al. 2001). The average cover and Phi coefficients together with Fisher's tests were conducted in JUICE 7 (Tichý 2002; Tichý and Holt 2006). The lower syntaxonomical units were manually assigned to the 23 relevés made in this study using subassociation concept developed by Kasprowicz (2010). The interpretation of this documentary table was based on the works by Matuszkiewicz (2008) and Kasprowicz (2010). The lack of an unequivocal diagnostic value of some of the plant species that coexist in the *Calamagrostio-Quercetum* association and mixed pine forest from *Dicrano-Pinion* alliance in central Poland was taken into account. The names of vascular plants were adopted after Mirek et al. (2002), mosses after Ochyra et al. (2003), liverworts after Szweykowski (2006) and lichens after Fałtynowicz and Kossowska (2016).

All of the newly documented stands of *Calamagrostio-Quercetum* were drawn on the map of the known distribution of the association in central and central-western Poland. The stands documented by Kępczyński and Cyzman (1991, 1992) and Cyzman (1991), classified as *Calamagrosio-Quecetum* in this analysis were also added to the map. The work by Kasprowicz (2010) was accounted as the basis of the known distribution of *Calamagrostio-Quercetum* in the western part of the analysed area and the summary by Zaniewski et al. (2020) for the eastern part of it. The ATPOL grid (Zając 1978; Komsta 2016) was used as a cartogram. The map was prepared using QGIS 3.14 software (QGIS Development Team 2021).

Results

Patches of *Calamagrostio-Quercetum* association were documented with 23 relevés within 10 stands (located within 8 ATPOL grid cells). Ward's Classification of all 547 relevés revealed three well distinguishable groups (Tab. 1).

The first one (A) consisted mostly of relevés representing *Calamagrostio-Quercetum* from Wielkopolska region, relevés from southern Mazowsze region, *Querco-Pinetum* "resembling *Quercetea robori-petraeae*" from Kujawy region and part of specific *Querco-Pinetum typicum* (intermediate with *Calamagrostio-Quercetum*) dataset from Puszcza Kozienicka forest. Most of relevés from present study was also classified within this group (Tab. 1). The group A represented *Calamagrostio-Quercetum* association with *Quercus petraea*, *Calamagrostis arundinacea* and *Convallaria majalis* being one of the best diagnostic species (Tab. 2).

Table 2. Average % cover (Barkman's TCV) and fidelity (upper index – Phi coefficient given if Fisher's test $p<0.05$) of species for the distinguished groups of relevés A-C (only species with higher covers within at least one group and statistically significant Phi coefficient were presented)

Name of the species	A (n = 233)	B (n = 131)	C (n = 183)
Trees and shrubs with cover > 2%			
Quercus petrea A1, A	$59.33^{63.8}$	3.63	2.92
Quercus petrea C	$2.94^{3.9}$	0.25	0.31
Quercus x *rosacea* A1, A	$2.94^{11.8}$	0.23	0.31
Quercus petrea B, BC	$2.03^{3.9}$	0.10	2.03
Quercus robur A1, A	1.83	$54.20^{50.7}$	15.09
Carpinus betulus A, A2	0.40	$5.09^{10.2}$	2.71
Quercus robur A2	0.22	$2.42^{5.3}$	1.90
Pinus sylvestris A1, A	5.11	2.68	$39.68^{46.2}$
Corylus avellana B, BC	2.11	1.69	$8.24^{15.2}$
Quercus robur B, BC	0.18	1.25	$3.84^{11.2}$
Carpinus betulus B, BC	0.72	1.13	$2.65^{6.7}$
Betula pendula A1, A	0.72	1.63	$3.04^{6.6}$
Pinus sylvestris B	0.02	0.10	$2.95^{13.6}$
Populus tremula A1, A	0.07	0.16	$2.31^{11.3}$
Forest floor species with cover > 1%			
Calamagrostis arundinacea	$13.41^{18.1}$	5.91	1.40
Convallaria majalis	$9.21^{15.7}$	3.40	1.13
Festuca ovina	$5.53^{5.3}$	3.62	3.02
Poa nemoralis	$1.69^{5.8}$	0.98	0.05
Holcus mollis	4.32	$15.24^{24.7}$	0.21
Agrostis capillaris	0.86	$2.29^{7.7}$	0.24
Polytrichastrum formosum	1.43	$4.10^{7.8}$	1.72
Anemone nemorosa	0.74	$1.96^{6.3}$	0.47
Carex pilulifera	0.85	$1.65^{5.9}$	0.14
Vaccinium myrtillus	16.57	13.33	$55.61^{42.5}$
Pleurozium schreberi	0.99	0.76	$15.00^{29.0}$
Hylocomnium splendens	0.01	0.08	$3.36^{14.7}$
Vaccinium vitis-ideaea	0.05	0.13	$2.28^{11.5}$
Molinia caerulea	0.25	0.46	$1.97^{8.1}$
Polytrichum commune	0.00	0.03	$1.24^{8.9}$
Sphagnum capillifolium	0.00	0.00	$1.16^{8.8}$
Dicranum polysetum	0.02	0.03	$1.00^{7.8}$

The second group (B) consisted of relevés representing especially *Calamagrostio-Quercetum* from Wielkopolska region and specific communities resembling acidophilous forests, previously classified as *Querco-Pinetum* from Kujawy region. The last remaining relevé from this study was also classified here (Tab. 1). This group also represented *Calamagrostio-Quercetum* association and is significantly characterized for example by *Quercus robur*, *Holcus mollis* and *Carex pilulifera* (Tab. 2).

The third group (C) consisted of especially *Querco-Pinetum* relevés from Puszcza Kozienicka forest and *Querco-Pinetum* and *Serratulo-Pinetum* relevés from eastern Poland and represented *Querco-Pinetum* association. The remaining three relevés from the dataset from Kujawy region were also classified here (Tab. 1). This group represented *Querco-Pinetum* association and can be distinguished, inter alia, by dominance of *Pinus sylvestris*, *Vaccinium myrtillus* and *Pleurozium schreberi* (Tab. 2).

Three subassociations were identified within surveyed stands: *polygonatetosum*, *typicum* and *molinietosum* (Tab. 3). Patches of them were found also outside the provisional range, especially in the most distant (ATPOL grid cell ED14) research site in Kampinos National Park (Fig. 1).

The age of dominant tree species in studied sites varied from 51 to 110 years, oak site index from I to III. Forest site types varied highly in fertility (from coniferous to deciduous sites) and much less in humidity (mostly semixeric and rarely wet sites). Brunic arenosols (typical and brown rusty soils) predominated as a soil subtype (Tab. 4).

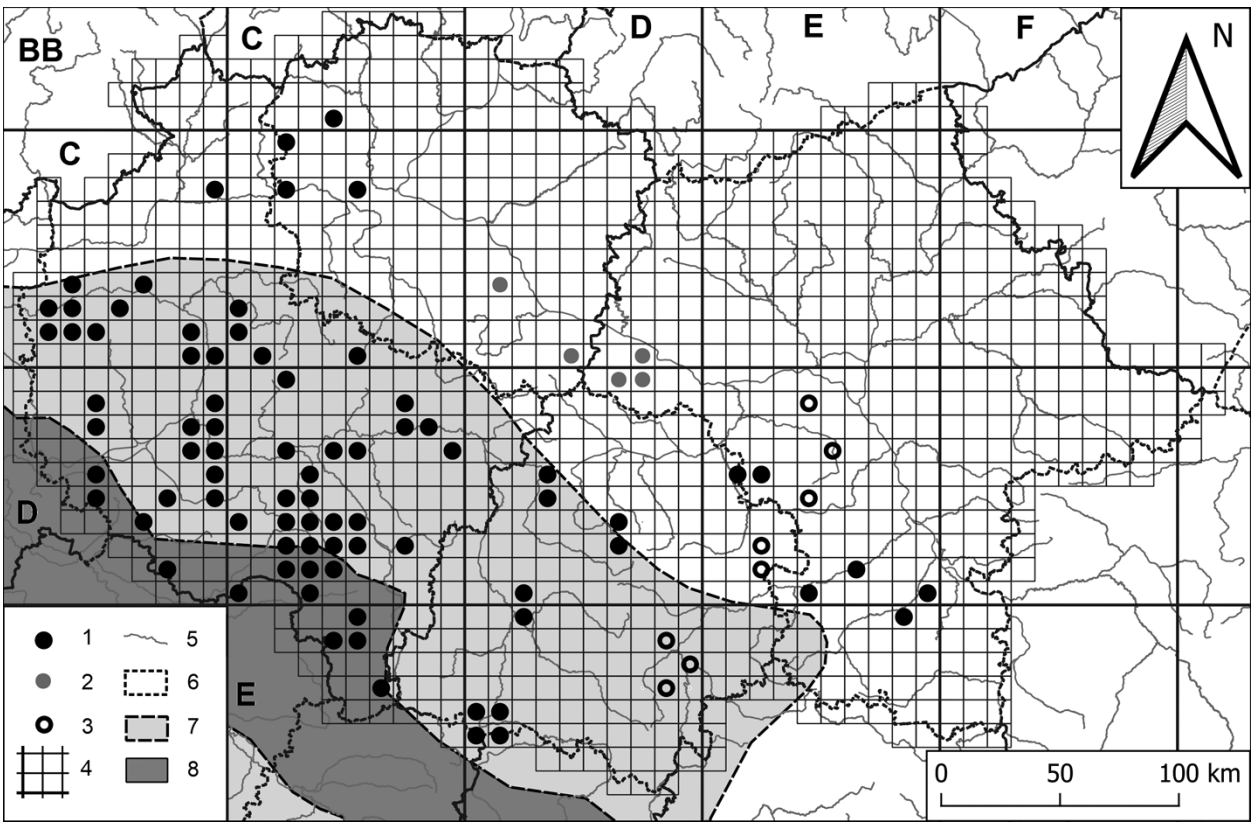


Figure 1. Location of stands of *Calamagrostio-Quercetum* association (modified and expanded on the basis of Zaniewski et al. 2020) within central and central western Poland (Kujawsko-Pomorskie, Wielkopolska, Łódź and Mazowieckie viovodeships)

1 – stands with published relevé documentation reviewed by Kasprowicz (2010); Zaniewski et al. (2020), 2 – stands from works by Cyzman (1991); Kępczyński and Cyzman (1991, 1992), classified in conducted analysis as *Calamagrostio-Quercetum*, 3 – new stands of *Calamagrostio-Quercetum* surveyed in this study, 4 – ATPOL grid (Zając 1978; Komsta 2016), 5 – rivers, 6 – borders of voivodeships, 7 – „provisional" association range – minor role in the landscape (Matuszkiewicz 1988; Matuszkiewicz and Matuszkiewicz 1996), 8 – main association range – moderate role in the landscape (Matuszkiewicz 1988; Matuszkiewicz and Matuszkiewicz 1996).

Table 3. Vegetation characteristics of *Calamagrostio-Quercetum* patches surveyed in central Poland

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Area of relevé [m²]	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Slope and exposition [°]	7°NW	2°W	2°W	2°N	3°S	2°NW	6°NE	3°W	4°NW	2°N	4°W	2°E	0°	1°S	0°	4°N	3°S	5°N	0°	2°SE	2°NE	2°SW	0°
Cover of upper tree layer A1 [%]	70	80	85	70	85	80	80	80	80	80	85	80	80	90	80	80	70	70	70	70	80	70	80
Cover of lower tree layer A2 [%]	0	0	0	0	3	5	15	2	0	5	1	2	3	15	20	2	0	10	1	20	15	20	5
Cover of tree layer in total a [%]	75	80	85	70	86	81	90	81	80	82	85	81	81	95	90	81	70	75	70	80	90	80	82
Cover of shrub layer B [%]	5	1	10	2	10	10	5	10	5	15	5	15	10	10	10	5	10	5	5	15	5	10	30
Cover of herb layer C [%]	40	70	40	45	40	45	50	60	80	80	70	75	60	40	45	85	75	90	85	90	95	90	70
Cover of moss layer D [%]	2	5	5	15	3	5	10	5	5	1	0.5	10	1	5	5	10	1	0.1	5	1	0.5	5	1
Subassociation of *Ca-Q*	polygonatetosum													typicum					molinietosum				
Ch Ass, D Ass* *Calamagrostio arundinaceae-Quercetum* (Kasprowicz 2010)																							
Quercus petraea A1*	4b	5a	4b	4b	4b	4b	4a	4b	5a	3b	5a	4a	5a	4a	3b	5a	4b	4b	3b	4b	4b	3b	2a
Quercus petraea A2*					1	1	2a	1		1		1	1	2a	2b	1		2a		2b	2a	2b	
Quercus petraea B*	r	r	1	+	r	+		1	+	+	1	r	1	1	+	+	2a	1		+	+	+	
Quercus petraea C*	1	2b	+	2a	r	1		1	1		1	+	+	1	+	2a	2b	1	+	1	1	r	
*Calamagrostis arundinacea**	r	r	r					+	r	1													
Hieracium lachenalii	r	1	1	1	1	2a	1	+	+	r		r	+	+	+	r							
*Festuca ovina**	2a	2a	1	2a	2b	2a	2a	1	1	+	1	2b	+	2a	2a	+			+	1	+	+	+
Ch Cl, D Cl* *Quercetea robori-petraeae* (Kasprowicz 2010), Ch/D Cl.** (Matuszkiewicz 2008)																							
Carex pilulifera	2a	1	2a	1		1		1	1		1	2a	1	r		r	+		2a	+	+		+
Holcus mollis			+				r		r				+						+		1		
Dicranella heteromalla D	rr		r	rr		rr	rr	+		rr				rr		rr	r	rr		rr			
*Melampyrum pratense**	r	1	2a	1	2a	+	+	2a	2a	1	2a	2a	1	1	1	2a	r	rr		2a		+	r
*Pteridium aquilinum**				1		1	+		2a	1	1		2b		1	1		2a			2a	2b	1
Polytrichastrum formosum D*			+	1		+		r	1		r	r		1	r	1	r		1				
Hypnum cupressiforme D**	r	r	+	rr	rr	r	r	1		rr	rr	+	+	r	r	rr	r	rr	r			r	rr
D *Ca-Q molinietosum* (Kasprowicz 2010)																							
Quercus robur A1						2a	2b			2b		2b		2a	2b				2b	1	2a		3b
Quercus robur A2							1			1				1					+		1		
Quercus robur B			+					+		+				r						r		+	

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Quercus robur C						rr							rr	r	rr				+	r		r	
Betula pubescens A1																							2a
Betula pubescens C																						rr	
Picea abies A2											+												
Picea abies B			r						+							r		+	1				
Picea abies C				rr				r															
Frangula alnus B	+	r	+	+	2a	2a	+	+	1	r	r	1	+	+	1	+	r	1	1	2a	1	2a	2b
Frangula alnus C	+		r	r	r	+		+		rr	r	+	r	r		r	rr	r	1	+	1	+	+
Molinia caerulea								r												3a	2a	r	3a
Carex nigra																							rr
Carex ovalis																	rr		r				
Lysimachia vulgaris																			r				
Juncus effusus																			+				r
Trientalis europaea		1		1					r	r		2a				r			1				
Carex pallescens			+	r	r												r		1				
Potentilla erecta																			r				
Hylocomium splendens D		r		r	r											rr							
D *Ca-Q polygonatetosum odorati* (Kasprowicz 2010), Ch/D Cl. *(Matuszkiewicz 2008)																							
*Hieracium murorum**	r	2a	1	2a		rr		+		r													
Convallaria majalis	1	r	1		1		r	1	2b	2b	1			r				r					
Polygonatum odoratum	r		+		rr	+	+	r	r	r	+							rr					
Moehringia trinervia			r		r		rr						r		r				r			r	
Veronica officinalis		r	1	r	r		+	r	r				r	r			r		r				
Mycelis muralis		r			1	r							+				+						
Melica nutans						+				+													
Galeopsis tetrahit			rr				rr						rr	r							rr		
Ch Cl/O *Vaccinio-Piceetea/Cladonio-Vaccinietalia* (Matuszkiewicz 2008)																							
Pinus sylvestris A1		1		1	+		1			1			1	2a	2a	1		+		+	1	2a	2a
Pinus sylvestris C	r		rr	rr	rr	rr	rr				r		rr		rr		rr		rr				rr
Vaccinium myrtillus	1	1	+	2a	r	2a	1	3b	3b	4a	4a	2a	2a	2b	2b	4b	4a	5a	3b	5a	5a	5a	3b

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Vaccinium vitis-idaea									r	r	r					r				r	r	+	
Pleurozium schreberi D	r	1	+	2a	+	1	1	r	r		rr	1		r	1	1				r			
Dicranum scoparium D	r	r		r	r	r	r	rr	r		rr	+	rr		r	rr	rr				rr	r	r
Dicranum polysetum D							rr					r			r	r							
Ch Cl/O *Querco-Fagetea*/ *Fagetalia sylvaticae* (Matuszkiewicz 2008)																							
Corylus avellana B										l													
Corylus avellana C	r			r						r													
Acer platanoides C					rr					rr													
Anemone nemorosa		r	r	l													+		2a				
Carex digitata									rr									rr					
Millium effusum		r																					
Poa nemoralis							rr			r			+	r			l		2a				
Polygonatum multiflorum														+									
Viola reichenbachiana		r																	r				
Atrichum undulatum D			r					r		r			r										r
Ch All *Carpinion betuli* (Matuszkiewicz 2008)																							
Carpinus betulus A1																							
Carpinus betulus A2										r													
Carpinus betulus B										+					r		l				+		
Carpinus betulus C				r	rr					rr					r		l				r		
Cerasus avium C		r	r	rr								rr	r	r									
Ch All *Alno-Ulmion* (Matuszkiewicz 2008)																							
Padus avium B																	r						
Festuca gigantea						r							r										
Ch Cl/O *Molinio-Arrhanatheretea*/*Arrhenatheretalia* (Matuszkiewicz 2008)																							
Agrostis gigantea													rr										
Cerastrium holosteoides	r																						
Holcus lanatus					r									rr									
Poa pratensis								r												r			
Achillea millefolium					rr																		

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Taraxacum sect. *ruderalia*												rr	r	rr									
Ch Cl/O *Nardo-Callunetea/Calluno-Ulicetalia* (Matuszkiewicz 2008)																							
Danthonia decumbens			r																				
Hieracium pilosella		+		r	+	rr	r						+		r								rr
Luzula campestris		r	rr	r				r															
Luzula multiflora			rr						r								r			r	rr	rr	
Lycopodium clavatum				r																			
Calluna vulgaris	+	+	+	+																			
Carex ericetorum	r		r				r						r	r	rr								
Hieracium umbellatum				r	rr							r			rr								
Other																							
Betula pendula A1					1	1	2a			2a	1	1		2a	2a							2a	1
Betula pendula A2							1																
Betula pendula C																			r				
Quercus x rosacea A1			2a		2a			2a	1	2a				1									
Quercus x rosacea A2										+													1
Quercus x rosacea B																							1
Quercus x rosacea C					rr			+															
Populus tremula A1																+						2a	
Populus tremula B												+				r					r	+	
Populus tremula C					r		r					+		r	r	r					r	r	
Sorbus aucuparia A2										+													
Sorbus aucuparia B					r					2a		2a							r	1	r		
Sorbus aucuparia C		r	r	r	r	r	rr			+	r	+	r	r	r	rr	rr		r	+			
Quercus rubra B	r												r										
Quercus rubra C	r												r		rr								
Juniperus communis B	1		1	r	r		r	1	r		r		+	r	1	1	r					r	
Juniperus communis C	+		r	r		r		r	r			r		r	+	r	r					r	
Abies alba C												r											
Padus serotina B			+				1			r		+	1	1						r	r		r

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Padus serotina C	r				r	r	+			r		r	r		r		rr					r	
Robinia pseudoacacia B																						r	
Robinia pseudoacacia C																					rr		
Sarothamnus scoparius B													r										
Sarothamnus scoparius C			r					r					+	rr									
Cotoneaster sp. C															rr								
Prunus domestica ssp. *insititia* C					rr	rr	rr					r			rr					rr			
Pyrus pyraster C					r	rr						rr		rr	rr				r		r		
Viburnum opulus C																				rr			
Agrostis capillaris			r		rr						rr				rr					r			
Agrostis vinealis							rr																
Ajuga reptans									rr														
Antoxanthum odoratum		+	+	1	r	r	r	r	r	r			+	1	r		r		+	r			
Calamagrostis epigejos																	r		+				
Campanula rotundifolia			+												r								
Chamaecytisus ratisbonensis					r			rr							rr								
Chamaenerion angustifolium																	rr						
Conyza canadensis					rr																		
Cruciata glabra		+		+															r				
Dryopteris carthusiana		rr		r								rr							1				
Epipactis helleborine					r																		
Fallopia convolvulus							r																
Fragaria vesca		r																	r				
Genista germanica				r																			
Gypsophila fastigiata							rr																
Hypericum perforatum		r	r	r			r					r	r	r					r				
Impatiens parviflora												rr	+				rr				r		
Leontodon autumnalis													r										
Luzula pilosa	+	1	r	+	r	r	+	1	r	+	+	+	+	1	+	1	r		1	r	r		r
Maianthemum bifolium	2a	+		2a	+	2a	2b		+		r	1	r	1		2a		+	1				

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Orthilia secunda					rr										r								
Oxalis acetosella		r																					
Peucedanum oreoselinum					1	r	r								r								
Poa angustifolia		rr		rr	rr				r		r							rr					
Poa compressa											rr												
Polypodium vulgare							+																
Rubus ideaeus																	r						
Rubus hirtus agg		+		r															+				
Rumex acetosella	r	+			r						rr		rr										
Sedum maximum			r		+		rr																
Solidago virgaurea			r		+	r	r					r	rr	rr									
Urtica dioica													rr										
Veronica chamaedrys		r		r									r						+				
Viola riviniana													+		rr								
Aulacomnium androgynum D								rr	r							rr							
Sciuro-hypnum oedipodium D			r		r	r	r	r		rr	rr	+		rr	r				r	r	r	l	
Brachythecia strum velutinum D										rr			r										
Brachythecium rutabulum D												r			rr								rr
Ceratodon purpureus D				rr											rr								
Leucobryum glaucum D									rr		rr												
Lophocolea heterophylla D			rr						rr														
Plagiomnium affine D	r	rr	+		+	rr	l	r	+		rr	+		r	+	l	rr	rr	r	r			
Plagiothecium curvifolium D			r				rr	r		rr			rr				rr	rr			rr		
Pohlia nutans D	r				rr	r		+	r				rr	rr		rr	rr						r
Polytrichum juniperinum D	r		r																				rr
Pseudoscleropodium purum D														rr		l						r	
Cladonia coniocraea D	r		rr	rr		rr	rr	rr								rr							rr
Cladonia fimbriata D	rr							rr															
Cladonia furcata D	rr																						

Table 4. Stand characteristics and selected parameters of soils within researched patches of *Calamagrostio-Quercetum*

Successive number of relevé			1	2	3	4	5	6	7	8	9	10	11
Subassociation			polygonatetosum										
Number of relevé			PZ20_050	PZ20_038	PZ20_055	PZ20_037	PZ20_064	PZ20_066	PZ20_060	PZ20_054	PZ20_032	PZ17_001	PZ20_033
													Information based on Forest
Forest District / National Park			Skiernie-wice	Smardze-wice	Grójec	Smardze-wice	Kampinos NP	Kampinos NP	Kampinos NP	Grójec	Piotrków	Chojnów	Piotrków
Forest range			Rylsk	Jaksonek	Wilczo-ruda	Jaksonek	Rózin	Rózin	Rózin	Wilczo-ruda	Felicja	Podkowa Leśna	Felicja
Forest subcompartment			121h	144h	35i	151g	258b	258b	04a	35i	127a	02l	128c
Age of dominant tree species [year]			105	101	82	96	107	107	110	82	86	66	77
Oak site index			III	II	III	II	II	II	III	III	III	II	II
Forest site type			LMŚW	LMŚW	LMŚW	LMŚW	LMŚW	LMŚW	BMŚW	LMŚW	LMŚW	LŚW	LMŚW
Soil subtype			BRw	RDbr	RDw	RDbr	RDbr	RDbr	–	RDw	RDbr	–	RDbr
													Results of laboratory analyses (samples
pH H20 (10:25)			4.25	4.51	4.42	4.49	4.54	4.56	4.39	4.14	4.46	4.50	4.33
Organic matter content [%]			2.5	1.9	3.4	3.8	1.9	2.4	1.4	4.6	2.4	4.3	2.6
Organic C content [%] (as 58% org.)*			1.5	1.1	2.0	2.2	1.1	1.4	0.8	2.6	1.4	2.5	1.5
Fraction diameter mm [%]	skeletal	> 20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		5–20	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
		2–5	0.6	0.3	1.4	0.1	0.0	0.0	0.0	0.6	1.3	0.8	0.7
	fine earth	1–2	2.5	0.8	2.1	0.5	0.2	0.5	0.2	1.3	1.9	2.1	1.7
		0,5–1	17.0	13.7	11.0	10.9	1.5	3.3	1.3	9.9	11.8	10.3	12.4
		0,25–0,5	47.2	50.5	40.6	41.3	25.0	27.5	28.2	36.7	42.1	24.8	46.9
		0.1–0.25	27.1	28.3	28.7	24.5	60.9	57.0	62.8	29.9	32.7	36.0	28.2
		< 0.1	5.6	6.4	15.6	22.6	12.2	11.7	7.5	21.6	9.9	26.1	10.1

* Value of 58% share of organic matter according to Nelson and Sommers [1982].

Forest site types: LŚW – semixeric deciduous forest, LMŚW – semixeric mixed deciduous forest, BMŚW – semixeric mixed coniferous forest; BŚW – semixeric coniferous forest, BMW – wet mixed coniferous forest; Soil subtype (Reference Soil Group): BRw – typical brown soil, RDbr – Brunic Arenosol (brown rusty soil), RDw – Brunic Arenosol (typical rusty soil), Pw – Haplic Luvisols, RDb – Albic Brunic Arenosol, Bgw – Gleyic Albic Podzols.

Surveyed stands (name, ATPOL GRID, date, coordinates – in WGS84– World Geodetic System '84)

1. Górki-Strzałki (ED82), 10-07-2020 (20.39312°, 51.68800°)
2. Jaksonek 2 (DE29), 07-06-2020 (19.97856°, 51.34288°)
3. Petrykozy 2 (ED54), 29-07-2020 (20.67518°, 51.93159°)
4. Jaksonek 1 (DE29), 07-06-2020 (19.98204°, 51.33814°)
5. Zaborówek 6 (ED14), 02-08-2020 (20.63504°, 52.27435°)
6. Zaborówek 8 (ED14), 05-08-2020 (20.63143°, 52.27360°)
7. Zaborówek 2 (ED14), 02-08-2020 (20.62202°, 52.27404°)
8. Petrykozy 1 (ED54), 29-07-2020 (20.67565°, 51.93101°)
9. Wielkopole 2 (DE38), 06-06-2020 (19.84515°, 51.21682°)
10. Kanie Helenowskie (ED35), 12-05-2017 (20.77558°, 52.12229°)
11. Wielkopole 3 (DE38), 06-06-2020 (19.83823°, 51.21375°)
12. Nadarzyn (ED35), 29-07-2020 (20.78170°, 52.09733°)
13. Petrykozy 3 (ED54), 29-07-2020 (20.67144°, 51.93201°)
14. Zaborówek 1 (ED14), 02-08-2020 (20.62076°, 52.27354°)
15. Zaborówek 3 (ED14), 02-08-2020 (20.62606°, 52.27279°)
16. Wielkopole 4 (DE38), 06-06-2020 (19.84381°, 51.21068°)
17. Julianów (ED72), 09-06-2018 (20.30782°, 51.80890°)
18. Wielkopole 1 (DE38), 06-06-2020 (19.84839°, 51.22167°)
19. Meszcze (DE18), 07-06-2020 (19.78225°, 51.43875°)
20. Zaborówek 5 (ED14), 02-08-2020 (20.63012°, 52.27039°)
21. Zaborówek 9 (ED14), 05-08-2020 (20.63139°, 52.26919°)
22. Zaborówek 4 (ED14), 02-08-2020 (20.62736°, 52.26986°)
23. Zaborówek 7 (ED14), 05-08-2020 (20.62673°, 52.26992°)

Discussion

All of the 23 relevés from this study did join with *Calamagrostio-Quercetum* groups A and B (Tab. 1) as well as most of the relevés by Cyzman (1991), Kępczyński and Cyzman (1991, 1992). This means that acidiophilous oak forests are present in central Poland. However it cannot be concluded, that the boundary of the association range is highly probable there. Due to only the move of the provisional range of *Calamagrostio-Quercetum* in central Poland by circa 60–90 km to the north-east is proposed. It should include nearly whole

12	13	14	15	16	17	18	19	20	21	22	23
typicum							molinietosum				
PZ20_057	PZ20_056	PZ20_059	PZ20_061	PZ20_034	PZ18_005	PZ20_031	PZ20_036	PZ20_063	PZ20_067	PZ20_062	PZ20_065
Data Bank (BDL 2019)											
Chojnów	Grójec	Kampinos NP	Kampinos NP	Piotrków	Skierniewice	Piotrków	Piotrków	Kampinos NP	Kampinos NP	Kampinos NP	Kampinos NP
Podkowa Leśna	Wilczoruda	Rózin	Rózin	Felicja	Julianów	Felicja	Proszenie	Rózin	Rózin	Rózin	Rózin
372b	36d	04c	423d	138a	71c	125i	105b	03z	423n	423s	03t
112	99	110	79	96	105	69	88	83	88	51	83
II	II	III	II	II	II	I	II	–	I	–	–
BMŚW	LMŚW	BMŚW	BMŚW	LMŚW	LMŚW	LMŚW	LŚW	BŚW	BMW	BMŚW	BMŚW
RDw	RDw	–	RDbr	RDbr	RDw	RDw	Pw	–	Bgw	RDb	–
collected at a depth of 0–20 cm)											
4.38	4.66	4.03	4.40	4.04	4.43	3.94	4.57	4.21	4.06	4.04	3.74
3.7	2.6	3.3	1.8	2.7	3.5	2.8	2.4	4.1	5.1	5.1	6.5
2.1	1.5	1.9	1.0	1.6	2.1	1.6	1.4	2.4	3.0	3.0	3.8
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.3	0.0	0.0	0.0	0.0
0.0	0.4	0.0	0.0	0.6	0.3	0.8	1.3	0.0	0.1	0.0	0.0
1.8	1.6	0.5	0.2	2.0	1.6	1.7	3.0	0.6	0.9	1.3	1.3
11.8	11.4	2.5	2.2	15.2	7.9	13.0	17.1	2.3	4.3	5.1	6.7
32.4	42.7	26.7	25.0	45.9	25.9	46.0	32.6	23.2	25.2	26.9	26.1
39.7	33.6	55.2	60.3	28.1	24.3	29.2	28.5	52.4	42.4	44.4	42.2
14.3	10.3	15.2	12.3	7.9	40.0	9.1	17.2	21.5	27.1	22.4	23.7

south-western part of Mazovia, approximately as far as the Vistula river line.

All three subassociations described by Kasprowicz (2010) were identified in the new stands surveyed in central Poland (Table 2). Patches of *Calamagrostio-Quercetum polygonatetosum*, *typicum* and *molinietosum* were found especially in Rózin range, Kampinos National Park (ATPOL grid cell ED14). In this study (Fig. 1) it is the most distant place (nearly 90 km) from the provisional range of the minor role of the association in the landscape proposed by Matuszkiewicz (1988), Matuszkiewicz and Matuszkiewicz (1996). Patches of *Calamagrostio-Quercetum polygonatetosum* differentiated by presence of many species, often together with bit higher cover of lily of the valley *Convallaria majalis* L. and wall hawkweed *Hieracium murorum* L. (Tab. 3). There was also noted relatively higher frequency of species from heathlands (*Nardo-Callunetea*). *Calamagrostio-Quercetum molinietosum* could be well distinguished with a high cover of purple moor-grass *Molinia caerulea* (L.) Moench and presence of common oak *Quercus robur* L. together with sessile oak *Q. petraea* (Matt.) Liebl. within tree stand. The highest values of common bilberry *Vaccinium myrtillus* L. cover were usually noted here. The differentiated subassociations corresponded well with the internal variation of *Calamagrosio-Quercetum* described by Kasprowicz (2010) from Wielkopolska.

All of the soil subtypes occurring within researched patches – Brunic Arenosols (brown and typical rusty soils), typical brown soils, Haplic Luvisols, Albic Brunic Arenosols and Gleyic Albic Podzols (Tab. 3) were also recorded in *Calamagrostio-Quercetum* stands in other parts of Poland (i.e. Lasota et al. 2005; Rutkowski and Maciejewska-Rutkowska 2007; Lasota 2013). The measured pH of upper soil horizons of the researched stands was usually similar or slightly higher than in western Poland (Lasota et al. 2005; Lasota 2013). The

average share of carbon in organic matter is about 58% (Nelson and Sommers 1982). Due to the organic carbon content in the examined patches was from 0.8 to 3.8% and was relatively similar to other areas of acidophilous oak forests in western Poland (Lasota 2013). Oak site index of researched patches was mainly in II class, rarely I or III one (Tab. 3). This is similar or slightly higher than in other parts of Poland (Lasota et al. 2005).

Although Fabiszewski and Faliński (1967) mentioned the occurrence of impoverished communities resembling *Calamagrostio-Quercetum* from vicinity of Łódź, acidophious oak forests were not registered in central Poland nearly to the end of the XXth century. The concept of degeneration and synatropization of plant associations was under development (Faliński 1966, 1972; Olaczek 1974) and the correct diagnosis of *Calamagrostio-Quercetum* could be difficult (Kasprowicz 2010). As a result, patches of acidophilous oak forests with antropogenically introduced Scots pine *Pinus sylvestris* L. could often be classified as mixed coniferous forests (Kasprowicz 2010). This was also the reason why the eastern boundary of range of *Calamagrostio-Quercetum* was only approximated (Matuszkiewicz 1988; Matuszkiewicz and Matuszkiewicz 1996). This state was also reflected in the concept of including specific sessile oak-pine forests occurring in central Poland within association *Quercetum sessiliflorae* (*petraeae*?)-*Pinetum* as a new name proposal for *Pino-Quercetum* Kozł. 1925 em. Mat. et Pol. 1955, presented by Zaręba (1988). The proposal was a result of division *Querco roboris-Pinetum* into moist oak-pine forests as *Populo tremulae-Quercetum* in the sense of Sokołowski (1968, 1980) and not wet oak forest with pine as a *Pino-Quercetum*. What is even more important, Zaremba (1988) stated, that well preserved patches of such an oak forest with pine admixture are present in central Poland, for example in Puszcza Kozienicka forest, Kampinos National Park and Włocławek-Gostynin Forest areas. Patches of *Calamagrosio-Quercetum* in Puszcza Kozienicka forest were recently identified by Koba (2012, 2013). The presence of acidophilous oak forest in Kampinos National Park was confirmed directly in this study (Fig. 1, Tab. 2, 3, 4). The presence of this association in Włocławek-Gostynin Forest area was also confirmed here in the carried out Ward's classification (Tab. 1, 2, Fig. 1). This suggest that ecological succession from mixed sessile oak-pine forests into acidophilous oak forests at the landscape level probably occurs in central Poland. The another possible way of progression of *Calamagrosio-Quercetum* may be a result of decline *Potentillo albae-Quercetum* phytocoenoses. Such a process was registered so far only in western Poland (Jakubowska-Gabara 1996), however the *Calamagrosio-Quercetum* stands registered in Petrykozy site (Fig. 1, ATPOL grid cell ED54) are located in the same small forest complex as in the case of old stands of *Potentillo albae-Quercetum* surveyd by Jakubowska-Gabara (1985). Due to the possible origin of *Calamagrosio-Quercetum* as a result of *Potentillo albae-Quercetum* decline, such a phenomenon cannot by excluded also in central Poland. This issue however cannot be sold in this analysis and additional studies are needed. From the other site regression of *Calamagrostio-Quercetum* patches within landscape scale was reported recently from Kujawy region (Załuski 2011). Cyzman (2010) stated, that acidophilous oak forest phytocoenoses in the area of Gostynin-Włocławek Forest are degenerated forms of oak-hornbeam forests. Due to it is possible that *Calamagrostio-Quercetum* in central Poland may not only be the actual and in some cases even potential forest community, but also the part of a longer successional series, beginning from oak-pine forests and finishing in deciduous hornbeam forests.

Conclusions

- Acidophilous oak forest *Calamagrostio arundinaceae-Quercetum petraeae* (Hartm. 1934 Scam. et Pass. 1959) is present in central Poland, its internal variation is also high,
- We propose to move the provisional range of *Calamagrostio-Quercetum* in central Poland by circa 60–90 km to the north-east (approximately as far as the Vistula river line) in order to include nearly whole south-western part of Mazowsze.

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