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Teleconnection of 23 modern chronologies of *Quercus robur* and *Q. petraea* from Poland

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Abstract: *Quercus robur* and *Q. petraea* are important forest-forming species in Europe. *Q. robur* is believed to require more fertile soils, to be more tolerant to low temperatures and more sensitive to oak decline than *Q. petraea*. Thus chronologies of the two species from nearby localities were hypothesised to differ more strongly between species than between localities. Wood cores were collected on 23 research plots in 2 national parks and 12 forest districts. In each locality two plots (one with *Q. robur* and one with *Q. petraea*) were established in forest stands of similar age at similar site conditions wherever possible. Similarity between chronologies was assessed by the test of parallel agreement (*Gleichlaufigkeit*), Pearson correlation coefficients, and principal components. The plots were grouped by the Ward clustering method and according to 1st and 2nd principal components. The first 2 methods segregated chronologies nearly ideally into pairs of species from the same forest district, indicating that the chronologies differ between forest districts but not between species. Chronologies clustered in 2 large groups: northern and southern (on the basis of correlation) or northeastern and southwestern (on the basis of parallel agreement). Principal components also distinguished northeastern and southwestern chronologies, but less clearly. The results suggest that differences in climatic and soil requirements between the 2 oak species are generally too small in comparison with the differences caused by climatic factors.

Additional key words: Gleichlaufigkeit, English oak, durmast oak, dendrochronology

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Introduction

Oak stands cover about 6% of the total forest area in Poland. Most of them are composed of 2 native oak species: *Quercus robur* (pedunculate or English oak) and *Q. petraea* (durmast oak). The third native species, *Q. pubescens* (downy oak), is found only in one locality, which is a nature reserve. *Q. petraea* reaches in Poland the north-eastern border of its natural range. *Q. robur* is believed to require more fertile soils, to be more tolerant to low temperatures and more sensitive to oak decline than *Q. petraea* (Przybył 1995, Levy et al. 1992, Siwecki 1994). Therefore this study aimed to verify the hypothesis that oak chronologies differ more strongly between species than between localities. This would enable distinguishing some factors determining the observed differences in soil requirements and sensitivity to climatic factors. There are no clear differences in wood anatomy between the two species (Frere et al. 1999, Feuillat et al. 1997), so differences in chronologies between them would help to determine the dominant species among oak wood samples from archaeological sites.

Material and methods

A total of 23 plots were established in oak forest stands in the Wolin National Park, the Wielkopolska

National Park and in forest districts: Smolarz, Dobrzany, Łobez, Sulechów, Jarocin, Chełm, Choczewo, Młynary, Jedwabno, Brodnica, Hajnówka and Skierniewice. Table 1 presents basic information on the localities and plots. Wherever possible, one plot with *Q. petraea* and one plot with *Q. robur* were established in oak stands of similar age and site type in each forest district (FD) and national park (NP). In the Dobrzany FD no stand of *Q. petraea* was found, therefore a stand of this species was selected in the neighbouring Łobez FD. *Q. petraea* was also lacking in the Młynary FD and all the adjacent FDs. In the Brodnica FD, Smolarz FD and Hajnówka FD, plots were established in mixed stands.

In each plot, wood cores of 15 randomly selected trees of each species were taken with Pressler borer. A total of 345 samples were analysed.

Ring width measurements and their initial analysis were made according to classic methods of dendrochronology, described e.g. by Fritts (1976), Schweingruber (1983), and Ważny et al. (1991). Ring widths were measured with LINTAB equipment to nearest 0.01 mm. For initial analysis, TSAP software (Rinn 1995) was used. The synchronization of growth curves was verified visually on the computer screen and additionally by COFECHA software (Holmes 1983, 1986, 1994). Doubtful samples were measured again and the verifying procedure was repeated.

Statistical analyses were based on standard chronologies created by ARSTAN software (Cook and Holmes 1986). A standard chronology for a given locality is created by averaging the calculated growth index values of individual trees in each year. The growth index in a given year is calculated by dividing the real ring width in that year by the value calculated from exponential regression for to the growth series of the tree.

A total of 25 chronologies were made: 12 for *Q. petraea* and 13 for *Q. robur*. Statistical analyses were based for the common interval of 1911–1994. Pearson correlation coefficients were calculated by STATISTICA 5.1 M software. The test of parallel agreement (*Gleichlaufigkeit*) was performed by TSAP software. This test calculates the number of years in which both chronologies show a decreasing trend or both show an increasing trend, as compared to the preceding year, and divides this number by the total number of years in the compared period (Schweingruber 1983). This coefficient, expressed in %, is abbreviated as Glk%.

STATISTICA software grouped the plots by the Ward clustering method on the basis of the dimension matrix. The software was also used for the analysis of principal components. The first two components were taken into account in the interpretation (Ważny, Eckstein 1991, Wilczyński et al. 2001).

Table 1. Characteristics of the localities and research plots (NP = National Park; FD = Forest District)

No.	Locality	Geographic coordinates	Oak species
1	Wolin NP	53°35’N, 14°30’E	*Q. robur* *Q. petraea*
2	Dobrzany FD	53°20’N, 15°25’E	*Q. robur*
3	Łobez FD	53°35’N, 15°35’E	*Q. petraea*
4	Smolarz FD	52°50’N, 15°50’E	*Q. petraea/Q. robur* (2 mixed plots)
5	Sulechów FD	52°05’N, 15°40’E	*Q. robur* *Q. petraea*
6	Wielkopolska NP	52°15’N, 16°48’E	*Q. robur* *Q. petraea*
7	Jarocin FD	52°08’N, 17°30’E	*Q. robur* *Q. petraea*
8	Choczewo FD	54°50’N, 17°50’E	*Q. robur* *Q. petraea*
9	Brodnica FD	53°15’N, 19°15’E	*Q. robur/Q. petraea* (1 mixed plot)
10	Skierniewice FD	51°50’N, 20°20’E	*Q. robur* *Q. petraea*
11	Jedwabno FD	53°33’N, 20°45’E	Q. robur *Q. petraea*
12	Hajnówka FD	52°43’N, 23°40’E	*Q. robur/Q. petraea* (1 mixed plot)
13	Chełm FD	51°10’N, 23°20’E	*Q. robur* *Q. petraea*
14	Młynary FD	54°15’N, 19°45’E	*Q. robur*

Results

Coefficients of correlation and parallel agreement between chronologies are shown in Tables 2 and 3. Fig. 1 a–b presents dendrograms constructed by the Ward clustering method for the dimension matrix, and illustrating the levels of similarity between chronologies. Distribution of chronologies with regard to 1st and 2nd principal component is presented in Fig. 1c.

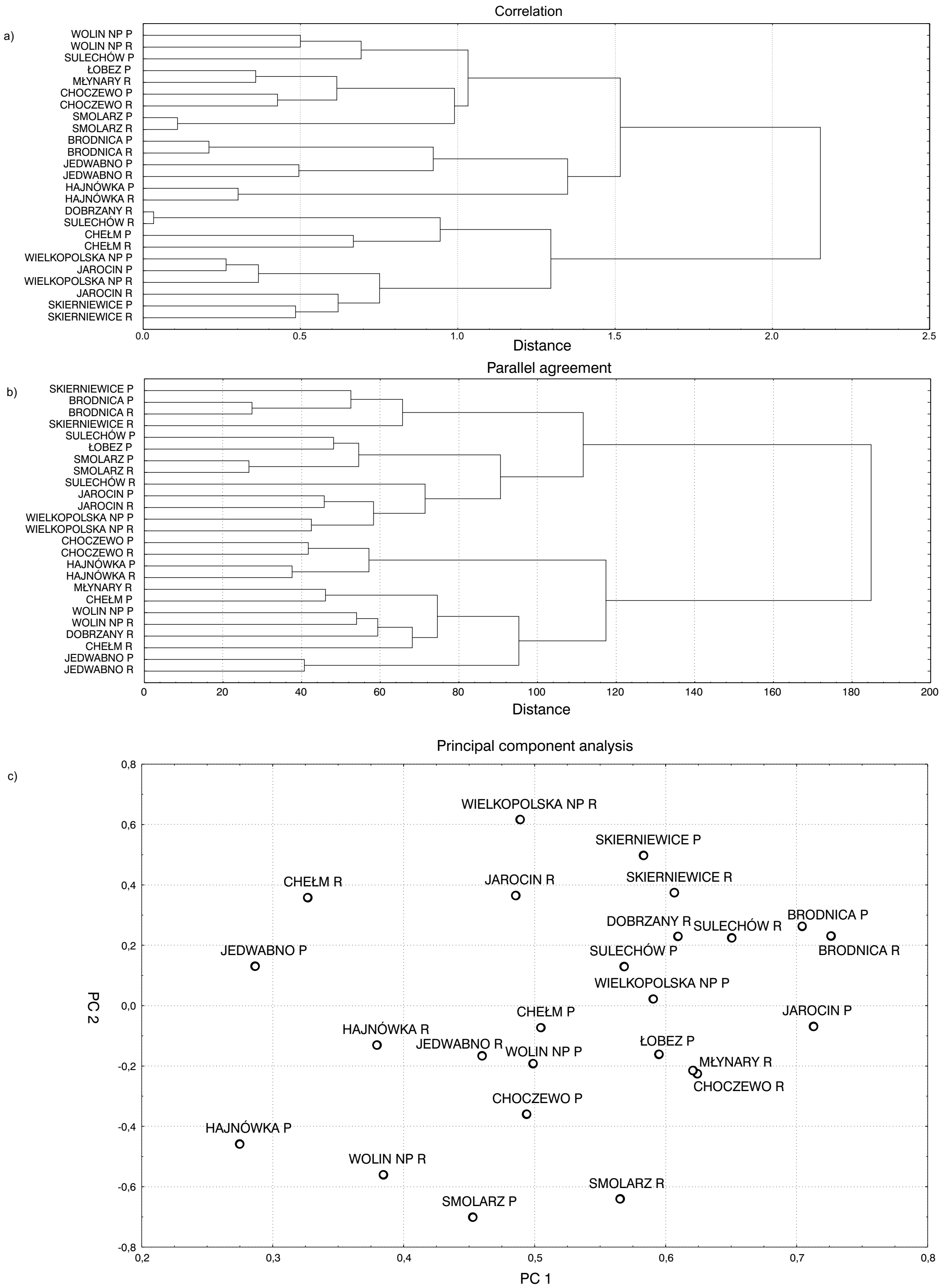

Fig. 1. Dendrograms illustrating similarity between chronologies of Polish forest stands of *Q. robur* (R) and *Q. petraea* (P) for 1911–1994, based on: (a) correlation coefficients; (b) parallel agreement coefficients; and (c) 1st and 2nd principal components

The dendrograms show that the two species cannot be separated on the basis of chronologies. Nearly always chronologies of both species from the same forest district segregated jointly.

The clustering based on coefficients of correlation (Fig. 1a) and parallel agreement (Fig. 1b) both attested to the existence of at least 2 large dendroclimatic groups. Fig. 2 a–b shows the geographic distribution of plots and groups of plots with a distance smaller than 0.8 (thin line) or 1.1 (thick line) for correlation coefficients, and smaller than 75 (thin line) and 100 (thick line) for parallel agreement coefficients. Two major groups for both species were distinguished: (1) southern: Skierniewice FD, Jarocin FD, Sulechów FD and Wielkopolska NP; and (2) northern: Choczewo FD, Hajnówka FD, Młynary FD (*Q. robur*), Jedwabno FD and Wolin NP. Chronologies from the Łobez FD, Smolarz FD and Brodnica FD were assigned to the northern group on the basis of correlation but to the southern group on the basis of parallel agreement. By contrast, plots from the Chełm FD and Dobrzany FD were assigned to the southern group on the basis of correlation but to the northern group on the basis of parallel agreement. Clarity of

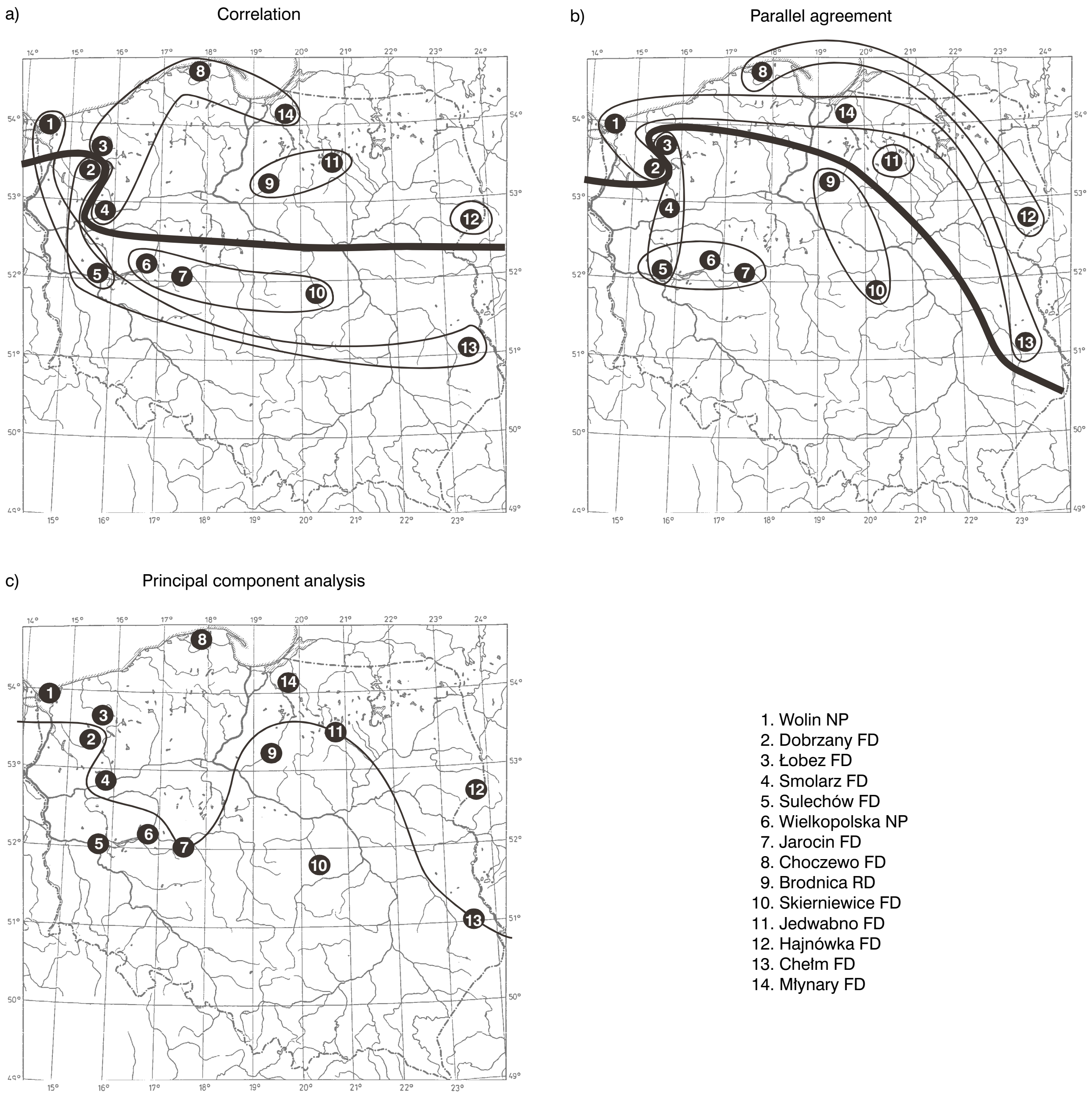

Fig. 2. Geographic distribution of oak stands and their grouping based on: (a) correlation coefficients – distance <1.0 (thin line) and <1.6 (thick line); (b) parallel agreement coefficients – distance <75 (thin line) and <120 (thick line); and (c) 1st and 2nd principal components

the division was complicated by the fact that the chronology of *Q. robur* from the Sulechów FD was assigned to the northern group.

In earlier studies on teleconnection of oak chronologies, they were grouped on the basis of principal components (Ważny, Eckstein 1991, Wilczyński et al. 2001), so this method was also used in this study. The 1st and 2nd components explained 41.6% of total variation. Results of the clustering based on those components (Figs. 1c, 2c) can be regarded as intermediate between results of the first two methods, but the division is disturbed by the fact that the chronology of *Q. petraea* from the Jarocin FD was assigned to the northern group.

Discussion

There are two possible explanations of the failure to separate chronologies of the two oak species. The first explanation might be that the choice of applied methods was wrong. It could be argued that the analysis should be based on pointer years, i.e. the years in which most of the studied trees on a given plot showed substantial changes in growth rate. In French studies (Levy et al. 1992, Becker et al. 1994), more frequent and stronger decreases in growth rate were recorded in *Q. robur*. However, such differences between the two species were not noticeable in Poland (Ufnalski 2001). Thus the second, more probable explanation of the failure is that the expected differences do not exist in fact. Field experiments failed to reveal any significant differences in stomatal conductance between those oak species (Breda et al. 1993). Experiments with seedlings of both species detected some differences in physiological reactions to defoliation and drought stress, but no differences in radial growth (Gieger, Thomas 2002). So far, no substantial differences between the two species were found at the genetic level (Zanetto et al. 1996, Moreau 1996, Kelleher 2005). As mentioned above, researchers failed also to detect any significant differences in wood anatomy (Frere et al. 1999, Feuillat et al. 1997).

Anyway, results of this study confirm the existence of at least 2 distinct dendroclimatic regions for oaks in Poland (Ważny, Eckstein 1993). The border between the two is not well-defined but it is generally oriented from the east to the north-west. Within each of the 2 groups, even very distant chronologies show a large degree of similarity (e.g. Wolin NP and Hajnówka FD), whereas nearby chronologies may differ remarkably (e.g. Skierniewice FD and Jedwabno FD).

Further research in this field should include chronologies from the south of Poland. Moreover, dendroclimatic analyses should be conducted to explain the differences between chronologies.

Conclusions

On the basis of the studied material, 2 dendroclimatic regions were distinguished for oak stands in Poland. The borderline is generally oriented from the east to the northwest.

The attempt to distinguish the 2 species on the basis of chronologies failed in this study. The greater similarity between plots of different species within one forest district than between nearby plots of the same species indicates that radial growth of both species is similarly affected by climatic conditions.

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