Are vessel traits of earlywood storing effect of hydroclimatic factors on radial growth of European ash? The case study of a floodplain forest

Bernard Okoński¹, Marcin Koprowski²

¹Poznań University of Life Sciences, Faculty of Forestry, Department of Forest Engineering, email - okonski@up.poznan.pl
²Nicolaus Copernicus University, Chair of Ecology and Biogeography, email - koper@umk.pl

Abstract: Radial growth of trees is highly determined by environmental conditions. Wood can preserve environmental effects at different levels of its structure, regardless if tree-ring level, seasonal wood, subseasonal or cell structures are considered. We decided to employ vessel cell parameters of earlywood to investigate how hydroclimatic parameters affect the development of earlywood structures of European ash growing on active terrace of medium size European river under the influence of river regime. The main conclusions of our research are: vessel cell parameters of earlywood of European ash, particularly average area of cell, seams to bear relatively strong hydroclimatic signal for trees growing in floodplain forests; the strongest relation between hydroclimatic parameters and vessel cell traits of European ash can be observed for the vessels of earlywood except the first row of vessel cells or the entire extent of earlywood rather than for the zone of the first row of vessel cells; the positive relation between precipitation or streamflow and all the investigated vessels parameters of earlywood was identified, the negative relation between temperature and all the investigated vessels parameters of earlywood was identified; the hydroclimatic parameters of the previous year seem to have predominant effect on development of traits of vessel cells in earlywood rather than parameters of current year; streamflow could be considered as the parameter that substitutes well, or even is more important than precipitation, as far as water availability for development of vessel cells of ash trees growing on active terrace of river valley is concerned. The results presented in this paper should rather be considered as preliminary. These results will be verified and challenged, in the course of currently continued studies, while farther empirical material is available.

Key words: European ash, floodplain forest, radial growth, earlywood, vessel traits, temperature, precipitation, streamflow

INTRODUCTION

Radial growth of trees is highly determined by environmental conditions. Wood can preserve environmental effects at different levels of its structure, regardless if tree-ring level, seasonal wood, subseasonal or cell structures are considered (Banks 1991, Schweingruber 1996, Fritts 2001). The classic approach employed in tree-ring science focused on tree ring as entity (Cook and Kairiukstis 1990), although many ecological problems require going beyond TRW, focusing on density of wood, chemical, isotopic composition of wood, or reaching cell level. Sometimes progress in understanding of ecological relations binding the environment and tree growth cannot be probably gained any more through employing only these classic methods of dendrochronology (McCaroll and Loader 2004, Čufar 2007).

Water availability is, in general, the main ecological factor modulating tree growth, especially if water is permanent or episodic limiting factor for the forest ecosystem (Peh et al 2015). Anyway water input for forests can be provided by various hydrological processes. Some ecosystems are supplied solely by precipitation, some use other sources in combination with precipitation in various temporal scales. These sources are groundwater, river flooding or dew combed in mountain areas (Chang 2012).

The forests growing on active river valley terraces are very distinctive ecosystems as far as water – ecosystem interactions are concerned (Daniellewicz 2008, Haase and Gläser 2009, Kamiński et al. 2011, Keddy 2013). The water availability for river valley ecosystems is not only related to direct precipitation but uniquely to river regime. Streamflow temporal pattern, rising and falling of water levels, overbank flow and flooding of floodplain are the determinants of water availability to forest environment there (Richards 1982, Zwoliński 1991, Bridge 2003, Charlton 2007). Although the river presence can be recognized as a steady source of water for vegetation, the variability of streamflow volume can effect in episodic excess of water or optimal availability, but also in temporal scarcity, resulting in drought at various temporal scales (Beaven 1989). Thus severe drought episodes impact not only higher elevated region but also ecosystems of active terraces of river valleys (Mitsch and Gosselink 2015). These episodes of drought stress to trees occur more often under temperate climate across Central or Western Europe lately (Klimo, Hager 2001).

The aim of our study was to assess if or which hydroclimatic factors are in relation with earlywood traits of European ash. The traits that we focused on are vessel
area and cell number at different zones produced during earlywood development. The study should be considered as preliminary regarding European ash radial growth pattern of cell structures under the hydroclimatic regime of river valleys. European ash is the tree species characteristic for floodplain forests of Atlantic and part of Mediterranean Europe (Klimo and Hager 2001, Danielewicz 2008). The species nowadays suffers from extensive dieback caused by fungi disease which is tough challenge for European foresters and forest ecologists (Pautasso et al. 2013). It is often assumed that the disease outbreak has been triggered by deteriorating of climatic conditions of European ash growth due to e.g. drought frequency increase since the last decades of 20th century (Gross at all 2014).

MATERIALS AND METHODS

Sampling site was located in mature forest stand growing on active river terrace in the Lazy Czeszewskie Forest, Poland. The forest area consists mainly of old growth floodplain stands composed of English oak, European ash reaching 200 years mixed with other mature tree species such as field and European whit elm, small-leaf lime, hornbeam, Norway and field maple. The sampling site lays within mid-course, lowland section of the Warta River. The WGS84 DMS coordinates of the sampling site are 52° 7’ 37” N, 17° 30’ 10”E. The Warta River of 808 km length and 54,529 km² basin area is a tributary of the Odra River flowing on the North European Plain (Fig. 1).

The Warta is a mid-size European river draining the basin of the Baltic Sea (part of the Atlantic). The river regime is dominated by snow-melt or ground thawing in late winter and early spring, sometimes coupled with substantial precipitation which triggers rising of streamflow to annual maximum peaks in the period ranging from January to April. Low water period occurs in late summer and early autumn from July to October usually under the high evapotranspiration and episodically low precipitation. The mean streamflow is around 100 m³xs⁻¹, absolute maximum and minimum flows noted in instrumental period for the river section are about 1700m³xs⁻¹ and less than 35 m³xs⁻¹. According to climate classification of Köppen-Geiger the sampling site lays within humid continental climate with warm summer (Dfb) in transitional zone into oceanic climate with warm summer (Cfb) which is typical for the western-central and western part of Atlantic Europe (Peel et al. 2007). The mean annual air temperature is 8.4°C and mean annual precipitation is 517mm for the WMO reference period 1961-1990. The minimum and maximum monthly temperature occurs in February (-2.8°C) and July (18.4°C), minimum and maximum precipitation occurs in February (24mm) and July (73mm). Frost can occur
regularly from December to March and episodically in April, May, October, November (Fig. 2).

![Figure 2. Climatic diagram for region of sampling.](image)

### Sampling pattern and sample preparation

The sampling scheme covered 15 European ash trees with 2 samples per a tree extracted (East and West axis sampling). The sampling stand was composed of English oak (approx. 80%) and European ash (approx. 20%) with admixture of hornbeam and small-leaf lime aged 137 year. Lower layer tree species were hornbeam, Norway and field maple, field and European whit elm, small-leaf lime of age ranging from 87 to 37 years. Understory layer consisted of European ash and English oak. The sampled stand was 28.6m high, crown height 18.0 m, DBH 50 cm. The selected trees represented dominant biosocial position of the upper layer. The random selection of trees for the site collection was employed provided that the biosocial assumption was obeyed.

The individual TRW series were tested against the rest of the total sample population for the site in order to exclude the series with weak site signal to create the robust chronology representative for the forest stand (Bräker 2002). Standard sample collection methodology and sample preparing procedures were utilized (Zielski and Krąpiec 2004, Speer 2010). The selected trees were drilled in 2012 year with Pressler borer. The TRW measurements were performed with CooRecorder software then the TRW series were initially tested and combined into a collection in CDendro software (URL: [http://www.cybis.se](http://www.cybis.se)). The final verification of individual sample series quality to be counted as representing the forest stand was conducted by means of COFECHA software (Holmes 1983, Grissino-Mayer 2001). Finally, the most robust sample, correlating with the mean for the site and representing TRW series the best, was selected for cell parameters analyses.

Preparation of the selected sample for cell study was conducted at the laboratory of Nicolaus Copernicus University, the Chair of Ecology and Biogeography and included following operations: preparation of microslides using microtome and thin section (ca 20 µm), staining with safranine for long storage by and closing by Histokitt (Fig. 3). The stills of slides were captured with use of microscope and Leica DFC495 camera and processed by dedicated camera software. Earlywood vessel parameters were measured for each tree-ring according to following scheme: for zone of first row of earlywood cells (I), for zone covering total extend of earlywood (II), for zone of earlywood covering the extent of difference between total and the first row of cells extent. The measurement of earlywood vessel cells was performed along the tangential length of 4 mm. If the tangential length did not met the requirement because of mechanical damage of cores that occurred during sample extraction or microslides preparation, the vessel parameters were proportionally adjusted.

![Figure 3 A microslide of sampled European ash wood.](image)

### Analysis of relations hydroclimatic factors – earlywood vessel traits

The cell parameters measured according to the scheme described above were cell total cell area (A), cell number (C), mean cell area(M) for the period from 1951 to 2011 year. Thus the total number of 9 earlywood categories of vessel cell parameters were set for dendroecological analyses (3 earlywood vessel zones x 3 vessel parameters). These parameters of earlywood, used as dependent variables and set as time series were:
- Total area of vessel cells in the first row of vessel cells in earlywood -IA
- Number of vessel cells in the first row of vessel cells in earlywood -IC
- Mean area of vessel cells in the first row of vessel cells in earlywood -IM
- Total area of vessel cells following the first row of vessel cells in earlywood -IIA
- Number of vessel cells following the first row of vessel cells in earlywood -IIC
- Mean area of vessel cells following the first row of vessel cells in earlywood -IIM
- Total area of vessel cells in earlywood -IIIA
- Number of vessel cells in earlywood -IIIC
- Mean area of vessel cells in earlywood -IIIM

...
The classic Spearman nonparametric correlation model was employed without bootstrapping and probability adjustment to investigate relations between hydroclimate and earlywood vessel parameters (Hollander and Wolfe 1999). For the model independent variables were:

- Mean area of vessel cells in earlywood -IIM

The raw climatic data were obtained from the network of Institute of Meteorology and Water Management for the meteorological stations Poznań, Nowa Wieś Podgóra, Kórnik and streamflow series derived from gauging station Poznań. The raw data were processed to produce the time series for the period 1951-2011 which follow the pattern described above. We assumed significance level for all statistical analyzes employed in research described here at p <0.05.

RESULTS AND DISCUSSION

The negative relationship were identified only for temperature of all hydroclimatic parameters used as the explanatory data. Thus the negative relations were identified between temperature of warm period of previous year (TWP) and total area of earlywood vessel cells except the area of first row of vessels, the number of vessel cells except the first row and the number of all vessel cells (IIA, IIC, IIIA, IIIC). The negative relations were also identified between temperature the early warm period of current year (ETWC) and total area of earlywood vessel cells except the area of first row of vessels, and the number of vessel cells except the first row and the number of all vessel cells (IIA, IIC, IIIA, IIIIC). In addition, the negative relation was found between temperature of the early warm period of previous year (ETWP) and the number of all earlywood cells. For the temperatures – the cell parameters relations the strongest occurred for early warm period of current year (ETWC) – r between ~-0.3 and -0.4, but the strongest relations as far as temperatures are concerned were for the number of all the vessel cells (IIIA) and the cells except the first row (IIIIC). Positive relation between temperature and vessel cells parameters occurred only for one case, namely between the temperature of late warm period of previous year and the number of all vessel cells in the first row of vessels (Fig. 4).

As far as precipitation is concerned the positive relations occurred only but never the relations for the precipitation of current year. The positive relations were identified between precipitation of previous year warm period (PWP) and all the investigated parameters of earlywood in zone II and III except for the only case which is the number of vessel cells in zone II (IIA, IIM, IIIA, IIIC, IIM). Another case for which the precipitation was bound with earlywood cell parameters was the late warm period of previous year (LPWP). The relations for that case were for the average area of vessels but for all studied zones except zone I for total area of vessel cells in zone II, zone III and average area in zone III. The strengths of relations were similar for these two periods mentioned above (about 0.3), but slightly higher for the area of vessel cells as explanatory data and for the late warm period of previous year as explanatory data.
As for the streamflow the positive relations were found only. These relations occurred between streamflow of previous year warm period or streamflow of previous year early warm period (QWP, EQWP) and exactly the same vessel cell parameters, but located in different earlywood zones. The parameters were average area of vessels (IM, IIM,IIIM). These positive relations occurred also between streamflow of warm period of current year and the number of cells in zone II covering the extent of earlywood but the first row of vessels, zone III covering the whole extent of earlywood or the total area of vessel cells in zone II. Finally, the positive relations occurred between streamflow of late warm period (LQWP) and total area of vessel cells in zone II, zone III and number of vessels in zone III. The strength of relation was the highest for the streamflow, particularly for the warm period of previous year (QWP), early warm period of previous year (QWP) or warm period of the current year (QWC), for which the correlation coefficients for the prevailing number of parameters ranged from 0.30 to almost 0.50. It seems that streamflow could well substitute the precipitation as far as earlywood vessel structure development of European ash is considered. In support for this assumption can be taken positive relation for precipitation and streamflow temporally coincide that as a rule the (PWP and QWP, LPWP and LQWP), for some periods the relation can only be identified for streamflow and never for precipitation (QWC, EQWP), the number of cases of relations for streamflow is higher than for precipitation (12 to 8 cases) and the highest strength of relation of all the investigated in this research was attributed for streamflow rather than for precipitation. Finally, out of 29 identified cases of relations in total, 7 cases could be attributed to the period of current year only.

Additional period was assigned as explanatory data for covering late winter and early spring high water and investigation of its impact on the parameters of vessel cells. It can be assumed that despite of the fact that the period extends mostly over the late dormancy and early vegetation period, the streamflow of late winter to early spring could influence the earlywood growth. Anyway, no relations were identified between the streamflow and studied parameters of vessel cells regarding both current and previous year for late winter-early summer period (QSP, QSC).

The results of the analyses described above, concerning the relations between hydroclimatic parameters and the morphometric parameters of vessels seem to be coherent. No relations were found between hydroclimatic parameters and vessel cell traits for the period of the late current year. Those relations could not be explained and supported by ecological knowledge since these environmental parameters would act after the earlywood structures were developed. Farther, all of these results achieved for the seasonal wood structures are coherent with the results that are usually the effect of studies concerning the investigations of the relations between hydroclimatic parameters and TRW or season wood width for European ash. These relations are usually negative for the temperature, and positive for precipitation in vegetation period in similar climatic conditions, so the similar results as that we have achieved (Karpavičus and Adomas 2006, Okoński and Koprowski 2012, Matisons 2016). It seems that the most sensitive parameters out of these studied, as far as relations between hydroclimatic factors and vessel cell traits are concerned, are the parameters of zone II and III – entire extent of earlywood and entire extent of earlywood but the first row of vessel cells. More than 10 relationships were identified for each of these zones (12 and 14 cases). In comparison, for the zone I only 3 relationships between hydroclimate and vessel cell parameters were found. Thus the zone I looks to react weak for hydroclimatic factors.
The most promising parameter could be average cell area, because it returned the highest strength of relationship (r≈0.5) and occurred 11 times out of 29 relations found altogether. In addition, the only 3 cases of relationship for zone I occurred just for the average cell area. However the limitation for more firm interpretation of these results have to be stated. These results should gain wider support by employing more substantial empirical material and then applying robust, multidimensional statistical verification. It is also required because other known factors may impact vessel cell traits (Tulik at al. 2010). Thus the results presented in this paper should rather be considered as preliminary. These results will be verified and challenged, in the course of currently continued studies, while farther empirical material is available.

MAIN CONCLUSIONS
1. Vessel cell parameters of earlywood of European ash, particularly average area of cell, seems to bear relatively strong hydroclimatic signal for trees growing in floodplain forests.
2. The strongest relation between hydroclimatic parameters and vessel cell traits of European ash can be observed for the entire zone of earlywood and the zone of earlywood except the first row of vessels.
3. The weakest relation between hydroclimatic parameters active in river valley and the earlywood traits was observed for the zone of the first row of vessel cells.
4. The positive relation between precipitation or streamflow and all the investigated vessels parameters of earlywood was identified. The negative relation between temperature and all the investigated vessels parameters of earlywood was identified.
5. The hydroclimatic parameters of the previous year seem to have predominant effect on development of traits of vessel cells in earlywood rather than parameters of current year.
6. Streamflow could be considered as the parameter that substitutes well, or even is more important than precipitation, as far as water availability for development of vessel cells of ash trees growing on active terrace of river valley is concerned.
7. The late dormancy period streamflow seems to have no effect on the development of earlywood vessel structures of European ash.

ACKNOWLEDGMENTS
This work was supported by the National Science Centre in the years 2011–2015, grant number N N309 708240. This paper is a part of the habilitation thesis of Bernard Okoński.

REFERENCES
CooRecorder, Cdendro Software. URL: http://www.cybis.se.


For citations