UNIVERSITY OF SZEGED
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COMPLEX DENDROCLIMATOLOGICAL ANALYSIS OF HUNGARIAN SCOTS PINE STANDS IN THE LIGHT OF CLIMATE CHANGE OF THE LAST 100 YEARS

THESIS OF PH.D. DISSERTATION

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1. INTRODUCTION

Investigating climate change the resolution of the analysis, whether it is a reconstruction or a prediction, is always a core issue, because alteration of climate factors affects many short-term processes like more often occurring heat-waves (Della-Marta et al. 2007), agricultural disasters related to extreme events or the increasing number of insects or rodents that may cause serious victualling problems. To measure the effects of historical and pre-historical climatic events on annual time-scale is not easy because most of the paleoenvironmental database do not able to store year-to-year information. There are only a few databases that can provide input data for a high resolution research in sufficient quality and quantity. Tree-rings, as it is widely known, are important records of former environmental and climatic conditions, as well as central elements of paleoclimatological reconstructions thanks to their annual resolution.

In my dissertation I aimed to answer the following four questions with complex dendroclimatological analyses of Hungarian Scots pine (*Pinus sylvestris*) stands: (1) which climate parameters affect tree-ring width variation, (2) how the influence of changing climatic conditions has evolved over the last 100 years and has modified the climate-growth relationship, (3) did special tree-ring characters (related to extreme events principally) appear in the Hungarian Scots pine stands, and if so (4) how their frequency has changed over the last 100 years?

In spite of the fact that Scots pine is one of the most widespread species in Hungary and covers larger area than beech (*Fagus sylvatica*), its role in the forest and tree-ring research is highly under represented. Although it is not native, it plays an essential role in Hungarian forest composition, moreover, thanks to its high adaptation ability, plantation of Scots pine is possible on poor sites where other species cannot find sufficient amount of nutrient.

Adaptation, however, not necessarily means undisturbed growing. Investigation of the growth response of the Hungarian pine populations is important because according to international studies (Reich-Oleksyn 2008; Bauwe et al 2015), growth dynamics of Scots pine may alter significantly in the future in Central Europe, moreover, the current state of climate change has already caused negative changes in one of the Hungarian Scots pine stands (Gulyás et al. 2014).

In my dissertation I studied four sample areas with different locations and growing environments to answer the above presented questions, to contribute in the enlargement of the Hungarian dendroclimatological database and to widen the existing knowledge on the tree-ring growth of Scots pines.

2. DATA AND METHODS

Sampling, sample preparation and data processing were according to the classical methodology of dendrochronology (Stokes-Smiley 1968). Measurement of tree-ring widths was applied with *on-line* and *off-line* technology using image analysis and microscope. Beyond total ring width, the width of earlywood and latewood was also measured. Rings formed before 1915 were excluded from the database.

All of the tree-ring series were therefore standardized by fitting a cubic smoothing spline with a 50% frequency response at 67% of the length of the individual series (Cook and Peters 1981). Autocorrelation was removed from each individual index; then all the detrended residual series were averaged into a site chronology using the biweight robust mean (Cook 1985). The stability of the common signal preserved in the index series was determined by calculating the Expressed Population Signal (EPS), which was applied with a 25-year window lagged by 1 year using the widely accepted threshold of 0.85 (Wigley et al. 1984). In addition, the mean interseries correlation (Rbar) was computed using the same window and lag as the EPS values.

To evaluate the connection between climate data and tree-ring indices, Pearson correlation coefficients were calculated from May of the previous year (MAY) to October of the current year (Oct) of tree-ring formation. Not only were individual months analyzed, but all seasonal and annual data as well. For the investigation of the effect of changing climatic conditions on tree-ring growth during the study period, 25-year moving window correlations of meteorological and tree-ring width data were computed.

Identification of special tree-ring characters was according to visual assessment using microscope. A year was considered as a year with special tree-ring character if it appeared in both samples of a given tree and occurred in at least 3 trees in the same year. Using the formula of Osborne et al. (1997) stabilized frequency was computed. The relationship between stabilized frequency and climate data was calculated using Spearman's rank order correlation from May of the previous year to October of the current year of tree-ring formation.

To characterize and examine climate conditions and their effects on the climate-growth relationship during the study period I divided the last 100 years into four 25 year-long periods and calculated mean and anomaly values of climate data using CRU TS 3.23 0.5°x0.5° (Harris-Jones 2015). Not only were precipitation and temperature individually examined, but aridity indces were also calculated to highlight the influence of drought conditions on tree ring-width variability. Computation was made for every month of the current year of tree-ring formation, for all seasons and for annual data.

3. SAMPLE AREAS

I selected the sample areas along the criteria to be able to cover the study period with samples from living trees only. In spite that in Hungary Scots pine covers a relatively large area, it is difficult to find stands with older than 100-years-old individuals. It was also important to select sample sites with different growing environment to ensure a larger database on the growing properties of Scots pine populations in Hungary.

Scots pine stands of four sample areas were studied:

- Bakonyalja. The Fenyőfő Pine Forest is situated in the northern part of Western Hungary on the northern slopes of the Bakony Mtns. This forest, which is the oldest pine stand in Hungary, is growing on secondarily evolved dune sand and weakly humic sandy soil formed on a calcareous sand bedrock (Szmorad-Tímár 2005). The forest is mixed, with oak (*Quercus cerris*, *Quercus robur*, *Quercus petraea*), silver birch (*Betula pendula*) and ash (*Fraxinus ornus*), but the canopy is dominated by a pine population of uneven age. The climate of the area is moderately warm; the annual mean temperature is 10.4°C. The warmest month is July (20.6 °C), the coldest is January (-1.1°C). The sum of annual precipitation is around 650 mm with a maximum in July (75 mm) (Harris-Jones 2015). In total 74 trees were cored in Bakonyalja.
- Őrség. The second site is situated in the western part of the country, near to the Austrian and Slovenian borders. The pedological conditions at this site are better; the dominant soil is brown forest soil formed on

Quaternary sediments. Precipitation income of the area is high, around 800mm. The wettest month is July (96 mm), the driest is February (34 mm). The mean annual temperature of the Őrség site is 10.2°C, its warmest month is July (20.2°C) (Harris-Jones 2015). 34 individuals were sampled in this site.

- Mecsek. The southernmost sample site is situated nearby Kővágószőlős, in the southern part of Mecsek Mtns. Its climate is moderately warm-moderately wet (Dövényi 2010), the annual mean temperature is 10°C, the warmest month is July, the coldest is January. The total precipitation of the area is around 650 mm, similarly to the Bakonyalja site. In line with its mountainous habit, the site is covered by forest soil. The pine population is mixed with oak and beech (Borhidi 2003). Seven Scots pine samples were investigated from the Mecsek site.
- Nyírség. The site Nyírség is situated in the eastern part of the country between Vámospércs and Nyírmártonfa. The climate of the area is moderately warm and dry (Dövényi 2010), the annual mean temperature is 10°C. The total precipitation is lower compared to the other sample sites, 570 mm, with a maximum in July. The area is mainly covered by sandy soil (Dövényi 2010). From the Nyírség site 10 discs were analyzed.

4. SUMMARY OF THE RESULTS

1. In total 103 individuals were cored and investigated from four sample areas. The climate-growth relationship observed in the tree-ring indices can be described with a positive dominance of summer precipitation and a negative maximum correspondence with summer temperature. Our

results indicate the amount of July precipitation is the most important limiting factor in tree-ring growth over the entire study period. Temperature, with its negative effect on tree-ring formation, dominates in summer. It has a particularly important role in tree-ring width variation, in particular due to its influence on the usable amount of precipitation. In addition to summer, a significant relationship between temperature and tree-ring widths can be found in February and March, but in case positive.

2. As a result of the increasing temperature, the positive effect of the thermal conditions of late winter-early spring period to tree-ring growth has totally disappeared by the end of the last century.
3. In spite of warming climatic trends, a decline is observed in summer in the correspondence between temperature and tree-ring width variability, which means that the increasing temperature caused decreasing connection between thermal conditions and tree-ring development.
4. While the amount of precipitation shows decreasing trend in every sample area, its effect on the climate-growth relationship of Scots pines is lower than it was expected. In general, a decline in the correspondence of July precipitation and tree-growth can be observed but in the entire summer period the connection between tree-ring width variability and precipitation is strong and stable.
5. According to the results of moving window correlation it can be stated that the correspondence calculated for long time-scale is not a result of a stable signal which makes the reported clime-growth relationship uncertain. Because of this, the reconsideration of the knowledge on the climate-growth system of Scots pine should be recommended in the light of climate change in Hungary.

6. In contrast to foreign researches (Campelo et al. 2006; de Luis et al. 2011; De Micco et al. 2013, 2016) I was not able to connect unequivocally the occurrence of intra-annual density fluctuations to summer temperature neither in the site Bakonyalja nor in the site Őrség, even though both areas experienced a massive warming in the last 100 years.
7. The number and frequency of narrow rings have increased by leaps and bounds in the last 25 years, fitting to the more often occurring drought events. According to my result the amount of summer precipitation is the main stress factor of the development of narrow rings, but in many cases the amount of previous summer’s precipitation is also crucial.
8. According to the results of the dissertation and based on the experiences of international studies (Bauwe et al. 2015), a reduced growth of Scots pine tree-rings is predictable in the future if the current climate trends will continue.

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