University of Sopron
Faculty of Forestry

Theses of doctoral (PhD) dissertation

The effects of climate change on distribution and production of sessile oak (*Quercus petraea*)

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Sopron
2017

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Background and purpose:

Climate change is one of the main global challenges in the 21st century. It has an influence on the economy, water management, agriculture, forest management and as well as the quality of our life. Thus, the aim of this doctoral dissertation is the complex analysis of climate change effects on sessile oak (*Quercus petraea* Matt. Liebl.) forests, which is one of the most important native tree species in Hungary.

The main goal of the dissertation is to determine those climate parameters which have the highest influence on the distribution and production of the selected tree species. Further aims are summarized by the followings:

- Quantify the connections between the past climate conditions, aridity indexes and the distribution of the selected tree species.
- Modelling the potential future sessile oak distribution by the end of the 21st century.
- Estimate the production capacity changes with selected climate variables.
- Identify the most climate sensitive and vulnerable regions, where the projected future distribution and production capacity may decrease significantly.

These investigations are important for sustainable forest management and help to define climate change adaptation strategies in forestry.

Materials and methods:

Carpatclim climate database were used for analyse the past climate condition (1961-2010), and the results of 12 regional climate model simulations for the 21st century have been analysed from ENSEMBLES EU FP6 project (2011-2100). Thirty year periods were used for investigate the tendencies of regional climate change based on the main water consumption period of the tree species.

The selected forestry databases were the Forest Inventory Database of the Central Agricultural Office, and the Long-term Growth Monitoring Network Database, where the mixture ratio of the stands were higher than 50%.

Four stochastic species distribution models were utilized (maximum likelihood, bioclim, domain, one-class SVM) to estimate potential future distribution. Feature analysis, model evaluation and accuracy assessment statistical methods were used before the predictions in Digiterra Map GIS software and ModEco ecological modelling program.

Long-term Growth Monitoring Network plots with zonal site condition and Carpatclim climate database were used for estimate the future production capacity [m^3/ha/year] and yield classes. The main climate variables were determined with principal component analysis, factor analysis and correlation analysis applying STATISTICA13. Based on the most influential site and climate factors, linear regression functions were given to estimate the future production capacity changes. The results were compared to field measurements, and as well as national and international studies.

Results and discussion:

The results of the statistical analysis showed, that the most important climate variables for the distribution of sessile oak are the followings: (1) annual temperature, (2) temperature of the critical period (July) (3) precipitation sum of the growing season (April - October) and (4) annual precipitation sum. Therefore, the long-term annual averages and the climatic extremes of the main water consumption period have the most important influence on distribution. Significant connections were found between the Ellenberg's climate quotient (EQ), modified Ellenberg's climate quotient (modEQ), beech tolerant index (BTI), forest aridity index (FAI) and the potential current distribution. The EQ and BTI indexes are special bioclimatic indices for beech ecological needs, thus these results suggest that the sessile oak and common beech tree species are comparative.

Optimum range and tolerant limit of the selected tree species determined by scatter plot and histogram analysis results. With the Ellenberg's climate quotient the optimum range was 27.0 – 36.0 °C/mm, the tolerant limit was 20.0 – 41.5 °C/mm. With beech tolerant index the values of optimum between 13.5 – 18.0 mm/°C and the tolerant limit was 10.5 – 26.0 mm/°C. Out of these ranges the probability of presence was really low.

The results of the models show considerable shrinkage of sessile oak distribution, because of the frequency of long-term dry periods are likely to increase by the end of the 21st century. It is extremely likely that these processes, which play an important role in the climate-dependent forestry sectors, will have severe economic consequences for stakeholders in the agricultural sector as well.

One model (domain) were unsuited for predicting because of the low accuracy value (AUC), which mean that there were significant regional differences between the modelled potential and the actual distribution.

The distribution models investigations determined the sensitive regions, where the shrinkage of sessile oak probably will be the highest. These areas are the followings:

- Cserehát,
- Heves-Borsodi-Hills,
- Bükkalji-Hills
- Cserhát-territory,
- Kelet-Zselic, Nyugat-Zselic.

In these areas it should be preferred more drought stress tolerant tree species.

Used all of the Long-Term Growth Monitoring Network plots the connections between the dendrometric parameters and the climate variables were undetectable. The reason of this result, that the local microclimate, the diverse slope angel and the exposure have more influence on the plots, than the macroclimate. Therefore, monitoring plots with zonal site condition used only in the statistical investigations.

According to principal component analysis and factor analysis results the annual temperature has slightly positive effect on yield. The precipitation sum of the growing season and the critical period have strong positive effects however the temperature of the critical period has a strong negative connection with yield factor. Significant correlations were found between the Ellenberg-index ($r^2 = 0.23$), Thornthwaite-type aridity index ($r^2 = 0.25$) and production capacity, which mean that these parameters suitable for future estimations. International researches showed that the forest aridity index has huge influence on production, but it was not detectable on the used monitoring plots.

By the end of the 21st century, the projected production capacity of the particularly vulnerable regions may decrease by as much as 80 – 85% of the current production value. The decreasing production implies changes of the yield classes, and it is likely that these processes will lead to one yield category changes on the 70% of the selected 139 monitoring plots.

Field measurement plots were selected by a humid-arid climatic transect in Hungary, and compared to the Long-Term Growth Monitoring datasets. The results showed, that the top height of the stands were decreased with the drying climate, however some of the plots showed increasing height growth. The reason is probably the good nutrient supply because in these areas the typical soil type is the brown forest soils.

The calculated relative top heights [%] and the past climate condition of the reference period (1981-2010) showed the highest correlation coefficient ($r^2 = 0.65$), which mean the top heights fits the best relations with Carpatclim past climate datasets.

Theses:

1) The four stochastic species distribution model (maximum likelihood, bioclim, domain, one-class SVM) results showed that the main climate drivers of the sessile oak distribution are the (1) Ellenberg's climate quotient, (2) the beech tolerant index, (3) and the forest aridity index. Further determinative climate variables are the (1) annual temperature, (2) precipitation sum of the growing season, (3) and the temperature of the critical period.

2) One model (domain) were unsuited for predicting the distribution because of the low accuracy value (AUC), but the maximum likelihood method in the Digiterra Map GIS software were suitable despite that it not a special ecological distribution modelling program.

3) With Ellenberg's climate quotient the optimum range of the selected tree species was 27.0 – 36.0 °C/mm, and the tolerant limit was 20.0 – 41.5 °C/mm. With beech tolerant index the values of the optimum range were between 13.5 – 18.0 mm/°C and the tolerant limit was 10.5 – 26.0 mm/°C.

4) The distribution models investigations determined the sensitive, vulnerable regions, where the shrinkage of sessile oak probably will be the highest. These areas are the followings:

- Cserehát,
- Heves-Borsodi-Hills,
- Bükkalji-Hills
- Cserhát-territory,
- Kelet-Zselic, Nyugat-Zselic.

5) Principal component analysis and factor analysis were detected that the annual temperature means, the precipitation sum of the growing season and the critical period had a huge influence on the Long-term Growth Monitoring Network plots with zonal site condition. Based on the correlation analysis the Ellenberg's climate quotient, Thornthwaite-type aridity index essential for production capacity, which mean that these parameters suitable for future estimations.

6) By the end of the 21st century, the estimations of projected production capacity showed decreasing on the monitoring plots. The estimated production capacity of four forestry land (North Hungarian Mountains, Trans-Danubian Mountains, Western Transdanubia, Southern Transdanubia) may decrease by as much as 83 – 86% of the current production value, and in the particularly vulnerable regions may 81.5 – 85%. The decreasing production implies changes of the yield classes, and it is likely that these processes will lead to one yield category changes on the 70% of the selected plots.

Publications:

Journal articles

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Gulyás K., Gálos B., Czimber K. (2013): Az "agrárklíma" döntéstámogató rendszer klímaadatbázisának előzetes kiértékelési eredményei. IV. Kari Tudományos Konferencia, Nyugat-magyarországi Egyetem, Erdőmérnöki Kar, Sopron, 2013. december 10.

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I. Berki, **K. Gulyás,** G. Veperdi (2017): The changes of the forests dendroproduction in the Carpathian basin - case study: *Quercus petraea*. Geophysical Research Abstracts Vol. 19, EGU2017-17583, European Geosciences Union General Assembly, Vienna, Austria, 23–28 April 2017.

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K. Gulyás, I. Berki (2013): Health condition of sessile oak (*Quercus petraea*) in Hungary. In: Neményi M., Varga L., Facskó F., Lőrincz L. (eds.) Science for sustainability: International Scientific Conference for PhD students, Proceedings, pp. 172-173. ISBN: 978-963-334-103-2