Long-term climate tendencies for adaptive forest management – a case study of the Keszthely-Mountains

B. Gálos, K. Gulyás, A. Horváth, A. Bidló
Institute of Environmental and Earth Sciences, Faculty of Forestry, University of West Hungary, Sopron
galos.borbala@emk.nyme.hu

Abstract

Analyses of long-term climate tendencies are precondition for the appropriate climate change adaptation in forestry. In the case study area (Keszthely-Mountains) forests are especially affected by the long lasting droughts and heat waves of the last decades. There is an ongoing complex analysis of abiotic and biotic factors in order to find connection between forest dieback and the changing site conditions. Additionally to the climate tendencies, a detailed soil sample analysis has been carried out. Observed temperature and precipitation time series of the last 50 years show the increasing frequency of hot days and consecutive dry periods. Based on the results of regional climate model simulations significant warming and drying of summers can be expected until the end of the 21st century. Both extreme droughts and heavy precipitation events are projected to be more frequent. Consequently, the already observed climate change impacts and damages in forestry are very likely to occur with increased probability and severity towards the end of the century.

Keywords: *regional climate modelling, climate change impact, adaptation*

Background and aim

The Carpathian Basin is considered to be highly sensitive and vulnerable to climate change and the related increase of the probability and intensity of extreme events. Summer droughts of the last decades have led to vitality loss of beech forests and to increasing forest die-back and mortality (Berki et al., 2009, Mátyás et al., 2010, Czúcz et al., 2011, Rasztovits et al., 2014). Reliable projection of health status, production, growth and yield for the next decades is in the focus of the ongoing development of the "Agroclimate" Decision Support System (Mátyás et al., 2013, Gálos et al. 2015) in order to decide about sustainable tree species preference and to assess the economic impacts of possible species changes.

The aim of our research is a complex analysis of site conditions in order to find the reason of the ongoing forest decay in the case study region of Keszthely-Mountains. In this paper, we introduce only on the climate tendencies. Long-term future climate projections were also investigated, focusing on the expected probability and magnitude of threatening climate conditions that are of primary importance in terms of forest management.

Data and methods

For the period 1961-2014, daily station data from the Hungarian Meteorological Service were investigated. For the 21st century, results of 12 regional climate model simulations have been analyzed that were created in the frame of the Ensembles EU FP6 project (www.ensembles-eu.org). This ensemble of 12 regional climate change projections for the SRES A1B emission scenario are accessible in 0.22° × 0.22° spatial resolution. Projected tendencies of precipitation and temperature means and extremes (total number of hot days, extreme hot days) have been analyzed for three 30-year time periods in the 21st century: 2011-2040, 2041-2070 and 2071-2100, respectively. Expected changes have been determined relative to the reference period 1981-2010.

Climate tendencies for the past

Annual temperature means in the Keszthely-Mountains increased in the last 50 years. The largest tendency of warming is in summer (figure 1). Precipitation sums showed no clear change on annual time scale, whereas for summer a decrease has been observed. In the last 25 years extreme dry summers can be almost characterized with extreme warm temperatures (figure 1). These consecutive drought periods are the main reasons of the forest damages in the early 1990s, 2000s and 2010s.

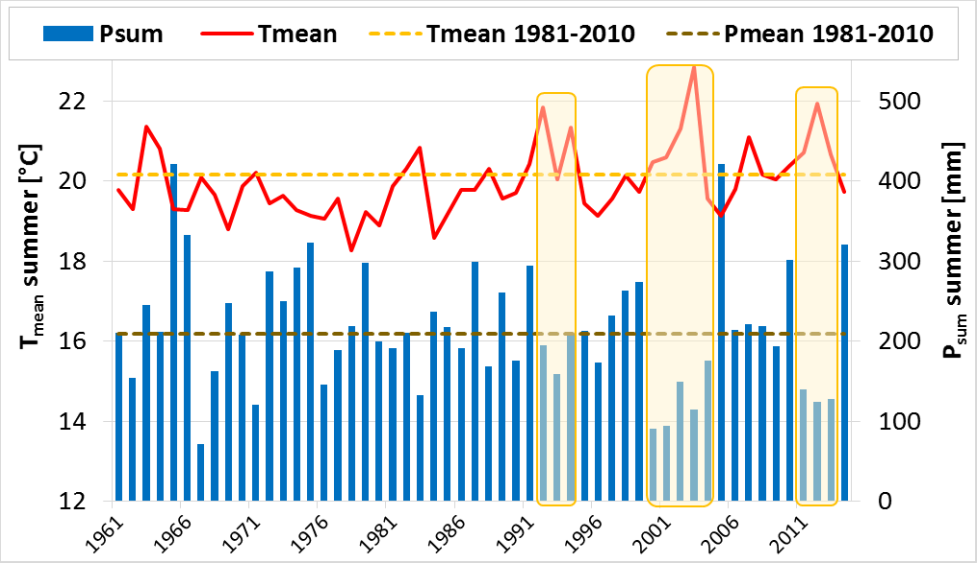

Figure 1. Summer temperature means and precipitation sums observed in Keszthely in the time period 1961-2014

Time series of hot days (Tmax ≥ 30 °C) show a clear increasing trend. In the last decade almost all values exceeded the long term mean of 1981-2010 (figure 2). In the years of 2003 and 2012, total number of hot days was larger than 1.5 months/year, whereas the total number of extreme hot days (Tmax ≥ 35 °C) exceeded 5. Consequently, after 2000, the hot extremes have become more frequent and severe.

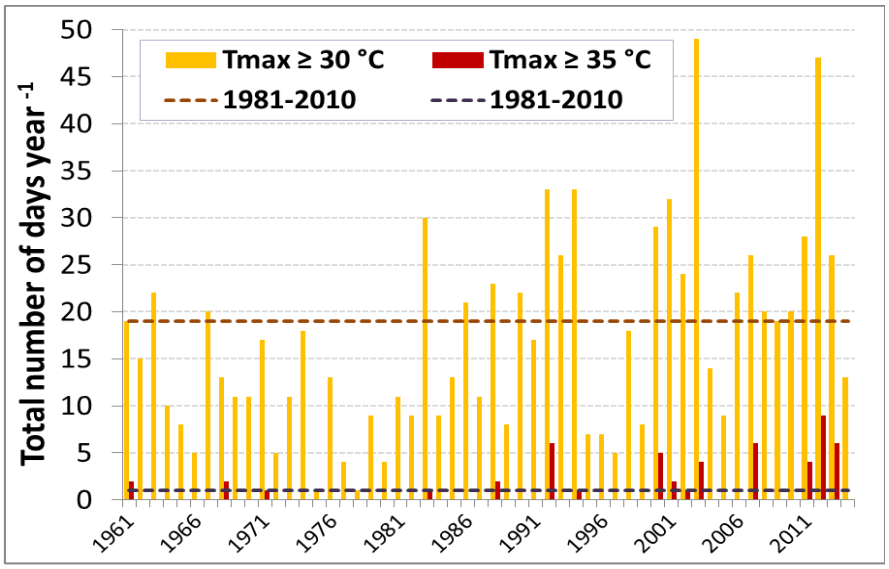

Figure 2. Total number of hot days (Tmax ≥ 30 °C) and extremely hot days (Tmax ≥ 35 °C) observed in Keszthely

Forest responses are also influenced by other factors, like soil. Besides of climate, a detailed analysis of soil conditions (soil type, topsoil layer thickness, soil moisture content, soil pH) has been also carried out. Fertility of soil shows a large diversity in the investigated region because of the big spatial differences of water holding capacity and $CaCO_3$ content (Bidló et al. 2015).

Projected climate tendencies for the future

For the region of the Keszthely-Mountains results of regional climate models show the significant tendency of warming for all seasons, especially for summer. Although the mean annual precipitation sum remain almost constant, its inter-annual variability is projected to change. For 2071-2100, winter precipitation sum is projected to increase by more than 10 % and temperature mean can be higher by 3.2 °C (figure 3). Whereas for summer increase of summer temperature can reach 4.2 °C, decrease of the precipitation sum may exceed 25 % compared to the baseline period 1981-2010. Warmer and drier conditions in summer can result in an increase of the probability and severity of droughts.

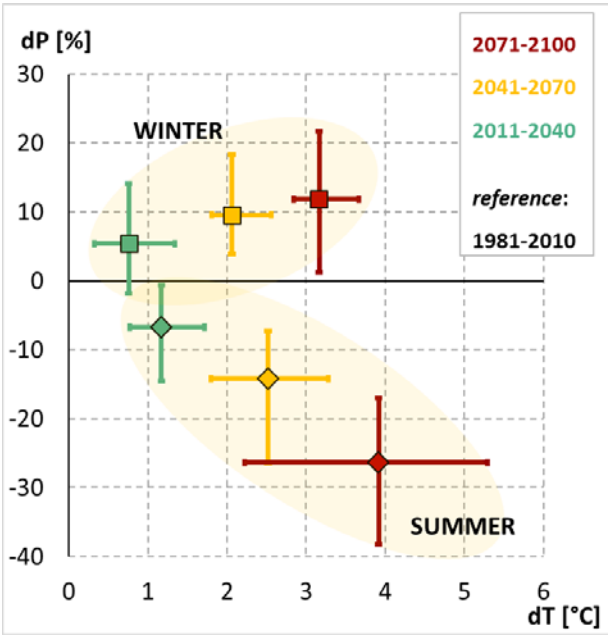

Figure 3. Projected change of the temperature means (dT) and precipitation sums (dP) for the 30-year periods in the region of the Keszthely-Mountains. Large symbols: mean projection of 12 regional climate models. Error bars: 66 % of all projected changes fall within this range.

Probability of hot days (Tmax ≥ 30 °C) and extremely hot days (Tmax ≥ 35 °C) can be significantly higher (figure 4). In the period 1981-2010, the total number of hot days were 19 days/year that can be doubled for 2041-2070. In the last 55 years there were only 2 years when the total number of hot days exceeded 45 days, whereas this amount can be the annual mean for 2071-2100. Return period of extreme hot days is expected to be shorter as well (21 days/year; figure 4).

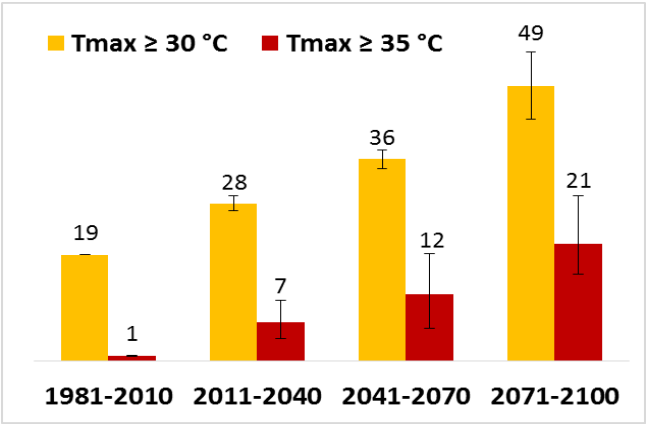

Figure 4. Total number of hot days (Tmax ≥ 30 °C) and extremely hot days (Tmax ≥ 35 °C) for the 30-year periods in the region of the Keszthely-Mountains based on the mean projection of 6 regional climate models. Error bars: 66 % of all projected changes fall within this range

Summary

In case study region of Keszthely-Mountains, increase of temperature as well as more frequent extreme warm events and dry spells have been observed in the last 50 years. These tendencies together with the unfavorable soil conditions and biotic damages can be the reason of the ongoing forest dieback. From all site conditions climate show the fastest change in this way it can be the largest threatening factor in the 21st century.
Based on the results of climate projections for the future, significant warming and drying of summers is expected. Decrease of the summer precipitation sum can exceed 25 % until the end of the century, probability of extreme hot days may increase. Consequently, the observed climate change impacts and damages in forestry are very likely to occur with increased probability and severity. Appropriate projection and analyses of long-term future climate tendencies can serve as basis of climate impact research and adaptation support in forestry.

Acknowledgements

Research is supported by the "Complex assessment of climate change impacts - preparing international R&D projects in the University of West Hungary (TÁMOP-4.2.2.D-15/1/KONV-2015-0023)" and the "Agroclimate.2" (VKSZ_12-1-2013-0034) EU-national joint founded research projects.

References

Berki, I., Rasztovits, E., Móricz, N., and Mátyás, Cs., 2009: Determination of the drought tolerance limit of beech forests and forecasting their future distribution in Hungary. Cereal Research Communations 37, 613-616.

Bidló A., Horváth A., Gulyás K. and Gálos B. 2015. Talajtani és klimatológiai vizsgálatok a Keszthelyi-hegységben (submitted)

Czúcz, B., Gálhidy, L., and Mátyás, Cs., 2011: Present and forecasted xeric climatic limits of beech and sessile oak distribution at low altitudes in Central Europe. Annals of Forest Science 68, 9–108.

Gálos B., Führer E., Czimber K., Gulyás K., Bidló A., Hänsler A., Jacob D., Mátyás Cs. 2015. Climatic threats determining future adaptive forest management – a case study of Zala County. Időjárás (accepted)

Mátyás, Cs., Berki, I., Czúcz, B., Gálos, B., Móricz, N., and Rasztovits, E., 2010: Future of beech in Southeast Europe from the perspective of evolutionary ecology. Acta Silv. Lign. Hung. 6, 91-110.

Mátyás, Cs., Gálos, B., Berki, I., Bidló, A., Drüszler, Á., Eredics, A., Illés, G., Móricz, N., Rasztovits, E., and Czimber, K., 2013: A Decision Support System for Climate Change Adaptation in Rainfed Sectors of Agriculture for Central Europe. Geophysical Research Abstracts 15, EGU2013-2942.

Rasztovits, E., Berki, I., Mátyás, Cs., Czimber, K., Pötzelsberger, E., and Móricz, N., 2014: The incorporation of extreme drought events improves models for beech persistence at its distribution limit. Annals For. Sci. 71(2), 201-210.