University of Sopron

Faculty of Forestry

Thesis of PhD dissertation

Long term trends in the health status of Hungarian beech forests

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Sopron
2021

Doctoral school: Roth Gyula Doctoral School of Forestry and Wildlife Management Sciences

Program: E2 Biological Basis of Forest Management

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Introduction:

One of the most challenging problems mankind is facing in the XXI. century is climate change. Regardless of the triggers not being known precisely, the progress itself has very remarkable effects on weather. This of course concerns forests too.

Among our abundant native tree-species in Hungary, beech (*Fagus sylvatica* L.) requires the most humid and the coldest weather conditions. That is why the climate change forecasted temperature and precipitation extremities will probably strongly affect our beech forests.

If we wish to forecast the changes in beech forest health in the future, it is advisable to inspect the past, namely the effects of warm and dry weather on beech.

Since the Forest Research Institute collected health-status data on its beech monitoring plots and the Hungarian Weather Service owns data series on these sites, it is possible to conduct the research plotted above. Concerning forest health, there are two available datasets: the forest protection forms filled by forest managers regularly and the data sets collected at the network of the forest health monitoring plots maintained by the Department of Forest Protection of the Forest Research Institute.

Aims of the research:

- Evaluation of the beech-health data series of the FRI's monitoring plot network.
- Evaluation of the meteorological datasets interpolated to the plots mentioned above and the comparison of forest health and meteorological datasets.
- Evaluation of the data derived from forest damage reporting sheets on beech forests and the comparison with meteorological data.
- Using mathematical statistics for interpreting data series and for detecting correlations between meteorological and forest health variables.
- Comparison of the previous correlation values at individual plots with the forest site and forest structure parameters of the monitoring plots.

Can and if so, how the site and forest structure parameters modify the weather-health correlations?
- Giving propositions for forest managers in the knowledge of the results on the management of beech forests in the future.

Hypotheses:

- The health status of beech is influenced by meteorological parameters, primarily by temperature and precipitation. Furthermore, it can be presumed (because of practical evidences and scientific literature references) that high temperature is in positive correlation with forest damage (e.g.: leaf-loss %), while the sum of precipitation is in a negative correlation.
- The above-mentioned influence can be retrospective according to observations and literature. Consequently, the weather of previous years may be in correlation with present forest health indicating variables.
- Since the used forest health indices are the results of complex ecological processes (leaf-loss, health-status index) and are influenced by complex weather actions, it is presumable that the above statistical correlations will not be describable by simple formulas or the strength of the correlations will not be high. This means that even lower correlation values must be inspected further and more sophisticated statistical methods must be used to interpret results.
- Furthermore, it is presumable that the detectability of the above mentioned correlations can be influenced by forest site parameters and this effect is very likely detectable by statistical methods.

Materials and methods:

The available beech forest health status data is delivered from two systems. In chronological order, the first one is the forest damage reporting system, which dataset is available from 1962 until 2011. In this system, the data was collected on paper-based sheets. The forest managers filled out these reporting forms and reported the type and extent of forest damage experienced four times a year.
The other method is the network of forest health monitoring plots. On these monitoring plots, the sample trees were surveyed on a yearly basis, at least

once a year at the end of the vegetation period (in the early period in spring too). In my dissertation, 15 of the 32 beech monitoring plots of the Forest Research Institute were examined since these were considered appropriate for statistical analysis.

The dissertation evaluates the temporal changes on every plot in average leaf-loss %, the average shoot damage %, other damage symptoms, and the Health-Deficit Index (HDI). The HDI is composed from the 5-grade health categories of the sample trees and is a parameter of the individual plot in a year. In the statistical analysis, leaf-loss % and HDI are used.

Meteorological data has been obtained from the Hungarian Meteorological Service from 1961 to 2010. This data has been interpolated to a 10 km x 10 km grid, from which we used those points that are the nearest to our monitoring plots. Used data series: monthly maximum temperature, monthly number of summer days, monthly number of heat days, monthly sum of precipitation.
From the meteorological parameters, drought indices were calculated (FAI and PAI) and the weather of individual sample plots was evaluated.

Basic statistics on the whole data series (averages, trend lines, linear regression) produced weak results, it was necessary to apply more sophisticated methods to examine the time series.
I used the CReMIT (Cyclic Reverse Moving Intervals Techniques) time-window method for this purpose. The method produces different length of time windows from the weather-indices which are correlated to forest-health values. The important considerations in selecting time windows are the following:

- The time windows should cover the months that may have the most significant influence on beech health.
- The time windows that happened 1 and 2 years before the damage also need to be examined.
- Time windows reaching from one vegetation period to another were excluded.

The method correlated the meteorological indices with health parameters in the time windows mentioned.

In the CReMIT results, significant differences could be observed between individual sample plots - on some plots the correlations were stronger while on others they were weaker. To identify the differences, it was necessary to apply the Principal Component Analysis (PCA) on the forest site parameters, the forest stand indices and on the main climatic variables. This made the grouping of the monitoring plots possible. The forest site and stand variables were derived from the National Forest Database. The climate data of the monitoring plots was converged by the long-term (1961–2010) averages of the meteorological time series of the plots. The PCA process produces new variables from the input parameters which are describing the variance proportions of the original dataset. The new (imaginary) variables give the variance levels of the original variables, so those parameters that have the most effect on the variance of the original database can be detected. Then, the monitoring plots can be grouped in the imaginary coordinate system.

Results

I correlated the data series of the reported forest damage data sets with meteorological data where the weather data input was taken from the interpolated meteorological data of all sample plots.
Temperature had a slightly increasing trend between 1961 and 2010, while in the case of precipitation, the trend was practically static. Remarkable forest damage often coincided with the year of extreme droughts, or 1-2 years after extreme droughts, however, it wasn't present in every region of the country and in every year of drought.

I evaluated the sample plot's meteorological database and identified droughty years on the basis of calculated FAI (Forestry Aridity Index). I also evaluated the site parameters and the forest stand parameters for every sample plot.

Forest health parameters (leaf loss %, HDI) were also evaluated plot by plot and were correlated with meteorological data series. Similarly to the results of the forest damage reports, damage often coincides with droughts or periods 1-2 years following the droughty years. However, this phenomenon did not occur on every plot and did not happen in each droughty year.
The CReMIT method was capable to investigate the year of damage and even the 2 years preceding the damage on a monthly resolution. The results made the grouping of the sample plots possible by their differences in correlations of the examined parameters. To have a more specific insight, the PCA (Principal Component Analysis) method was applied on the sample plot's site, forest stand and climatic parameters.

The grouping of the plots, according to CReMIT results, was congruent with the grouping results of the PCA, so the variance differences of the PCA method can be detected in forest health results too.

Theses:

1. According to the results of the analyses, the correlation r-value between the Forestry Aridity Index and beech leaf-loss % in the year of the damage was between -0,17 and +0,78 on the monitoring plots. While with the 3-year moving average of the Forestry Aridity Index, the r-value moved between -0,18 and +0,61, so the influence of the previous 2 years' weather on beech health was statistically detected.
2. The CReMIT method was capable to investigate previously gathered leaf loss and HDI time series.
3. The most remarkable damage events were detected in years with significantly outstanding drought values (2-3-4 times the average FAI drought value for the given sample plot).
4. According to the CReMIT results, the deficit in precipitation causes less problems,than high temperature in beech health.
5. The examined monthly temperature-parameters with leaf-loss resulted in a strengthening correlation, but more and more rare occurrences in the time windows in the following order: maximum temperature, number of summer days, number of heat days.
6. The two different health indices show different dynamics. Leaf loss correlated mostly with the maximum temperature of the year of the damage while in the case of HDI, it correlated with the precipitation sum of the former years.
7. Statistical connection was revealed between the individual plot site and forest stand parameters, and the correlation values resulted between forest damage parameters versus meteorological parameters. In general, less favourable site and stand parameters for beech occurred with stronger damage-weather correlation.
8. Among climatic, forest site and forest stand parameters, according to the results of PCA, the most influential ones on beech health are: temperature, topsoil depth, altitude, precipitation, canopy closure, slope, species mixture, respectively.

Suggestions for further research:

- Today there are more available modern methods for measuring tree health status compared to the time when the Forest Research Institute's monitoring network started off. Some of them are: photosynthetic activity measurement or sap-flow and sap pressure measurements.

- The weather data could be more accurate with the application of meteorological measuring equipment directly on the monitoring plots.
- Some weather parameters were not available which may have some significance, for example: air humidity in the canopy, insolation on the canopy, soil temperature and water content.
- The dissertation's results suggest that such weather indices that were not used before should be applied to get more precise results on weather-damage correlations, for example the number of consecutive 0 precipitation days and the heat sum of these days.

Naturally, these above suggestions would also mean remarkable financial and human labour expenditure for the forest health monitoring network.

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