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**FAKOPP 3-DIMENSIONAL ACOUSTIC TOMOGRAPHY
MEASUREMENTS, IN THE EASTERN ALPS, ALONG A DESIGNATED
VERTICAL TRANSECT**

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Abstract: The global temperature increase in high mountain areas is higher than average, which can significantly affect the physiognomy of the vegetation, can change the dominant species of different alpine zones, or lead to the shift of vegetation belts. During our research, we focused on how the state of health of the dominant conifers in the montane belt and subalpine belt regions of Central Europe's mountainous areas changes along an elevation transect. However, the number of field measurements focusing on the health status of dominant trees in temperate mountains is limited. Our measurements were carried out in the Stuhleck Mountains along an elevation gradient from 850 to 1750 metres. Health status analysis of *Picea abies* and *Pinus mugo* have been completed by using FAKOPP 3D acoustic tomography, which is able to detect the size and location of decayed regions in the trunk non-destructively. For modeling, the relationship between the decay of trees and other factors simple linear regression models were used. The results showed that the individuals of *Picea abies* and *Pinus mugo* had the worst health status in the lowest and uppermost range of the taxa in the studied area. It could be a sign of the upward shift of their range. A positive significant correlation was found between the decay and the ratio of whole trunk/healthy wood both in the case of *Picea abies* and *Pinus mugo*. It seems that acoustic tomography measurements are adequate to indicate non-destructively the altitudinal optimum and upward shift of different taxa.

Keywords: climate change, conifers, vertical vegetation belts, ArborSonic FAKOPP 3D acoustic tomograph, health status.

INTRODUCTION

Upper treeline ecotones are important life form boundaries and particularly sensitive to a warming climate. Changes in growth conditions at these ecotones have wide-ranging implications for the provision of ecosystem services in densely populated mountain regions like the European Alps [1]. The rate of increasing temperature in mountain systems is projected to be two to three times higher in this century than that recorded during the 20th century [2]. In addition, there is growing evidence that the rate of warming is amplified with elevation, such that high-mountain environments experience more rapid changes in temperature than environments at lower elevations. Elevation-dependent warming can accelerate the rate of change in mountain ecosystems [3].

Increasing temperatures are driving rapid upward range shifts of species in mountains. An altitudinal range retreat of 10 m is predicted to translate into a approximately 10-km latitudinal retreat based on the rate at which temperatures decline with increasing altitude and latitude, yet reports of latitudinal range retractions are sparse [4].

For example, the average warming within the last century was 1.6°C in south-eastern Switzerland, which is two times higher than the average increase for the Northern Hemisphere [5].

Climatic warming is expected to induce an upward shift in species and forest distribution in parallel with alpine tree line [6] [7] [8]. The latter is because regeneration and growth of trees there are limited by low temperature [9]. An instrumental analysis focusing on the health status of different-aged *Quercus petraea* stands in the Carpathian Basin showed that sessile oak stands located in a subatlantic area were the healthiest [10]. The most severely deteriorated stands occur in the continental region where the value in the 60 years old age group reached 4.24%. The aim of the searching with the Fakopp 3D acoustic tomography was the following; determine the state of health of *Picea abies* in the mountain, and *Pinus mugo* in the subalpine belt in a typical Eastern Alps mountain.

MATERIALS AND METHODS

The examinations were carried out in the Stuhleck Mountain, in the Eastern Alps along a vertical transect from 850 m to 1750 m above sea level. Among the dominant species of the given vegetation belt 3-3 tree individuals were measured in every 5 (between 1705-1750 m), 10 (between 850-1000 m) or 50 (1000-1700 m) meters. The measurements were completed in different layers from the soil respecting the various physiognomies of the species (0.4, 0.8, 1.2 m for *P. abies* and 0.2, 0.4 m for *P. mugo* respectively).

Measurements were made using the FAKOPP 3D acoustic tomography, which is able to detect the size and location of decayed or hollow regions in the trunk non-destructively [11] and calculate the ratio of the whole trunk and healthy wood. This non-destructive mobile instrument is suitable for determining the extent of rotting.

FAKOPP has been developed based on this considerable difference as well as on the fact that propagation speed of sound waves is in strong correlation with the mechanical characteristics of wood substance [12]. This advanced method of examination measures the propagation speed of sound within the tree.

GRAPHICAL PRESENTATION

Data input and processing was carried out in Microsoft Excel 365 online version.

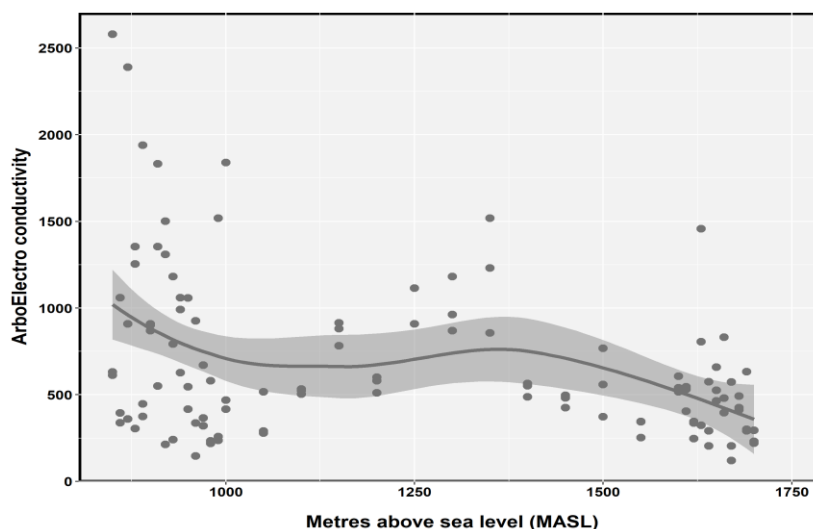


Figure (1): As the height increases, the rate of decay decreases.

Picea abies and *Pinus mugo* had the worst health status in the lowest range of the taxa in the studied area (Figure 1). It can be concluded, that there is a middle stronger relationship between the decay and the wall thickness ratio of whole trunk/healthy wood only in the case of *Pinus mugo* (Figure 2).

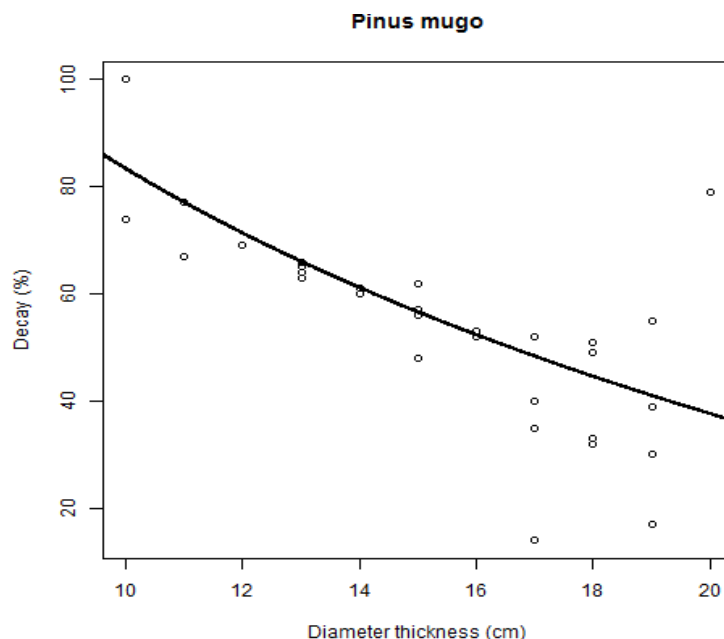


Figure (2): Figure 5. Correlation between the decay (expressed in percentage) and the wall thickness (ratio of whole trunk/ healthy wood) in case of *Pinus mugo*

RESULTS AND DISCUSSION

The results showed that the individuals of *Picea abies* and *Pinus mugo* had the worst health status in the lowest range of the taxa in the studied area. The higher deterioration rate observed in the lower limits of Norway spruce and shrubby pine stands could be a sign of the upward shift of their range. The latter is in harmony with [8] findings, that ongoing climate change shift tree species distribution. In addition, the higher rate of decay at the uppermost range of *Picea abies* and *Pinus mugo* may indicate that upward shift of trees coupled with increasing stress and declining fitness. The greater absolute and average decay of *Pinus mugo* compared to *Picea abies* could be explained by the most severe environmental conditions.

CONCLUSIONS AND RECOMMENDATIONS

The results showed that the individuals of *Picea abies* and *Pinus mugo* had the worst health status in the lowest range of the taxa in the studied area. It could be a sign of the upward shift of their range. It seems that acoustic tomography measurements are adequate to indicate non-destructively the altitudinal optimum and upward shift of different taxa.

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