HABILITATION THESIS

SUMMARY

Title: Phenotypic and structural descriptors of the acoustic quality of standing timber

Domain: FORESTRY

Author: Assoc. Prof. Dr. Eng. Florin DINULICĂ

Transilvania University of Brașov

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This thesis presents my scientific and didactic achievements as Associate Professor at the Faculty of Silviculture and Forest Engineering in Brașov during the post-doctoral stage, and outlines the main directions which I plan to expand in the near future.

Discussed herein are only the scientific achievements that fall under the topic of the habilitation thesis. My research on the acoustics of standing timber consists in identifying the external and internal physical traits of trees and stands that signal the acoustic properties of timber, specifically its potential in string musical instruments manufacture (Chapter 1).

Following a detailed background description of the vibrational properties of wood (Paragraph 1.1-1.3), which is necessary for foresters, as they are not so familiar with concepts related to acoustics, I present the methodology of organizing and conducting field and lab work to diagnose the acoustic quality of timber in relation with the external traits of trees and the annual ring structure (Chapter 2). I opted for a comprehensive description of tree phenotypes (Paragraph 2.1) using: tree biometrics (height, diameter, slenderness, age), bole shape (ovality of the trunk cross section, root swelling), bark features (thickness, scale morphology, scale colour), bole pruning (lengths of self-pruned sections of the bole), crown metrics (diameter, ovality, slenderness, asymmetry and length of crown sectors), and branch features (diameter and angle of insertion). These are instrumental measurements, designed for fieldwork, for which I provided guidelines (Paragraph 2.2-2.3).

The parent acoustic parameters that can be determined in standing trees are acoustic velocity and density; by using their values, impedance, radiation ratio, and modulus of elasticity can further be derived. The measurements will be referenced in the longitudinal, radial, and tangential direction, which are involved in the acoustic of soundboards (Paragraph 3.2).

Since the tree rings features are still favorites when selecting wood for manufacturing musical instruments, Paragraph 2.3 provide recommendations regarding the sampling with core from standing trees. For the sake of accuracy, the samples should be weighted immediately after harvest and seasoned until equilibrium moisture content is achieved in the environment for the storage and use of musical instruments.

The external phenotype characteristics and the structural traits of standing timber (sapwood metrics and tree ring features) repeatedly underwent acoustic screening using the Fakopp Microsecond Timer tree sonic device, the Arbotom sonic tomograph, and an increment borer for cores 5 mm in diameter. The screening (Chapter 3) was performed with the support of Dr. Voichița Bucur, a world leading expert in acoustics, to whom I remain grateful for her assistance.

The statistical significance tests emphasized the consistent variations of the acoustics among trees (according to their age, social class, and geographic provenance), as well as along

and across the tree (Paragraph 1.4). The relations between these acoustics were identified, and the niche of the resonance wood in the spruce trees from the sampled populations was delineated (Paragraph 1.4.2).

The selection of the phenotypic and structural markers of timber with high acoustic value was done using Principal Component Analysis, partial correlation (with the removal of either the influence of tree age, or tree diameter), and simple regression. Mixed models of the measured or calculated acoustics were built using multiple linear regression (Paragraph 3.2).

The result was that the radial acoustic parameters, rather than the longitudinal acoustic parameters, were better explained by the phenotype and wood structure. Bark thickness and redness, branch diameter, crown diameter, sapwood depth, and tree height were the best predictors. The regressions between the acoustics and the phenotypic and structural features (paragraphs 3.1-3.3) allowed for a rendering of the portrait of resonance trees and wood, by comparing them with common spruce trees (Table 1).

Table 1. Discriminating the phenotype of acoustic quality spruce trees*

Tree and wood characteristics**	**Resonance spruce*****	**Common spruce****
Phenotype characteristics		
Tree age (years at breast height)	90-180	120-420
Crown social class	Dominant	From predominant to dominate
Tree height (m)	32-40	26-50.3
Tree slenderness (%)	60-77	39-95
Basal area ovality (%)	0-12	0-15
Root swelling (cm)	≤ 27	≤ 36
Clear wood length (% of tree height)	12-46	1-20
Bark colour on the south-facing side at breast height	Darkred	grey-brown
Crown ratio (%)	46-70	19-90
Crown shape	Column-like (quadric paraboloid)	Paraboloidal, conical, pyramidal
Crown diameter (m)	2.6-8.0	2.3-12.8
Branch diameter (mm)	≤ 45	40-80
Angle of the lowest crown branches (^{o} between bole and branch)	90-120	90-135
Sapwood depth (mm)	37-80	17-60
Wood physical characteristics		
Mean annual ring width of sapwood (mm)	1.2-3.5	0.5-3.4
Ring-to-ring mean width difference in sapwood (mm)	≤ 0.6	0.1-0.8
Mean latewood percentage (%)	20-35	16-43
Compression wood percentage (%)	0-12	0-33
Green wood density ($kg \cdot m^{-3}$)	850-950	750-1060
Acoustical parameters of standing timber		
Longitudinal velocity ($m \cdot s^{-1}$)	≥ 4200	1300-4200
Radial velocity ($m \cdot s^{-1}$)	1100-1800	960-1200
Longitudinal to radial acoustic velocity ratio	2.7-3.7	0.8-3.0

Longitudinal radiation ($10^{-3}\cdot m^4\cdot kg^{-1}\cdot s^{-1}$)	4500-6200	1600-4500
Longitudinal impedance ($10^3\cdot N\cdot s\cdot m^{-3}$)	2900-3900	1000-4550
Longitudinal modulus of elasticity (MPa)	14000-21000	3000-17000

*Trees with dbh ≥ 50 cm overbark, from high value forests; **Only the features of standing trees verified acoustically; *** Wood for manufacturing string instruments.

The last part of the thesis (Chapter 4-5) presents my chronological academic evolution and the development directions envisioned. Among my most relevant didactic preoccupations will be to involve my students more actively in fundamental research (the study of the properties of forest resources) and applied research (obaining extracts with medicinal properties from forest resources). I also intend to include resonance sycamore and other valuable deciduous trees under the umbrella of research topics for doctoral students in order to outline a monograph of resonance wood in the Carpathians.