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BUILDING A CHRONOLOGY FROM COMPRESSION WOOD YEARLY RECORDS: SOME METHODOLOGICAL COORDINATES

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Abstract: *Unlocking the trees' reactions archive, tracked in the structure's anomalies by morphostructural potential stimuli, imposes the adopting of some dendrochronology particular protocols. There are methodically presented the necessary operations for sampling activities of the necessary data needed for events reconstruction which influenced (are the origin of) the compression wood emergence, as well as samples preparing for determinations, growth rings translating into digital format, cross-dating and growth rings series standardization (assisted by software packages such as WinDENDRO and STATISTICA). In order to transpose the compression wood to dendrochronological coordinates there are proposed specific indexes.*

Key words: *Compression wood, dendrocronology, sampling.*

1. Introduction: Compression wood as a bio-indicator of abiotic stresses

The reaction wood capacity to stock in its structure and morphology the stands' responses to external mechanical stimuli allows their storage in trees' xyloteque, from where, by using transfer functions, these events' history can be reread [6]. Their fixation in the tree's memory, on the compression wood support was intuited a long while ago (8 decades), and exploited at its deserved extent once dendro-geomorphology appeared [11]. In dendro-geomorphology studies, the reaction wood currently serves to dating activity of hill-slope gravitational processes and geological hazard related events such as: snow avalanches, landslides and earthquakes [1], [3-5], [13], [17], [22-23].

The mechanical determinism of radial growth [16] motivates the reconstruction of the tree's morphogenetic history, by considering the pressure induced by different external stresses. Structural and physic-chemical individuality of compression wood [14], [24] represents the main trump in dating events which influenced its mechanical ontogenesis. The most spectacular events are represented by peaks of the wind. The marked wind trail in wood structure chronicle has been discovered on species from tropical cyclones zone; around this subject another

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dendrochronology direction has been built, borrowing essentials from paleoclimatology – dendrotempestology [8].

Compression wood represents the material finality of xylogenetical responses offered by trees to environmental factors or conditions interpolation which is capable to induce genetic stresses having compression nuance: wind, solid precipitations, solar radiance, terrain morphology, geological hazard, humidity, soil acidity and mineral deficit, antropic factor [6], [24]. Any fluctuation in concentration or direction of these stimuli, capable to overrun the presentation time or the limit intensity for trees' reaction, is percepted and translated in xylems' biostructures [7]; these new-formed structures offer the ulterior possibility of recognition of the spatial and temporal events which generated them.

2. Sampling

The option in collecting the research material is conditioned by the researched stimulus nature as well as by the technical availability in sampling activity (Figure 1). The interrelations complexity, which is reflected in development of compression wood insertions, imposes the multistage organization of the sampling activity as it follows:

- Standing trees wood can be investigated at four hierarchical levels: stand, tree, basal area – using one or two growth samples and annual growth ring in each sample;
- On the felled trees, the determinations resolution is improved by increasing the observation levels (by observing the indexes variation versus the distance from the tree base and considering a complete examination – up to the physiological center and taking in consideration multiple radii at each level).

SITE LOCALIZATION. For dendroclimatic rebuilding of multiannual dynamics of air masses movement using compression wood, there are preferred sites presenting strong wind phenomena indicators, usually located at the upper limit of forest vegetation or on the oceanic coasts. Aeolian events dating is also possible in forest stands (presenting optimum ecological conditions) but it becomes more difficult due to the wide range of factors which influence the subjects ontogenesis, especially those involved in inter and intra-species competition [19].

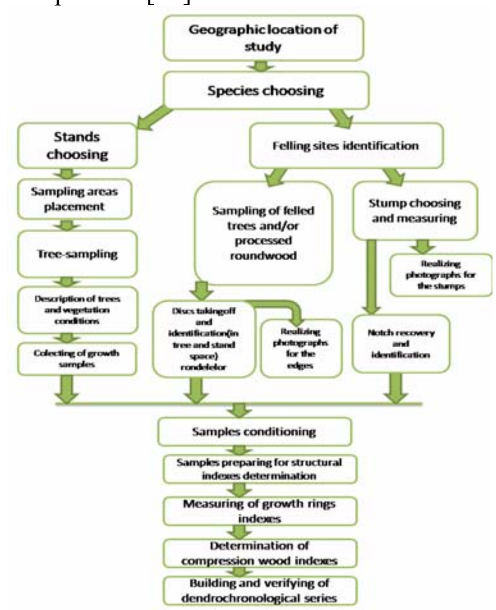

Fig. 1. *Material selection and preparing for dendrochronological investigations*

For extreme or risk geomorphic phenomena dating, the material will be collected from their active surface which keeps proof of their previous manifestation or from surfaces which have achieved information regarding the researched phenomenon. For example, in case of historical reconstitution of snow avalanches, the samples are prevailed from trees located on the edges of formed corridors [15].

Landslides are the subject of dating activity only in case of the existence of some dislocated trees which survived in landslide deposit or in landslide surface.

In impact studies regarding the forestry activity on wood formation dynamics, in general, and compression wood in particular, the rings series are compared with forest administration archives in order to rebuild the chronology of performed operations in a given stand.

SAMPLE AREAS DIMENSIONING. The collectivity volume which serves to history rebuilding regarding the reactions to fluctuation of environmental factors is established by optimizing technical limitations, statistical confidence level for average growth rings and the amplitude of the observed signal – an increased number of samples amplifies the noise presence in the series' structure. The optimum number of trees for environmental signal reconnaissance varies in rapport with their nature, the age of receiver trees and the extent of reception in time. Usually, the micro-zonal climatic signal is rebuilt by using 20-30 trees [19]. In stands in which the observed ecological factor is limitative, there is allowed (without repercussion on chronology series) the sample sub-dimensioning (a number of 5-7 trees is required). The dynamics study of snow avalanches requires material from at least 10 trees [9].

Table 1

The statistical recommended sample volume in case of dendrochronological investigations applied for fir stand

Structural index	Source of size index variation				
	stand	tree	basal area	Heights section	Cross-section in height section
Ring width	15 stands	41 trees/sample plot	56 cores/sample plot	10 height sections	20 discs
Latewood %	2 stands	9 trees/sample plot	13 cores/sample plot	7 height sections	12 discs
Compression wood degree of severity	21 stands	40 trees/sample plot	53 cores/sample plot	2 height sections	15 discs

• The number of units has been established by using the simplified formula for infinite populations, and by adopting 10% for standard error and 5 % for *p*-level

For mathematical objectivity there can be used the simplified formula for infinite or extra-large populations [10], and for its terms there are appropriate values resulted for our previous research in fir stands (Table 1).

SAMPLING ACTIVITY IN SAMPLE AREAS. The average dendrochronological series combines individual series provided by trees which are sociologically compatible, from the same age class, stand or neighboring stands, belonging to geobotanical and climatic equivalent ecosystems [19].

Regardless of the investigated stimulus nature, the dominant trees are preferred. The climatic signals are more accurate on old remote trees (from tree line ecotone). The dendro-geomorphological applications require trees which are caryring the marks of the studied events - „event-response trees", externalized through wounds having different healing stages, trunk tilting, mechanical disappearing of the brunches or partial burial of the trunk [3]. In dendroclimatic investigations regarding the compression wood there is recommendable the choice of trees without tilting and curvature, or those presenting insignificant values of the mentioned defects; this way the interference possibility of other stimuli in mechanical determinism of the compression wood sequences is expelled.

The structural reconstruction of the dynamics of inter-specific relations for a given trees community starts from the premise that the signals transmitted by biotic and abiotic environment are differently received in rapport with the age, encouraging the sampling of trees having inferior social positions.

The trees presenting an increased compression wood potential are recognizable by trunk defections – curvatures, sinuosity, saber butt, tilting, forking, ovality, buttress. In the determination of shape an important contribution (which is more obvious in certain circumstances) is assigned to temperament of species as the light demanders had proved; in these situations, trunk shape becomes a secondary sampling criterion. From the standing trees chosen for determinations there are collected two growth samples, harvested on two perpendicular directions. In order to highlight the reaction wood at coniferous species, one of the two growth samples is harvested on a radius oriented in down tilted side of the trunk. The trunk shape instability in relation with exogenous pressures occurred in the juvenile stage makes a good reason for which some researchers recommend the exclusion from compression wood study of the first 20 performed growth rings [9]. For samples harvesting there are to be used tools which are correlated with sampled wood dimensions and density.

Due to different cambial receptivity (in rapport with position on its height) to vibrations provoked by seismic activity [12], in dendrochronological applications of paleoseismology, the reference cross-sections are adopted on several meters above the ground [1].

3. Growth Rings Input in Digital Format

The use of digital images in growth rings analysis imposes the preparation of material after the conditioning period. Growth samples, for example, can be mounted with adhesive on wooden supports. The last ones as well as washers are polished using abrasive strips with successive smaller granularities (for example 40, 60, 120), until there is obtained a surface having an adequate quality for operable scanning resolution as well as for determination accuracy.

From the multitude of technical possibilities for annual rings measurement there is recommended the electronic procedure (with samples scanning), which offers the advantage of their transposing in formats which permit their stocking and processing. The equipment used for this purpose is composed from a high resolution scanner and software for semi-automatic delimitation including the measurement possibilities for structural formations. The scanning resolution will be adopted by considering the narrowest growth ring and pixel's dimension [6]; for example, on a resolution of 900 DPI, the corresponding pixels have a dimension of 0.03 mm [26], which is satisfying in rapport with current widths of annual rings in case of indigenous coniferous species.

Growth rings measurement using the image analysis is performed only on a user-defined path surface, which takes in consideration the investigated wood radius (Figure 2). In case of fir washers there is sufficient the measurement of only three radii [6].

4. Compression Wood Indexes

Compression wood presence can be quantitatively defined (showing the extent of defect on the length or surface of a sample) and qualitatively defined (showing certain intensity of manifestation, presented by cellular morphostructure and exteriorized by color).

Regarding the last aspect, the following severity steps can be suggested (Figure 3), which are inspired by previous classifications of fir compression wood [20], [24-25]:

LC1: Mild compression wood– having late wood color ranging from orange to red-yellowish;

LC2: Moderate compression wood – having late wood color which varies around brown-yellowish-reddish colors;

LC3: Severe compression wood – having late wood color ranging from brown-reddish-yellowish to brown-blackish, and occupying more than 50% of growth rings width.

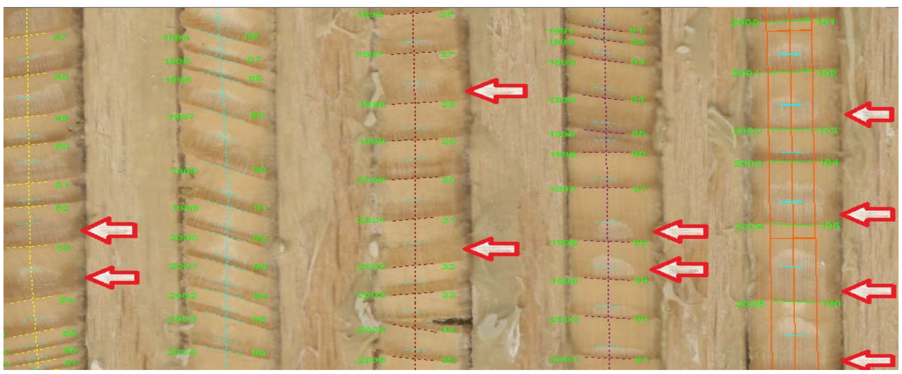

Fig.2**.** *The detail of some WinDENDRO paths with growth rings measured on a fir compression wood sample (marked with arrow)*

Digital format of growth rings permits their individual classification, after macroscopic examination (if there is needed – stereomicroscopic examination), by considering the identified structure type (the afferent codes will be: 0 – normal wood, 1 – LC1, 2 – LC2, 3 – LC3); the width of each classified section serves to determination of global and fractional percentages of defect from the analyzed sample length.

Fig. 3. *Radial dynamics of structure types on a multi-centenary fir tree*

For mathematical prominence of multiannual fluctuations in wood formation, other indicators can be proposed such as:

- Annual frequency of compression wood *($YCWF_i$)* – as the percentual ratio between the number of samples or radii presenting compression wood during calendar year *i* and the total number of samples on which the respective season is represented;
- Average frequency of compression wood on the sample *($MCWF_k$)* – as the percentual ratio between the number of growth rings presenting compression wood from sampling unit *k* and the length of growth ring series on the respective unit;

Similarly, for the manifestation grades of the defect there will be used:

- Annual intensity of compression wood *(YCWDS)*– as the arithmetic mean of defect intensities values resulting from average series of washer, section, tree or stand;
- Average intensity of compression wood per sample *(MCWDS)* – as the arithmetic mean of defect intensities values resulting from individual series.

The calendar ordered statistical series regarding the annual presence of the defect on the washers can generate binary series by combining the measured directions (individual values indicate by 0 or 1 the absence respectively the presence of compression wood on at least one of directions).

5. Elaboration of Dendrochronological Series

Technical sampling conditions as well as trees growth particularities (especially false rings and missing rings) can concur to create difficult conditions for right calendar identification of the rings and they impose the comparison of results with master chronologies previously elaborated being geographically representative for the studied stand. The operation is called cross-dating [18]. In the absence of a local master-chronology there can be previously sampled the perimeter in order to identify a location having a dendrochronological potential, where a source sample area can be deployed. For noise exclusion and climatic signal individualization the series of the cross-dating verified growth rings widths (which become, by applying this procedure, growth series) are transformed by standardization in index series.

The individual series of growth samples, as well as average series on tree and sample area, will be converted, ring by ring, in indexes series, by applying a low frequency filter which facilitates the exclusion of medium-long duration signals (attributed to age and concurrence processes) and the retention of the oscillations with small period which are characteristic to climatic stimuli. In standardization using WinDENDRO, the filter is represented by cubic-smoothing spline. The decimal logarithm of the Lagrange parameter influences the filter efficiency: at high values which transform the spline curve into a cubic polynom the adjustment is more sensible to high frequency variations while in case of small values it stimulates the filter rigidity by function linearization. In case of standardizations regarding series which present strong correlations between corresponding rings (signalled by measure and significance of autocorrelation – Figure 4) there is recommended [2] the *AutoRegressive Integrated Moving Average model* (ARIMA). This model is incorporated into STATISTICA 8.0 [21]. There can be the subject of standardization only the stationary series (presenting variance and autocorrelation which are stabile in time), and having a wave length of at least 50 years.

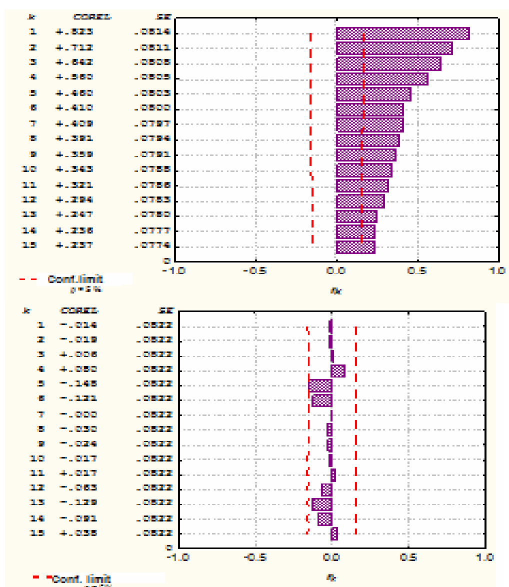

Fig.4. *Autocorrelation spectrum up to 15th order, before (up) and after (down) the autoregressive filtering of a primary series*

The annual rings indexes' series and compression wood degree of severity which have been studied on fir are optimally normalized, in order to prepare the standardization, by natural-log transformation, while the compression wood frequency series are best fitted by mobile moving average smoothing procedure – comprising from the replacement of observed values by the average or median of a determined surrounding number (which indicates the measure of so-called smoothing window). There is also recommended that the smoothing window dimensioning be realized by considering the highest order of the significant partial autocorrelation.

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