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A REVIEW OF ROMANIAN DENDROCHRONOLOGICAL APPROACHES AND FUTURE RESEARCH PERSPECTIVES FOR DENDROCHRONOLOGY IN ROMANIA

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Abstract: *A Review of Romanian Dendrochronological Approaches and future research perspectives for Dendrochronology in Romania*. Dendrochronology is the scientific dating method based on the analysis of trees` annual growth rings. The international research has a rather poor correspondent in the Romanian scientific world. The present paper is a brief review of Romanian dendrochronological approaches and describes the perspectives of future research expanding possibilities. First mentioned in the late 60`s by acad. V.Giurgiu, dendrochronology becomes an exclusive attribute of forestry research. The geographical point of view emerges only after the first dendrogeomorphological studies. There are currently few research centres and universities in Romania, with suited „dendro" equippment. The future development of this dating method proves to be important for its practical usefulness, as well as regarding the geographical and historical potential of our aountry in this field.

Rezumat: *Relatarea cercetărilor dendrocronologice româneşti şi perspectivele de cercetare în viitor pentru Dendrocronologia din România.* Dendrocronologia este metoda ştiinţifică de datare a trecutului care se bazează pe studiul inelelor anuale de creştere ale arborilor. Cercetările internaţionale pe scară largă nu au un corespondent pe măsură în cercetările româneşti. Prezenta lucrare reprezintă o succintă trecere în revistă a studiilor dendrocronologice din România şi descrie perspectivele de dezvoltare ale acestei ştiinţe în ţara noastră. Prima oară menţionată de către acad. V. Giurgiu în anii `60, dendrocronologia va fi studiată aproape exclusiv de cercetători din domeniu silvic. O dată cu

primele studii dendrogeomorfologice se pun bazele unei cercetări „dendro" cu tentă geografică. În prezent, există în România câteva centre universitare şi de cercetare dotate cu echipament dendrocronologic. Dezvoltarea în viitor a acestei metode de datare se dovedeşte a fi importantă atât din punctul de vedere al utilităţii practice a aplicaţiilor dendrocronologice, cât şi din punctul de vedere al potenţialului geografic şi istoric al ţării noastre în acest domeniu.

Key words: *dendrochronology, scientific approach, Romania.*
Cuvinte cheie: *dendrocronologie, abordare ştiinţifică, Romania.*

1. INTRODUCTION

Etymologically speaking, the name "dendrochronolgy" is related to the ancient Greek terms *dendron* - tree, *chronos* - time and *logos* - science. Dendrochronology is a scientific method, based on the comparative analysis of tree-ring records, that aims to reconstruct past environmental conditions and date several types of events that manifested in the past. Speer (2010), asserts that among the other dating methods of the past processes and environmental elements, dendrochronology is the most accurate one, being able, in some cases, of intraannual dating precision (Fritts, 1976). Dendrochonology can also be defined as „*the science of dating events (historical, ecological, etc.), based on the analysis of the annual tree-ring structure variability, also approaching the complex issue of the environmental factors – radial tree-ring growth relationship"* (Tissescu, 2001, pp.16).

In all the approaches to define this scientific quaternary dating method, reference will be made to the trees` *annual-* or *growth ring*. The formation of an annual tree-ring is a feature of trees living in climatic zones characterized by seasonal changes. The transition from the growth favourable season to the climatic non-favourable season (when trees will stop the wood-cell production), is clearly observable in the structure of the wood (Schweingruber, 2007). This transition implies obvious, macroscopically observable demarcations, within a transversal cross-section of the trunk, branches or roots, with the appearance of concentric rings. Within the tree-rings` structure lies a „database" that stores information on the environmental conditions that led to their formation.

By studying the tree-rings, it is possible to extract information on the past climate (Fritts, 1976, Grissino-Mayer, 1989, Speer, 2010), and reconstruct long-term trends of past climatic variables, being helpful in a better understanding of the possible future evolution of a particular climate parameter. Tree-rings store information about past wildfires, snow avalanches, landslides, volcanic activity, floods, riverbed changes, evolution of the forest treeline, atmospheric pollution, and many more. The frequency and magnitude reconstructions of natural processes (such as geomorphic processes), could be useful in future planning and land use, and, at the same time, it could prevent losses of human lives and goods, through the understanding of the periodicity and the triggering factors of these natural phenomena. In another train of thoughts, dendrochronologists are able to date archaeological buildings, wooden artefacts, and to certify the originality of valuable musical instruments, like the Stradivari violins (Grissino-Mayer, Sheppard and Cleaveland, 2004).

Dendrochronology includes a series of fundamental techniques based on the understanding of tree anatomy and wooden plant reactions to environmental stimuli. These techniques are supported by several *theoretical principles* (Grissino-Mayer, 2005), some of them shared with other natural sciences, others specific for dendrochronology. The basic level of dendrochronology consists in counting the tree-rings and identifying the exact year in which they were formed, step called crossdating. Along with the thoroughgoing study, researchers are required to correctly understand and decode the complex tree language, process that rarely proves to be simple. The physical structural (macroscopic and/or microscopic) characteristics, as well as the chemical properties of tree-rings, are the tree`s response to a plurality of internal and external factors. Among them, "*climate is the main factor that dictates the type of growth"* (Vuia, 2006, pp.3). On one hand, there are influences inherent for every tree as an individual, such as age and genetic legacy (Popa, 2004), called *internal factors*. On the other hand, the above mentioned climatic influences together with the morphogenetic processes and the anthropogenic influences are called *external factors*. The position of each tree within the forest community, as well as the specific physical substrate are also important in judging the degree of vulnerability to external factors for each tree (Negulescu and Stănescu, 1964). Dendrochronology can be implemented in several scientific fields, according to the objective aimed by the researchers. The study of the influencing factors and the focus on extracting the response generated by a particular one gave birth to the different applications of dendrochronology:

- Dendroclimatology aims to reconstruct the variation of climatic factors for the periods before existing meteorological records (Tissescu, 2001). Precipitation, air temperature, nebulosity, winds or snow depth, are some of the climatic variables that affect width, structure or density of annual tree-rings. The favourable the climate factors are, the wider the tree-rings will be, and the rough these conditions are, the narrower the rings will result (Tessier, Guibal and Schweingruber, 1997). This would be the simplest approach, but details and controversies regarding one or another of the influences obscure significantly some of the dendroclimatological constructions. Nevertheless, meeting the requirements of the dendrochronological principles and a better understanding of tree reactions at specific sites, allows precise climatic reconstructions for hundreds and even thousands of years (8400 years for Northern America, from archaeological wood and 10479 years for Europe, from oak).

- Dendrogeomorphology studies tree-rings in order to date processes which created, changed or shaped the relief (Alestalo, 1971). The affected trees show specific growth disturbances within tree-rings formed in the year the event took place. According to these responses, dendrogeomophologists can precisely tell the year a volcanic eruption, a landslide or a snow avalanche took place. At the same time, it is also possible to study slow processes such as creep, rockglacier movements, shoreline fluctuations, etc.

- Dendroecology concentrates on investigating past environmental issues such as dating ecologic events and determining the scale of these events, readable in the tree-ring records. For example, it is possible to measure the impact of industrial pollution on certain forest communities, and to estimate future disturbances of polluting human activities.

- Dendropyrochronology aims to reconstruct the occurrence and periodicity of wildfires, by dating fire scars and other specific growth responses generated by this phenomenon (Grissino-Mayer and Swetnam, 1997, Lafon, 2005). There are some forest communities dependent on periodical wildfires, such as *Pinus pungens*, and organized wildfire control can lead, on one hand to species threatening, and on the other hand, to the

accumulation of big amounts of dry wood that can result in major devastating wildfires (Sutherland et al., 1993). Due to these facts, understanding the role of periodic wildfires in some forests, by applying dendropyrochronological methods of investigation, authorities can optimize their wildfire control planning and better evaluate the degree of risk generated by wildfire in certain regions.

- Dendroglaciology studies the movement and extent of glaciers. The glacier dynamics can be observed by sampling tree trunks found in moraines, by analysing colonisation behaviour after glacier withdrawal or by studying trees` reactions to the proximity of ice (Vuia, 2006). Regarding the crossdating accuracy of moraine deposits, dendroglaciology is preferable, being more precise than the C14 dating method.

- Dendrohydrology is based on research focused on suffocation of trees related to flooding and colonisation on abandoned riverbeds. It also can precisely describe the evolution of lake levels, or estimate periods of time in which some regions were flooded.

- Dendroarchaeology analyses wood used in historical buildings, ancient artefacts, and other wooden pieces, in order to find out the exact year of felling the trees, using the method of crossdating, specific to dendrochronological and dendroarchaeological research.

- Dendroentochronology uses the annual growth ring features to study the historical dynamics of insect outbreaks, which affect the forest canopy by destroying the leaves and thus reducing or stopping the photosynthesis.

2. ROMANIAN DENDROCHRONOLOGY

2. 1. First Dendrochronological Approaches in Romania

As a first observation regarding the Romanian dendrochronological approaches, it has to be stated that the interest for this science was for some time shown only in the field of forestry, the geographical studies being initiated only some decades later. Dendrochronology was first mentioned in a Romanian writing by acad.dr.doc. Victor Giurgiu in 1967 in his work „*Studiul creşterilor la arborete*" (Giurgiu, 1967). In the 70`s, there were isolated forestry researches, also undertaken by V. Giurgiu, who analyzes the correlation between tree-ring widths and droughts, thus accomplishing the first Romanian dendroclimatological studies (Giurgiu 1974, 1977). Other forestry researchers operating in the field of tree auxology followed V. Giurgiu by obtaining the first series of growth indexes for Swiss stone pine (*Pinus cembra)* from Rodna (Seghedin, 1977) and Retezat Massif (Soran and Gârlea, 1981). At the same time, first dendroecological efforts were undertaken for measuring the impact of growing industrial pollution in the second half of the XX-th century, on the forest health state (Ianculescu, 1977).

After 1980, the influence of ecological factors on tree growth draws the researchers` attention and conducts to a series of dendroecological studies (Pânzaru and Soran, 1983, Tissescu, 1989). Ing. M. Ianculescu performs a dendroecological research in the Copşa Mică region and emphasizes on the catastrophic effects of industrial activity on the surrounding forests (Ianculescu, 1987). Two years later, together with ing. Al. Tissescu, he completes the paper „*Cercetări auxologice şi dendrocronologice în arboretele de brad afectate de fenomenul de uscare"* (Ianculescu and Tissescu, 1989), awarded in 1992 by the Romanian Academy. By the late 80`s the dendrochronological approaches tend to diversify, and interesting studies, such as „*Investigarea dendrocronologică a unui trunchi subfosil de*

stejar" appear, confirming the parallelism between sun spots and annual tree-ring growth index variations (Dumitriu-Tătăranu and Popescu, 1988). Also interesting, the work „*Dendrocronologia ca metodă de cercetare a istoriei poporului român"* (Giurgiu, 1987), draws attention on using dendrochronology for dating historical wooden buildings. On this line, at Lund University in Sweden, the researcher Alexandru Babos conducts a dendroarchaeological study focused on dating the wooden churches of Maramureş (Babos şi Eggertsson, 2002). Along with the collapse of the communist regime in Romania, the cooperation between Romanian and foreign universities and laboratories with dendrochronological activities becomes possible, and Romanian researchers are able to develop their knowledge. Al.Tissescu acquires a Fulbright stipend at the Laboratory of Tree Ring Research in Tucson, Arizona (the first and most important laboratory for dendrochronology), and writes a PhD. thesis in dendrochronology. After 1990 M.Flocea writes important papers on dendroecology and impact studies (Flocea, 1992, 1996).

Existing since 1974 at a global level, the International Tree-Ring Database (ITRDB) is an organisation which aims to unify, preserve and provide to researchers, all the existing dendrochronological data around the world. Thus, a quality standard for dendrochronological data, called the ITRDB standard, was developed to assure homogeneity and a high degree of data quality. În Romania, the first ITRDB data were developed by F.Schweingruber (1985) for Norway spruce. Further, ITRDB series are developed for fir (Ianculescu and Tissescu, 1989, Alexandrescu, 1995, Popa, 2002, 2003), oak (Tissescu, 1990, Borlea, 1999, Popa, 2002), Norway spruce (Alexandrescu, 1995, Popa, 2002), and Swiss stone pine (Popa, 2002).

2.2. Present Romanian Dendrochronology and Dendrogeomorphology

The Experimental Station for Norway spruce in Câmpulung Moldovenesc, led by Ionel Popa, plays a major role in the development of present Romanian dendrochronology. For over a decade, the research is focused on the fields of dendroclimatology, dendroecology and the constructing of dendrochronolgical index series for several native species (Popa, 2002, 2003a, 2003b, 2005a, 2005b, 2010, Popa, Kern and Nagy, 2006, Popa and Kern, 2009, Popa and Sidor, 2010, Sidor, 2009). The first Romanian dendrochronological software, CAROTA (Popa, 1999), was also developed here, as well as Popa`s „*Fundamente metodologice şi aplicaţii de dendrocronologie"*, which represents a suitable guide for upcoming dendrochronological studies in Romania (Popa, 2004). The research project called „*Implementarea reţelei naţionale de serii dendrocronologice pentru speciile de răşinoase – RODENDRONET"* was implemented at Câmpulung Moldovenesc between 2006 and 2010, with a budget of 505.955 RON. The main objectives of this project were the development and implementing of a national network of dendrochronological series, called RODENDRONET, for the following softwood species: (*Picea abies* – 32 series, *Abies alba* – 21 series, *Larix decidua* – 11 series, *Pinus cembra* – 4 series, *Pinus silvestris* – 15 series, *Pinus nigra* – 1 series, and *Pinus strobus* – 1 series), as well as accomplishing the work for an excellence centre of dendrochronological and dendroclimatological research (Popa, 2010, Popa şi Sidor, 2010).

The dendrogeomorphological approaches start in the late 90`s in Romania. P. Urdea writes a paper regarding the dynamics of the Stânişoara and Pietrele rockglaciers (Retezat Mts.), using dendrochronological techniques in determining the ages of the oldest *Pinus mugo* installed on the front lobes of the above mentioned rockglaciers (Urdea, 1998

in Vuia, 2006). This can be considered as the first dendrogeomorphological study in Romania and one of the pioneering dendrochronological approaches from a geographical point of view. Along with the equipping of the DendroLab at the Faculty for Chemistry, Biology and Geography in Timişoara, F.Vuia starts a set of dendrogeomorphological studies concentrated on the analysis of a Norway spruce covered slope, affected by a massive avalanche in 2005, in Doamnei Valley (Făgăraş Mts.), analysis of slope processes in the Carp Valley (Bucegi Mts.) by studying growth anomalies in European larch (*Larix* decidua) tree-rings, and constructing of a master chronology for black pine (*Pinus nigra var. Banatica*) in the Domogled Massif (Mehedinti Mts.) (Vuia, 2006). At Timişoara as well, other notable dendrochronological approaches are the following: dating of a major snow avalanche near Urlătoarea Waterfalls - Bucegi Mts. (Voiculescu, 2010), analysis of snow avalanche frequencies and magnitudes in Doamnei Valley – Făgăraş Mts. (Voiculescu and Ardelean, 2011), Bâlea Valley – Făgăraş Mts. (Voiculescu, Onaca and Chiroiu, in press), and the reconstruction of annual precipitation for the last 150 years at the Domogled Massif – Mehedinți Mts. (Chiroiu and Ardelean, in press).

The research team in Cluj-Napoca`s Babeş-Bolyai University, led by V.Surdeanu, accomplished a series of dendrochronological papers with emphasis on geomorphic and ecological issues. Among them, the study on the anatomical reaction of Norway spruce to sedimentation by toxic debris in the sulphur mining area at the Dumitrelul Basin – Călimani Mts. (Pop et. al., in press), the bio-dendro-geomorphic study focused on the relationship between trees colonisation, landslide and debris flow activity at the same site in the Călimani Mts. (Surdeanu et al., in press). Pop (2011) conducted a research on the typical landslide activity - *glimee* - in the Saschiz area, Transylvania Depression, by sampling and analyzing *Pinus sylvestris* affected by this processes. The dendrogromorphology lab in Cluj-Napoca benefits of a partnership with the Laboratory of Dendrogeomorphology in Bern, Switzerland, and the Swiss dendrogeomorphologist dr. Markus Stoffel has recently received the *Doctor Honoris Causa* title at the Babeş-Bolyai University.

The approaches of V. Ilinca at the Bucharest University, are mentionable as well. He studied three areas affected by debris-flow activities in the Lotru Valley, analyzing tree-rings of white alder (*Alnus incana*) for the Brădişor and Malaia flows and fir (*Abies alba*) tree-rings for the Cărbunele Basin (Ilinca, 2010). The same author conducts, in 2011, a research in the Red Lake landslide area by sampling cores from tilted trees, results being published in the *Carpathian Journal of Earth and Environmental Sciences* (Ilinca and Gheuca, 2011).

Romanian dendrochronological research is present at the following research centres equipped with dendrochronological laboratories: The Experimental Station for Norway Spruce in Câmpulung Moldovenesc (http://www.icassv.ro/), The Faculty of Chemistry, Biology and Geography at the West University in Timişoara (http://www.geografie.uvt.ro/), The Faculty of Geography at the Babeş-Bolyai University in Cluj-Napoca (http://geografie.ubbcluj.ro/), The Faculty for History and Geography at the „Ştefan cel Mare" University in Suceava (http://fig.usv.ro/www/), The Faculty of Geography at the Bucharest University (http://geo.unibuc.ro/cercetare.html) and The Forestry Faculty at the „Transilvania" University in Braşov (http://www.unitbv.ro/ Default.aspx?alia s=www. unitbv.ro/silvic).

3. PERSPECTIVES FOR FUTURE. DENDROCHRONOLOGICAL RESEARCH IN ROMANIA

Romania holds an important forest stock bearing benefits that transcends the limits of economics. Thus, the dendrochronological information stored in the annual growth rings of the trees offers an unique image of the past environmental conditions, the geomorphological events that manifested in certain areas, the period in which a tree has been felled in order to be integrated in a certain historical building of national importance, the evolution of riverbeds, etc. Eventually, dendrochronology helps in understanding some aspects of our past. The dendrochronological method, with its various applications, shows a higher degree of accuracy, compared with other dating methods, such as those based on the analysis of varves, ice cores, speleothemes, corals or pollen. The tree-rings` high-frequency answers (sometimes with monthly precision) are not yet fully unravelled, but technologies that help analyzing their features are continuously improving. Currently, the most detailed dendrochronological analyses are focused on densitometry, X-Ray analysis, dielectric constant analysis, etc. So far, dendrochronology showed a wide range of various applications, such as dating the wood and proving the authenticity of Stradivari`s „Messiah" violin (Grissino-Mayer et al., 2004), criminal investigations (Harlan, personal communication, Swetnam, personal communication, in Speer, 2010), setting federal boundaries in the U.S.A. (Sellards et al., 1923, in Speer, 2010), analyzing the Tunguska phenomenon (Vaganov et.al., 2004, in Speer, 2010).

Taking a look at the Romanian dendrochronological approaches, it is obvious that research is scarce and the high potential is currently undervalued. Even dendroclimatology and dendroecology, the most practiced dendrochronological branches in Romania, show only punctual studies, from a spatial, as well as from a temporal point of view. The available meteorological data is only exceptionally longer than 60-70 years. The dendroclimatological methods allow reconstructing faithful, century-long images of some climatic parameters` past trends. The present global climate trend is more obvious in the highly sensitive mountain areas, where meteorological data are usually missing. Regarding international research in dendroecology (Vaganov, Hughes and Shashkin, 2006, Soule et al., 2003, Knapp, et al., 2001), we consider that numerous regions in Romania are suitable for studying the evolution of treeline limits, the effects of pollution on wood cell production, the effects of deforestation on the health of forest communities, the effects of growing atmospheric carbon dioxide concentrations on trees, etc.

Dendrogeomorphology aims the dating of earth shaping geomorphological events by analyzing growth disturbances and growth anomalies in tree-rings (Shroder, 1980). The affected trees are recording event years by showing specific growth responses (abrupt growth reduction and release, formation of callus tissue, reaction wood, tangential rows of traumatic resin ducts, eccentric growth, etc.). International literature includes studies regarding landslides (Astrade et al., 1998), mass movements and isolated rockfall (Bollschweiler and Stoffel, 2010, Schneuvly, 2009), glacier dynamics (Luckmann, 1998), snow avalanches (Burrows and Burrows, 1976, Butler, 1979, Bezzi et al., 2003), volcanic eruptions (Yamaguchi and Lawrence, 1993), earthquakes (Page, 1970), etc. Romania has plenty of regions characterized by active geomorphic processes suitable for dendrogeomorphological approaches. Geomorphic processes are, in most cases, highly destructive, and sometimes their trajectories intersect human activities (housing and

infrastructure), generating risks that need to be quantified and as good as possible controlled. Determining the frequency, magnitude and spatial extent of past geomorphic processes, and correlating them with climate and morphological triggering conditions, leads firstly to a better understanding of these phenomena, and secondly, to a just evaluation and minimization of their negative consequences on human lives and activities. Dendrogeomorphological methods offer useful answers to the process of creating prevention models and construction planning, and are, therefore, required in some high risk areas around the country. For instance, it is possible to suggest when, where and how it is essential to enforce protection measures in snow avalanche affected touristic areas. Knowledge about spatial extent, magnitudes and frequency of snow avalanches is vital, as the present touristic infrastructure and accommodation development is currently booming in Romania. This information will affect future land use decisions especially at sites where archival data on the manifestation of these processes is scarce or even missing. Connecting snow avalanche occurrence with triggering factors and natural cyclicality, by calibrating meteorological, archival and geomorphic data with tree-ring records, becomes imperative in Romanian touristic areas.

In another train of thoughts, the dendropyrochronological research in Romania is inexistent. Reconstruction of natural wildfire incidence is achievable and again, very useful (Sutherland et al., 1993, Grissino-Mayer, H.D., 1995). The Domogled Massif, for instance, part of the Domogled – Cerna Valley National Park, home for the legally protected endemic species of the Banat Black Pine (*Pinus nigra var. Banatica*) is characterized by frequent wildfires of various scales. The big ones, as the one occured in August 2000 (Török-Oance, and Török-Oance, 2002), are real threats for the Băile Herculane resort and the protected pine forest. The development of a truthful fire history, integrating acknowledgements on spatial extent and observed cyclicality, is of actual interest. Joining archival data with tree-ring records results in a complete image of some risk phenomena. Not least, applications in hydrology, archaeology, entochronology are shallow or absent in Romania.

Like any scientific sphere, dendrochronolgy faces a series of limitations that are to be taken into account. Firstly, the spatial boundaries are to be emphasized, dendrochronology being dependent on the existence of trees. Secondly, in order to generate quality results, the sampled trees must be carefully selected, according to the principle of limiting factors, not every tree is suitable for dendrochronological analysis,. Another „bushy" problem is the complex tree growth process and the issues of wood anatomy. Therefore, considering only the clearest tree reactions and minimizing the „noise" by sampling depth are imperatives in dendrochronological research. Last but not least, every dendrochronological approach is time limited by the age of trees. Dendrochronological methods, alongside to the practical importance of their applications, are useful in enlarging the scientific view on certain phenomena and processes. Raising awareness on dendrochronology in universities by organizing research teams composed of students, master students, PhD. students and teachers, has to be an important issue in the future.

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