University "*Ștefan cel Mare*" Suceava

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SUMMARY HABILITATION THESIS

Evaluation of environmental information through interdisciplinary silvicultural techniques – achievements and perspectives

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Foreword

The paper presents a synthesis of personal achievements cumulated with results obtained with the support of colleagues from different research institutions. The efforts that led to the occurrence of the research discussed in the present habilitation thesis are mainly due to the collaborators, respectively, to a few people with exceptional professional character and training. The rush to compete in national and international competitions has often resulted in the approach of ambitious work teams. I started my career with a lot of enthusiasm and unconsciousness, discovering mentors outside the host institution, which is particularly beneficial for me, defining a particular path in researching complex environmental processes. Very rarely and only in exceptional moments do I look to the past, my aspirations being current and especially for the future, so I "run the time" pursuing the assimilation of new knowledge for professional completion. In the rare moments of retrospect, I carry in my soul researchers who have left a unique mark on my professional training. Thus, I would like to express my sincere gratitude to the groups of geomorphologists, archaeologists, historians, physicists, chemists, biologists, and pharmacists from prestigious institutions such as "Ștefan cel Mare" University of Suceava, Maramureș Museum, "1 Decembrie 1918" University of Alba Iulia, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, National Research-Development Institute for Cryogenic and Isotopic Technologies Râmnicu Vâlcea, National Research-Development Institute for Isotopic and Molecular Technologies Cluj Napoca, University of Medicine and Pharmacy "Grigore T. POPA" Iași. I am equally grateful to researchers and professors Andreea Maria Iordache (ICSI Analytics), Maria Rădoane (USV), Tomasz Ważny (Nicolaus Copernicus University), Tom Levanič (Slovenian Forestry Institute), Katarina Čufar (University of Ljubljana), Karel Lemer and Tomas Pluháček (Department of Analytical Chemistry Faculty of Science Charles University), Olafur Eggertsson (Icelandic Forest Research), Marco Carrer (University of Padua TESAF). Special thanks go to my family, Peter and God more than anyone.

(A) Summary

The main scientific interest followed the quantification relationship between climate change and extreme events associated with mitigation risks. The holistic and integrated approach to environmental hazards requires standard methodologies, including risk assessment, analysis and management. The paper's subject consists of a comprehensive and conceptual description of previous work detailed to demonstrate the scientific maturity of the author. It also presents quantitative methodologies of environmental hazards research, indicating various statistical approaches are accessible. Thus, ensuring the audience regarding the doctoral supervisor's capacity to establish research objectives sustained by scientific arguments. The future concerns mentioned are fully assumed and aim at three essential perspectives: (i) training new specialists (researchers/professors), (ii) capitalizing on research in the most valuable journals globally, and (iii) obtaining findings through national and international competitions, contributing to increasing the host institution's visibility. Future studies will use more than dendrochronological techniques to highlight environmental processes that affect people's quality of life. Currently, we started by quantifying the presence of hazardous risks with a strong influence on human bodies. In the future, we will try to adapt techniques to eliminate hazards from the ecosystem, respectively to prevent and treat disease using environmental remedies. Plant organs will be used as raw material in the silver nanoparticles synthesis process of extraction, and some studies are already prepared to be submitted for evaluation. The research methodologies consisted of an up-to-date statistical approach specific to each research. Modelling growth patterns induced by different restrictive factors using machine learning techniques will represent the tool for quantifying past environmental processes.

The habilitation thesis "Evaluation of environmental information through interdisciplinary silvicultural techniques – achievements and perspectives" discusses the theoretical and experimental contribution to the forestry research, with applicability in environmental processes conducted after graduating doctoral studies. The thesis is systematized into three sections, (B-i) scientific and professional achievements, (B-ii) career development plans, and (B-iii) references. Section B-i encloses three distinct arguments, the most important research topics, conducted from 2013 until the present (2021). The research activity is presented as follows: i) tree-ring chronology construction and interpretation of environmental information, ii) dendrochronological dating – tool in cultural heritage and cultural identity studies, and iii) identifying the socio-environmental impacts of anthropogenic heavy metal pollution, analyzed in various matrices.

The first main research topic detailed in the first subsection (B-i1) presented the importance of filling gaps in the European tree-ring network, for which we created databases with continuous / floating chronologies in northern Romania, covering the period after the late Holocene until the present; (1) *Ważny, T., Lorentzen, B., Köse, N., Akkemik, Ü., Boltryk, Y., Güner, T., Kyncl, J., Kyncl, T.,* ***Nechita, C.****, Sagaydak, S. and Jeni Kamenova, V., 2014;* (2) *Rădoane, M.,* ***Nechita, C.****, Chiriloaei, F., Rădoane, N., Popa, I., Roibu, C., Robu, D., 2015;* (3) ***Nechita, C.****, Eggertsson, O., Badea, N.O., Popa, I., 2018.* The first study emphasized a project regarding

building oak tree-ring chronologies from the forest and historical/archaeological sites along a north-south transect between Poland and north-western Turkey. The scope was to create the link between North-Central European and East Mediterranean tree-ring networks, creating a pan-European oak data set suitable for dendrochronological dating and paleoclimatic reconstruction. The results demonstrated a solid bridge based on South-Eastern European chronologies between major European dendrochronological networks. The second study evaluated two rivers' environments (Moldova and Siret Rivers) along a 100-144 km-long floodplain and 77 samples of subfossil trunks. Twenty-six subfossil trunks were subjected to ^{14}C absolute dating. Based on subfossil trunks were identified wet phases (i.e., 3500–2900 YBP, 2200–2075 YBP, and 1000–800 YBP) and dry phases (e.g., 3200–3150 or 2775–2700 YBP, 1400 YBP). The potential for creating a long oak chronology covering the last 7000 YBP in North-Eastern Romania was sustained. The third study presented a 781-year oak tree-ring chronology covering the continuous period A.D. 1236–2016 in Maramureș county, including 824 samples. We separated 271 tree-ring series into a new chronology (A.D. 1406–2016), adequate to reconstruct past climate and environmental changes.

Interpreting climate and genetic information from tree-ring chronologies was also used: (1) ***Nechita, C.**, Popa, I., Eggertsson, O., 2017*; (2) ***Nechita, C.**, Macovei, I., Popa, I., Badea, O.N., Apostol, E.N., Eggertsson, Ó., 2019*; (3) ***Nechita, C.**, Čufar, K., Macovei, I., Popa, I., Badea, N.O., 2019*. The first study analyzed sixteen oak (*Quercus robur* L.) and sessile oak [*Quercus petraea* (Matt.) Liebl.] site chronologies along a longitudinal gradient (from 22.47 to 26.58 E) in Northern Romania. The North-West (NW) and North-East (NE) sites were established by comparing two mean regional chronologies separated by the Carpathian chain. We demonstrated a decreasing trend in correlation intensity with precipitation from NW to NE, particularly during March-July growing season. Oak trees from the NW and NE regions responded differently to local environmental conditions, synchronicity being observed only when analyzing severe climate events (e.g., the 1904 drought). In the subsequent study, we evaluated the climate drivers and the adaptability of *Quercus robur* L. (pedunculate oak) and *Q. robur* subspecies *pedunculiflora* K. Koch. (greyish oak) from three sites located in southern Romania. For both varieties (tardive and praecox), the greyish oak was noted to have a high tolerance to environmental stress between 1951-2016. Tree-ring correlation with daily climate data showed an apparent offset of the starting growth between greyish oak varieties. The resilience components analysis emphasized the moderate response of trees in the years with extreme events. The influence of three gridded datasets containing interpolated daily and monthly precipitation and temperature values over the past five decades against four tree-ring chronologies of oak (*Quercus robur* and *Q. petraea*) were also investigated. Climate-growth relationship and differences of Pearson's product-moment correlation coefficients when precipitation and temperature data extracted from different databases (CRU, E-OBS and ROCADA) are used to emphasize the importance of choosing suitable input data. From 1961 to 2013, E-OBS underestimated the mean daily temperature and precipitation compared with ROCADA. There was observed a discrepancy through datasets when analyzing earlywood and climate relationships. The results emphasize the importance of the proper selection of climate data for assessing climate-tree growth relationships. We recommend the ROCADA and E-OBS databases for dendrochronological oak studies in Romania.

The second subsection (B-i2) presented several monasteries part of the UNESCO patrimony, dendrochronologically dated under project obtained in the competition PN-III-P2-2.1-PED-2016-1058 "A new technique regarding dendrochronological dating. Statistical, biological and chemical approach". A complete list of patrimony objectives was presented in one book published in 2019 - **Nechita, C.**, Timur, C.V., Dendrochronological dating of the cultural heritage in Maramureș. 2019. Editura Silvică. ISBN 978-606-80-20-60-0, (in Romanian).

The third subsection (B-i3) included anthropogenic heavy metal pollution monitoring in various environmental matrices. Greenhouse gas (GHG), burning fossil fuels, deforestation, air pollution, solar irradiance and volcanic activity forced spatial and temporal climate change. The interest of the author in the evaluation and removal of GHG emissions was demonstrated in the publication *Zgavarogea R., Iordache, M., Iordache A.M., Constantinescu, M., Bucura, F., Ionete, R.E., Grigorecu, R., Nechita, C.,* 2021. Under a rapidly changing climate, an accelerated understanding of the diverse patterns and processes driving dynamic ecosystem responses is needed to effectively address the challenges of sustainably managing and restoring affected forest ecosystems. One of the significant potential effects of warming climate across terrestrial biomes is an increase in climate-driven tree mortality, particularly mortality triggered by drought and hotter temperatures. Increased spatial and temporal frequency of drought has been associated with woody plant mortality, and canopy dieback (loss of aboveground biomass while the belowground survives and regenerates) has been documented throughout several research studies. It is known that the earlywood vessel area is a suitable ecological indicator, due to the tremendous physiological relevance, in comparison with latewood. In Romania, thus far, we were the first scientific group to analyze tree decline from the perspective of cumulative environmental factors that interact with physiological processes. The latest-generation technologies and techniques are involved in achieving the objectives for future research studies. We foresee a challenge in quantifying heavy metals/radioactivity / polycyclic aromatic hydrocarbons in various matrices and establishing the potential source (soil, atmosphere). It may also be considered a possible influence in tree formation and tree reaction in sites of other types of stressors. These aspects underline an awareness of the altered environment. Having this overall perspective, we took the next step and started looking for remedies from nature (altered by humans) against one of the most frequent diseases and causes of mortality – cancer, with a higher incidence in areas affected by the Chornobyl disaster or industrial activity, as is the case of Copșa Mică Industrial Area (*Nechita, C., Iordache, A.M., Lemr, K., Levanič, T. Pluháček, T., 2021a*.

Annually resolved tree rings enable us to distinguish past pollution and climate change effects on chronic tree decline, affecting significant areas worldwide, a considerable topic of author studies interest. Thus, ***Nechita, C.**, Iordache, A.M., Lemr, K., Levanič, T., Pluhacek, T., 2021* study aimed to establish a pattern for the assimilation of heavy metals in regular and declining *Quercus robur* L. trees. Here laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS), ICP-MS, and atomic absorption spectroscopy (AAS) was used to investigate the present and historical changes in elemental levels. Twenty different environmental species were analyzed, including water, soil, sediments, mushrooms, acorn, leaves, branches, bark, and wood. Time profiles of elements in earlywood tree rings were also evaluated. We demonstrated higher HM contamination in the present background with increasing Pb and Cd levels. The presence of Li and Sr in groundwater was reported for the first time. We found significant differences ($p < 0.001$) between declined (D) and normally (N) growing trees only in the 1960–

2019 period (Levene's *t*-test), which was sustained by a significant negative trend in D– chronology (*MK*-test, two-tailed). The bootstrapped correlation showed a weak positive relationship between D– chronology and soil moisture and a negative relationship with temperature and evapotranspiration. Declined trees were less resistant to environmental stress factors than N– growing trees at present (2012 compared to 1953). Mn, Cu, Cd, Pb, Zn, and Ni contents in tree rings correlated with climate-induced drought conditions, explaining the increasing elemental contents after 1980. A significant relationship between earlywood tree rings, climate and HM contamination explained different response patterns for normal and declining trees. Metal availability increases with climate change effects, leading to higher rates and future concerns, especially considering the high environmental health risk of some elements, such as Pb and Cd.

A second study which investigated environmental pollution was *Iordache, A.M.,* ***Nechita, C.****, Voica, C., Pluhacek, T., Schug Kevin, A., 2022*, where the author of the habilitation thesis was the corresponding author. Here, the relationship between metal levels in the Olt River ecosystem in southern Romania (measured during 2018–2019, with 1064 sediment and water samples) and daily climate data were explored to assess the need for targeted source identification and mitigation strategies. In 2018, there was a strong relationship between the sediment Pb, As, Cd, and Hg contents and temperature ($r > 0.8$, $p < 0.001$). Mercury in sediments had a positive correlation with precipitation, and Hg in the water correlated with minimum temperature in May 2018 ($p < 0.01$). In July 2019, heavy metals were positively correlated with precipitation and negatively correlated with temperature. According to nonsymmetrical correspondence analysis, the four climate parameters analyzed were linearly correlated with the frequency of metal detection ($p < 0.001$) in both years. The statistical analysis showed strong relationships between heavy metal levels and climatic factors and attributed the discrepancies in elemental concentrations between 2018 and 2019 to climate warming. This study also presented examples of critical thematic areas that transboundary policymakers, environmentalists, and decision-makers can use for possible discussion concerning future management practices and endorsement strategies. Modern society acts through various engines to disrupt natural ecosystems. Water pollution and scarcity represent a sensible face of the contemporary world. The realistic discussions regarding lack of water for irrigation and in various world regions even for a drink until 2030 make this subject most sensible nowadays.

Climate change is not involved only in the reduction of water amounts but even is a significant factor in acidification and increasing pollution în the river's ecosystems. As a fact of genuine interest for ecosystem and human exposure to environmental pollution, the author was a corresponding author with equal contribution as the first author to the following article: *Iordache, A.M.,* ***Nechita, C****., Zgavarogea, R., Voica, C., Varlam, M., Ionete, R.E., 2022*. Here the heavy metals concentrations in southern Romania the Olt River surface sediment samples were investigated to assess their spatial distribution, seasonality, and contamination levels. The results showed that the concentrations of Ni, Cu, Zn, Pb, Cd, and Hg in surface sediments were generally higher than their respective national background values—up to 8.28 times more in the case of As. The spatial variability pattern had similar trends for all HMs, indicating increasing concentrations in the middle compared to the lower sites. The statistical tests showed a statistically significant difference between the mean and variance only for Cr and Pb when investigating the temporal variability between site measurements. We observed a strong

association between HMs in March and May and a strong relationship in March between elevation and Pb, Ni, Cu, Cr, and Zn, demonstrating that river velocity accumulated with spring discharges are conditioning metal levels in the spring. The HMs Cd, Hg, and As had mixed sources, less geogenic and more from anthropogenic activities. The *CF* indicated that the Olt River was highly contaminated with As at 15 of 19 sites. A low degree of contamination was also observed in various locations for the investigated elements. *PI* analysis indicated that the Olt River sediments were highly polluted ($PI > 3$). The *PLI* showed varying degrees of pollution in more than 89% of the sites surveyed, increasing the authorities' need for action. The I_{geo} indicated that Zn, Cr, Cu, Ni, Pb, Cd, and Hg were at a pollution-free level and that As was present at levels ranging from unpolluted to moderately polluted. A higher involvement by national authorities, including monitoring measures to control contamination in industrial areas and municipal waste discharges, is needed to improve the Olt River environment.

Knowing the actual stage of metal contamination in various matrices from Romania led the author to be involved in publishing studies that can reveal the impact of pollution on the human body. The results motivated me to be involved in searching for the natural remedies for fighting diseases ofter occurred after daily or occasional exposure. These articles are: *Voica, C., **Nechita, C**., Iordache, A.M., Roba, C., Zgavarogea, R., Ionete, R.E., 2021* and *Macovei I, Luca SV, Skalicka-Woźniak K, Sacarescu L, Pascariu P, Ghilan A, Doroftei F, Ursu E-L, Rimbu CM, Horhogea CE, Lungu C, Vochita G, Panainte AD, **Nechita C**, Corciova MA, Miron A. 2022.* As the main results, we found pollution with toxic metals (As, Cd, Hg, Pb) in foodstuff that can threaten human health. Also, the research team found possible utilization of phyto-functionalized silver nanoparticles derived from conifer bark extracts which were further evaluated for their antimicrobial and cytogenetic effects.

Chapter B-ii presented the professional and scientific evolution and career development plans. Scientific research experience was pointed out by the number of projects the author has occupied the position of manager or expert. The number of articles published in the high ranked journal as the first/corresponding author sustains scientific achievements. Also, the reviewer member position in the commissions for defending the doctoral thesis at the University "Stefan cel Mare" Suceava "Faculty of Forestry" is mentioned. Career development plans are focused on maintaining and developing collaboration agreements between research institutions and universities in Romania and Europe. Since 2013 the author has performed training stages in prestigious universities worldwide. From 2017 until 2019, I led the research team activity in the National Research and Development Institute for Silviculture "Marin Dracea", Câmpulung Moldovenesc station. I published four books and 22 ISI articles in high-rank journals.

20 May 2022 Candidate,

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