Universitatea Transilvania din Brașov
FACULTATEA DE SILVICULTURĂ ȘI EXPLOATĂRI FORESTIERE

DEWOOD

UNDERSTANDING BIOTIC AND ABIOTIC CONTROLS OF WOODY DEBRIS DECOMPOSITION AND ITS CARBON BUDGETS IN OLD-GROWTH FORESTS

cod PN-III-P4-ID-PCE-2020-2696

Unitatea Executivă pentru Finanţarea Învăţământului Superior, Cercetării, Dezvoltării şi Inovării

Final report

Implementation period: 04 / 01 / 2021 – 31 /12 / 2023

Project Director:

dr. Ion Cătălin Petrițan

Brașov

2023

RST – Scientific report regarding the implementation of the "DEWOOD – **Understanding biotic and abiotic controls of woody debris decomposition and its contribution to carbon budgets in old-growth forests"** project (PN-III-P4-ID-PCE-2020-2696; Financing Contract for Project Execution PCE 98 / 2021)

FINAL REPORT (04/01/2021 - 31/12/2023)

1.FORESEEN AND ACCOMPLISHED OBJECTIVES

The main goal of the DEWOOD project was to quantify the role of deadwood in the carbon cycle of the Sinca Forest ecosystem and thus to gain a better understanding of how the interactive effects of climate (temperature, humidity), wood characteristics (wood density, wood chemical properties), decomposers (xylophagous fungi, saproxylic insects) and organisms inhabiting on deadwood (bryophytes) influence the decomposition process of deadwood.

In order to achieve this general objective, the following specific objectives have been foreseen and fully achieved:

1.1. Quantification of carbon stored in dead wood in the Șinca virgin forest

In virgin forests, dead wood is an important component of the forest ecosystem. It is a crucial reservoir of nutrients and carbon, responsible for several ecosystem functions (Christensen et al., 2005; Di Cosmo et al., 2013; Harmon et al., 1986; Hermann and Bauhus, 2018), and is an important source of food and habitat for numerous species of bacteria, fungi, bryophytes, arthropods, birds and mammals (Ódor et al., 2006; Stokland et al., 2012), as well as rare, endangered species (Persiani et al. 2015). Inventorying dead wood in forests is usually done by dividing it into two categories: standing dead wood and lying dead wood. For each category, they are measured and visually classified into several decay classes (Petritan et al. 2015) based on the physical properties of the wood (Bütler et al., 2007; Weggler et al., 2012). Most existing studies provide information on the volume of dead wood and its distribution by decay class (Keren and Diaci 2018; Oettel et al., 2020; Petritan et al. 2015, Öder et al. 2021), with few providing information on the carbon stock stored as dead wood (Přívětivý et al., 2017; Weggler et al., 2012; Seedre et al., 2015; Seedre et al., 2020). Such information is very valuable, especially given that estimating carbon stored in dead wood is a reporting requirement for the Kyoto Protocol (Tobin et al., 2007), as deadwood is one of the five carbon pools to be reported in national LULUCF reports. It has been shown that using a single value for conventional wood density regardless of the degree of decay of deadwood to convert deadwood volume to biomass leads to either under- or overestimation of biomass (Di Cosmo et al., 2013; Merganičová and Merganič, 2010; Weggler et al., 2012). It is therefore recommended to use an average deadwood density value for each decay class (Petrillo et al., 2015; Seedre et al., 2013). As the conventional deadwood density of different classes may vary depending on environmental conditions, a local determination of these values is necessary for the most accurate estimation.

As a result, in the DEWOOD project, both an inventory of dead wood and a more precise determination of the density of dead wood per standing and lying down by decay class were carried out. To this end, 5 decay classes were defined according to Weggler et al. (2012). Using the methodology proposed by Teodosiu and Bouriaud (2012), a number of about 15 pieces of deadwood for each species (fir and beech), deadwood category (standing and lying down) and decay class were randomly chosen. For standing category only the first three decay classes were found. Cores were extracted from dead standing trees either with a 5 mm inner diameter borer for the first decay classes or with a 12 mm diameter borer the last decay class. Cores were extracted from at 1.30 m height above ground. For the decayed wood, cores were extracted with the 5 mm diameter borer for class A, for classes B and C the 12 mm diameter borer was used, and for decay class D a parallelepiped was cut and its dimensions measured. From the decay class E dead wood, the sample was taken using a 5 cm diameter cylindrical tube. The volume of each sample was determined either with the cylinder volume formula based on the inner diameter of the borer and the length of the core, or with the parallelepiped volume formula in the case of the fourth decomposition class. All samples were hermetically sealed in plastic bags immediately

after harvesting to avoid loss of sample moisture. Samples were weighed as soon as possible after harvesting with an existing precision balance at the University's Research and Development Institute, dried at 105°C for 48 hours after which they were reweighed to determine dry mass. Fresh mass, dry mass, rot percentage and moisture content were determined for each sample. The conventional density of the samples was determined as the ratio of dry mass to green volume of the sample. To quantify the volume of dead wood in the virgin forest of Șinca, the dead wood was inventoried in 21 randomly distributed sample areas of 35 x35 m. In each sample area, standing deadwood with a base diameter ≥ 6 cm and lying deadwood with a diameter at the thick end ≥ 15 cm and a length ≥ 3 m was inventoried (Petritan et al 2015, Vasile et al. 2017). Each individual piece has been assigned to a decomposition class. For standing trees, the species was identified, the base diameter and height were measured, and for dead standing pieces, in addition to determining the species, the length of the piece within the sample area and the diameters at the two ends were measured. The volume of each inventoried piece was calculated either with the cone trunk formula for dead standing timber or with the formula for determining the volume of trees developed by Giurgiu and Drăghiciu (2004).
The results achieved for objective (1) of the DEWOOD project are described in detail in section II.
RESULTS AND INDICATORS below and have been published in **Forest Ecology and** Management: Petrițan I.C., Mihăilă V, Curiel Yuste J., Bouriaud O., Petrițan AM, 2023.

1.2. Variation in decay rates of dead wood in relation to seasonal climatic fluctuations (temperature and humidity)

To monitor the long-term dynamics of dead wood decay, we followed the method proposed by Freschet et al. (2012). We began by assessing the effect of seasonal climatic variation on deadwood decay by independently modelling deadwood decay rates considering 4 time points (summer, autumn, winter and spring). The method consisted of incubating pieces of logs at a known stage of decay. In the summer of 2021, we selected 5 logs of 60 cm length for the 25 cm diameter size class per replication (we opted for the 5 replications per area variant), for 3 decay classes of each species (fir vs. beech) in 3 sample areas. Each log was then divided into 6 sections in total, 5 intended for field incubation and 1 for chemical analysis (10 cm each). The dry biomass and volume of the 6th section were measured in the laboratory, while a subsample of it was extracted and prepared to be sent to a laboratory in Bilbao for chemical properties determination the following year. For small deadwood we opted for two other size classes, namely for the 10 cm diameter and 1 cm diameter class. For each of these size classes, 5 pieces per replicate (total 5 replicates per sample area) for 3 decay classes of each species (fir vs. beech) were installed in each sample area. To continuously monitor dead wood temperature and humidity, we installed humidity and temperature measuring sensors (TEROS 11) on 25 cm trunks in each experimental lock in each area, as well as temperature measuring sensors at different soil depths (0 and 15 cm deep) TSM-4 sensors. The TEROS 11 sensors also required coupling to dataloggers and were set to measure hourly humidity and temperature. To measure the CO_2 flux released from each log of each species and decay class we fitted 10 cm diameter PVC collars and measured in July, October, December and April.

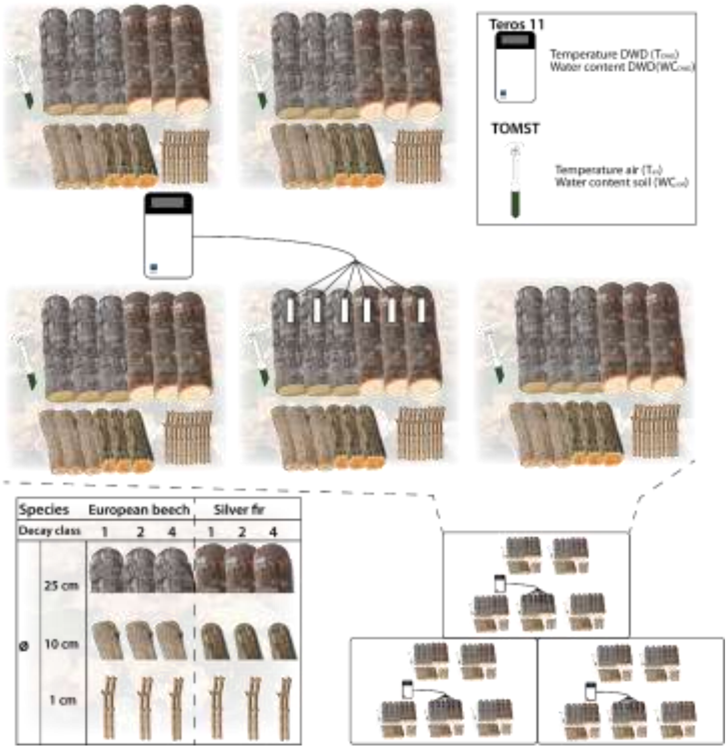


Figure 1. *Experimental design of incubation epxeriment carried out in Sinca virgin forest*

1.3. Decomposition rates of dead wood in relation to the chemical properties of the wood.

This objective described how the different chemical properties of dead wood were correlated firstly with the degree of decay, and secondly with the species. Concentrations of the main nutrients (C, N, P, K, Ca, Mg, Fe, Mn) in deadwood were measured for each plot, decay class and species. The determination of chemical composition was carried out in the laboratory of the external partner of the project, Esteban Raquel (Department of Plant Biology and Ecology, University of Basque Country (UPV/EHU), Leioa Bizkaia, Spain), while lignin and cellulose analyses were carried out in the laboratory in Amsterdam under the supervision of another external collaborator, Hans Cornelissen (Systems Ecology, Amsterdam Institute for Life and Environment (A-LIFE), Faculty of Science, Vrije Universiteit, Amsterdam, The Netherlands). Wood samples were extracted at the beginning of the experiment, considering 2 cm for 1 cm diameter samples, as well as 5 cm discs from 10 cm and 25 cm samples, respectively. The determination of nutrient content was carried out by inductively coupled plasma optical emission spectrometry. For the determination of cellulose and lignin the methods described by Fasching et al. (2008) and Fahmy et al. (2006).

1.4. Decomposition of dead wood in relation to biotic decomposers (fungi, saproxylic insects)

This objective investigated how biotic decomposers (fungi, saproxylic insects) contribute to the decomposition of dead wood. It was the first time in Europe that these relationships were studied in a virgin beech-fir mixed forest.

1.4.1. The role of saproxylic insects in the decomposition of dead wood

Flight traps (wing) and ground traps (Barber) were used to collect saproxylic insects in 15 sample areas of 500 m2 containing large amounts of dead beech and fir wood in various stages of decay. Collection of insects from the forest was carried out every 2 weeks for two seasons (June-October 2021 and April-September 2022), while the identification of species, genera and families to which the collected individuals belonged was carried out in the laboratory throughout the 3 years of the project.

1.4.2. The role of fungi in the decomposition of dead wood

Internal transcribed spacer ITS2 of the rDNA cassette was amplified using PCR with primers specific for fungi and sequenced on Illumina MiSeq (2x 250 bases). Molecular taxa were constructed by merging sequences into 97% similarity clusters. Each molecular taxon was identified by BLASTn search in the UNITE database and ecology was assigned to those molecular taxa that were classified into known fungal genera. Diversity of fungi was expressed as number of observed molecular taxa when 4000 random sequences were selected from each sample. The effects of host tree species, tree decomposition stage and diameter cathegory were tested on diversity of fungi and the composition of fungal communities across samples.

Sequencing: We amplified the ITS2 region of fungal rDNA in triplicate using gITS7 and ITS4 primers (Ihrmark et al., 2012) with unique barcodes. The PCR used 1 µL of 5 ng/µL DNA, 2.5 µL 10× buffer, 1.5 µL 10 mg/mL BSA, 0.5 µL 10 mM nucleotide mix, 0.75 µL 2 U/µL DyNAzyme II Polymerase, 1 µL 10 µM each primer, and 16.75 µL water in a 25 µL reaction. PCR conditions were 94 °C for 5 min, 35 cycles of 94 °C/30 s, 56 °C/30 s, 72 °C/30 s, then 72 °C/7 min. PCR products were pooled, purified (MinElute Kit, Qiagen), quantified (Qubit dsDNA HS Assay Kit, Thermo Fisher), and sequenced on an Illumina MiSeq (2×250 bp paired-end reads) after library preparation (TruSeq DNA PCR-free Kit, Illumina). ***Bioinformatics Processing:*** Sequencing data were processed using SEED2 (Vetrovsky et al., 2018), filtering out low-quality (<30 mean) sequences. We de-replicated sequences, extracted ITS2 (ITSx 1.0.11), re-replicated, removed sequences <40 bases and chimeras (UCHIME). Remaining sequences were clustered into OTUs at 97% similarity (UPARSE), discarding singletons. The most abundant sequence per OTU was used for taxonomic identification against UNITE 9.0 with BLASTn, excluding non-fungal and unidentified hits. Fungi were categorized ecologically (FungalTraits database).

1.5. The role of the bryophytes inhabiting deadwood in its decomposition.

In order to measure the contribution of bryophytes covering the dead wood pieces from the Șinca forest, we used the same sample as in 1.2., but only the 10 cm diameter pieces were doubled in number, half of them being covered with bryophytes, and half of the pieces were kept as a control without moss. Moss material was collected from dead trees in the vicinity of our experiment. Before each CO2 measurement, the moss layer was removed (to avoid the photosynthesis produced by the mosses), and re-attached immediately after the measurement.

1.6. **Carbon stock dynamics in Sinca forest**

1.6.1. Development of a model for the response of dead wood decay to climate fluctuations

In this sub-objective an attempt was made to develop a model to predict the carbon dioxide flux released from dead wood pieces in different stages of decay as a function of climatic fluctuations (temperature and precipitation). Different linear mixed-effects models (LME; "nlme "Rpackage, Pinheiro et al., 2020) were run to analyze the trends of deadwood respiration on different decay classes, for the two tree species and as a function of other climatological variables. The variables included as fixed part in the model were selected based on the Akaike Information Criterion (AIC) (models with the lowest AIC) using the MuMin package (Barton, 2022). Finally, the variables selected were: air temperature, soil moisture, decay class (1, 2 and 4), species (beech and fir), density, diameter and all interactions between species and all other variables mentioned.

1.6.2. Dynamics of carbon stock in Sinca forest (2013-2023)

In this sub-objective we have determined the dynamics of the carbon content of dead wood in the virgin forest Șinca over the 10 years since the first inventory (2013) by conducting a new inventory in 2023. The volume of dead wood was quantified in the 21 permanent survey areas for each of the two species, separately for the five decay classes defined in chapter 1.1. Based on the dead wood density values determined for each species and each decay class found in chapter 1.1., the volumes were transformed into necromass, and by multiplying by the percentage of carbon the changes in carbon content were quantified.

2. PRESENTATION OF THE RESULTS ACHIEVED AND THE RESULT INDICATORS

The objectives set out in the DEWOOD project have been fully achieved according to the original project proposal and implementation plan. The results of the DEWOOD project are detailed below based on the specific objectives presented in section I. OBJECTIVES PLANNED AND ACHIEVED.

2.1. Quantification of carbon stored in dead wood in the Șinca virgin forest

The mean conventional density of both species decreased significantly from the least decayed class of deadwood to the most decayed class (Fig. 2). This decrease was more pronounced for beech than for fir. Thus, while in beech, differences in conventional density were significant between all three decay classes defined for standing dead trees, in fir, no significant differences were found between the three classes. For dead standing wood, the decrease in conventional density from class A to class E was significantly greater for beech (68%) than for fir (55%). This was due to the significant differences in conventional wood density between the two species in the first decay class (486 kg m-3 average density of beech dead wood in class A compared to only 359 kg m-3 for fir) and the blurring of this interspecific difference for dead wood in the class with the highest decay rate (151 kg m-3 density of beech in class E and 161 kg m-3 density of fir).

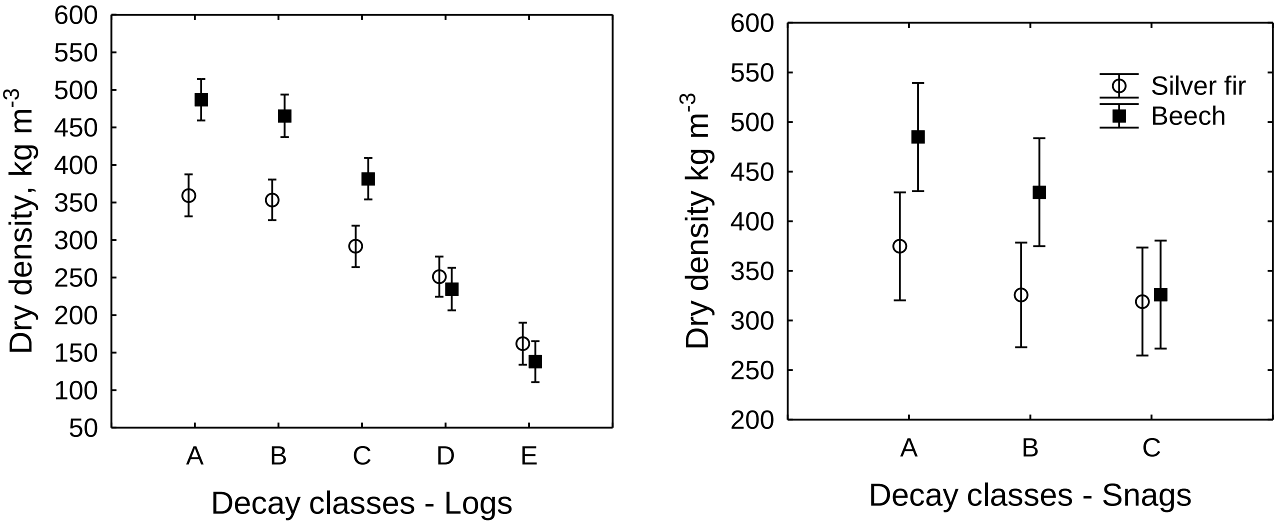


Figure 2. *Dry wood density of lying and standing deadwood.*

Based on the data obtained from the inventory of dead wood lying and standing in the 21 randomly distributed sample areas, the volume of dead wood was calculated for the two categories of dead wood (lying and standing), for each of the two existing species and for each decay class. By multiplying the obtained volume by the mean conventional density determined for each species, deadwood category and decay class, the amount of biomass stored as deadwood in the inventoried sample areas was estimated, whose distribution by decay class is shown in Figure 3.

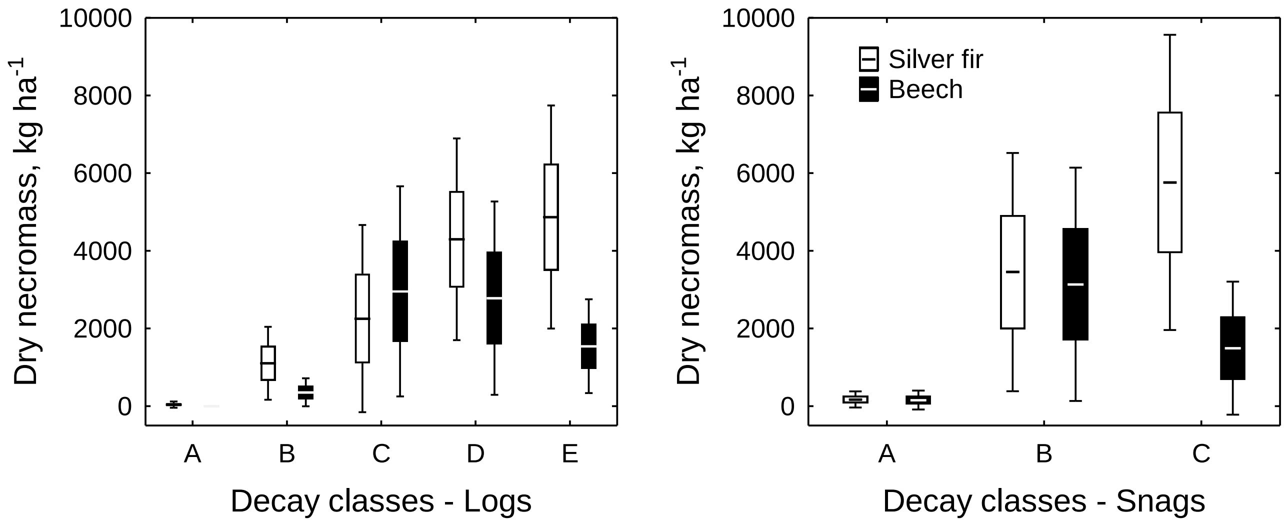


Figure 3. Necromass stocked in deadwood.

The average value of total biomass stored as dead wood in the Șinca virgin forest was 34.4 ± 5.1 t ha-1, ranging from 0.77 to 89.12 t ha-1. Of the biomass stored as dead wood 64% is represented by fir species and 59% by dead wood fallen on the ground. The conversion of biomass to carbon stock was done using an average carbon concentration value of 46.3% for beech and 47.2% for fir (values determined from samples collected in the project).

Table 1. C amount (t ha^{-1}) stocked in deadwood of Sinca forest

Carbon (t ha^{-1})	Beech	Fir	Total
Total deadwood	5.75 ±1.23 (0.02-17.31)	10.36 ±1.77 (0 -28.34)	16.12±2.39 (0.36-41.77)
Lying deadwood	3.54 ±0.91 (0-13.38)	5.93 ±1.13 (0-17.36)	9.47±1.64 (0.21-28.05)
Standing deadwood	2.22 ±0.89 (0-16.02)	4.43±1.13 (0-19.41)	6.65± 1.39 (0-21.15)

This resulted in an average value of 16.12 ±2.39 (t ha-1) of carbon stored as dead wood in the Șinca virgin mixed forest (Table 1). In Figure 4, the distribution of the amount of carbon stored in dead wood by the two categories and species was shown, depending on the volume of live trees in each sample area. As can be seen there is no correlation between the two variables.

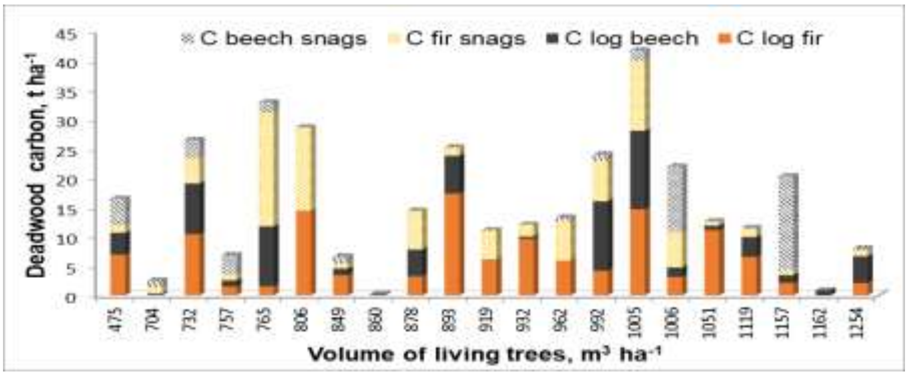


Figura 4. Carbon amount stocked in deadwood related to the living stock volume.

Indicators of results:

The results presented in this section were presented at a conference - oral presentation: Petritan AM, Mihaila V, Braga I. Petritan IC. Species-specific deadwood density and its controlling factors in a virgin European beech-silver fir mixed forest in the Southern Carpathians. 5 th Edition of the International Conference "Integrated Management of Environmental Resources", 29 October, Suceava, Romania (http://www.silvic.usv.ro/imer2021/).

In addition, the results presented in this section were included in a scientific article published in the

prestigious journal Forest Ecology and Management (Q1): Ion Catalin Petritan, Victor-Vasile Mihăilă, Jorge Curiel Yuste, Olivier Bouriaud, Any Mary Petritan, 2023. Deadwood density, C stocks and their controlling factors in a beech-silver fir mixed virgin European forest, **Forest Ecology and Management**, Volume 539, 2023, 121007, https://doi.org/10.1016/j.foreco.2023.121007.
(https://www.sciencedirect.com/science/article/pii/S0378112723002414)

2.2. Variation in decay rates of dead wood in relation to seasonal climatic fluctuations (temperature and humidity)

The decomposition of dead wood and thus its CO2 emissions are determined by the climatic conditions of the ecosystem, in particular temperature and humidity. As a result, a good understanding of temperature and moisture fluctuations in the ecosystem could allow prediction of future CO2 emissions.

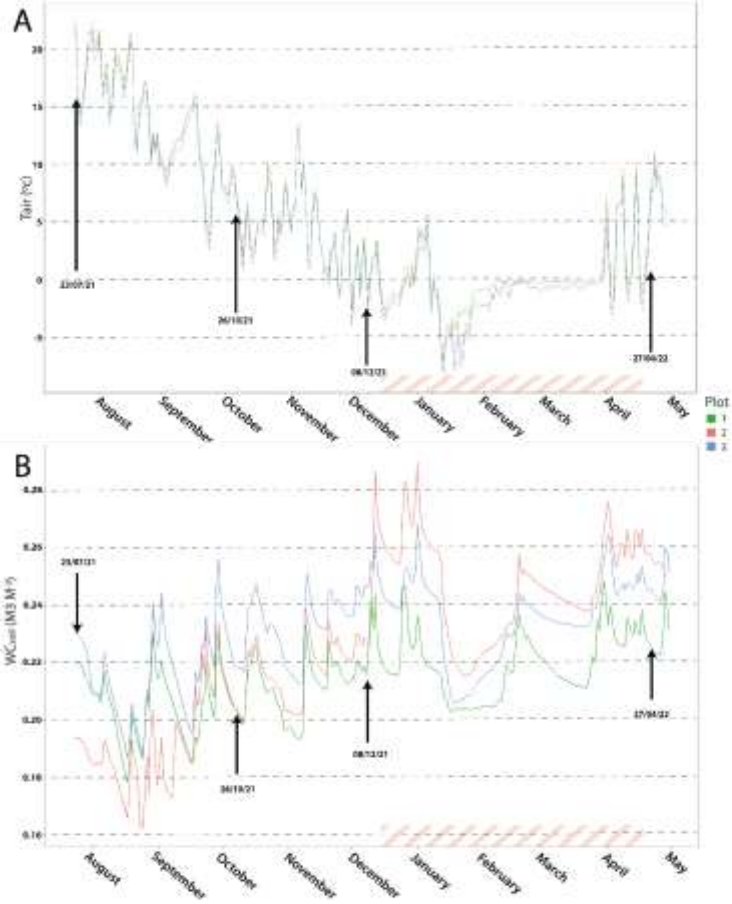


Figura 5*. Air daily temperature* (Tair in ºC, A) and soil humidity (WCsoil in M3/M3 ,B).

The recorded climatic data indicate a forest with a very stable climate (Fig. 5), where both the daily and annual temperature range is low (between -5 and 25 ºC) compared to other forest types. The three sample areas in which the study was carried out are located at so-called distances from each other, and differ in altitude, slope, canopy and dominant species. However, temperatures in the three sample areas either did not differ or differed little. This indicates that the temperature is relatively homogeneous throughout the entire ecosystem represented by the virgin forest investigated, with the high value of the leaf area index in this forest acting as a buffer against its diurnal variability. Soil moisture was relatively high throughout the year, with little variation. Although it had a similar profile in the three sample areas, soil moisture showed significant differences between areas, which seem to be mainly caused by the slope of the surface. Respiration of dead wood and CO2 emissions were affected by both temperature and humidity. The results give a good picture of how both climatic variables affect the decomposition process of dead wood. Temperature is one of the most important factors determining the amount of CO_2 emitted into the atmosphere, but moisture seems to be the factor that determines differences within the ecosystem, making each part of the forest different from the other.

Influence of deadwood characteristics on climatic characteristics

The climatic characteristics of the ecosystem can be influenced by dead wood, which can act as a sponge for water and reduce sudden temperature changes in the environment. Therefore, careful study of the conditions within deadwood will allow us to determine how these processes are linked. While the temperature inside the deadwood was almost no different from that outside, the humidity was strongly influenced (Fig. 6). Thus the humidity inside the deadwood was determined by both species and decay class. These differences were, however, completely overshadowed by the different moisture content of each sample surface, which played a predominant role. These characteristics of the studied forest and deadwood highlighted by the present study are very important in determining deadwood respiration and should be key elements for future carbon cycle research, as the accuracy of models that do not take into account the specificities of each forest is questioned.

Dead wood respiration flows

CO_2 emissions from dead wood are complex and variable. This variability is not only determined by environmental characteristics (temperature, humidity, position), but also by the intrinsic properties of the tree species, decomposing organisms and the chemical composition of the wood. In this study we will attempt to present and understand the characteristics of carbon emissions and model them for prediction purposes.

The average respiration expressed in g CO_2 per kg dead wood per year showed low values in spring, high values in summer and then decreased again in autumn and winter (Fig. 7). The respiration rate also differed according to the diameter of the dead wood pieces. Thus, while deadwood pieces with diameters of 1 and 10 cm had a respiration rate between 2 and 30 g CO_2 kg deadwood-1 year-1, the amount of CO_2 emitted into the atmosphere by pieces with a diameter of 25 cm was 10 times higher per gram of deadwood compared to smaller pieces. In summer, when respirations are high, significant differences between decay classes can be observed, but these differ between species. Thus, while fir appears to have higher respirations in decay class 4 at 10 and 25 cm diameter, beech tends to have higher CO_2 in decay class 2.

Indicators of results:

All the results presented in this section were presented at two international conferences - oral presentations:

- Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Stoian Remus, Ilinca, E., Petritan AM, Petritan IC. DOWNED DEAD WOOD IN TEMPERATE OLD-GROWTH FORESTS: NOT JUST CARBON LEFTOVERS. INTECOL 2022: Frontiers in ecology: science and society, Geneva, Evetia, 28.08.2022-2.09.2022. Oral presentation.
- Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Stoian Remus, Ilinca, E., Petritan AM, Petritan IC. Downed Dead Wood. A Really Complex Carbon Stock. 10TH INTERNATIONAL SYMPOSIUM FOREST AND SUSTAINABLE DEVELOPMENT. Oral presentation.

In addition, the results presented in this section have been included in a scientific article under review (round 2) in the prestigious journal Science of the Total Environment (Q1).

- Buezo Javier, Medina Nagore, Hereș Ana.-Maria., Petritan Ion Catalin, Cornelissen Hans, Petritan Any Mary, Esteban Raquel, Ilinca elisabeth, Stoian Remus, Curiel Yuste Jorge, 2023. Downed woody debris carbon emissions in a European temperate virgin forest as driven by species, decay classes, diameter and microclimate. Science of The total Environment. ACCEPTED 3.12.2023.

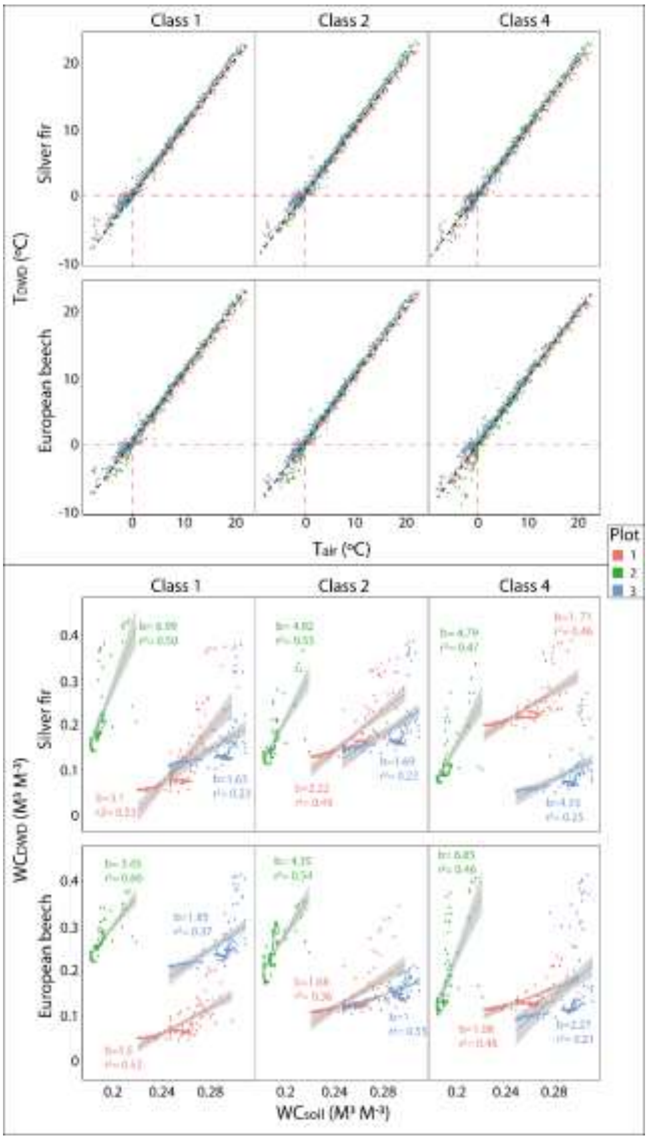


Figure 6. A, Comparison of temperature measured at 10cm above ground (Tair, X-axis) and at 10cm inside 25cm diameter pieces of fir (top) and beech (bottom), decay classes 1, 2 and 4 (TDWD, left to right). B, Comparison of volumetric moisture content (M3/M3) 10cm inside the soil (WCsoil) and 10cm inside the dead wood pieces (fir-top, beech-bottom, decay classes 1, 2 and 4) (WCDWD). Colours represent the 3 plots.

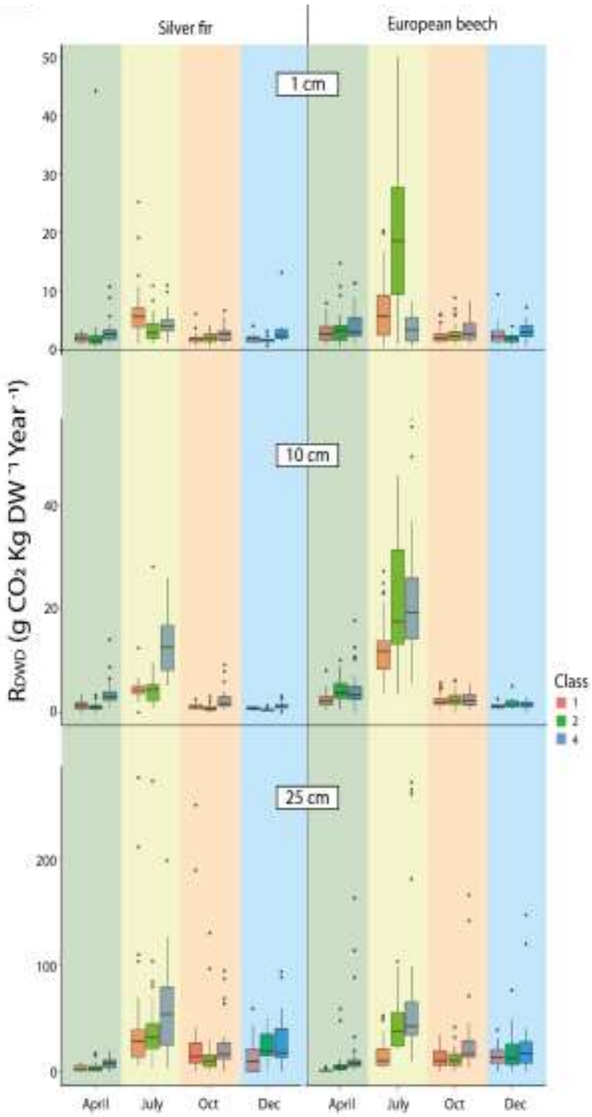


Figure 7. Average respiration in g CO2 per kg dead wood and per year separately for fir (left) and beech (right) for 1, 10 and 25cm diameter dead wood pieces (top to bottom). The decay classes are shown in colour (red, class 1; green, class 2; blue, class 4). Different backgrounds represent different seasons.

2.3. Decomposition rates of dead wood in relation to the chemical properties of the wood.

Principal component analysis (PCA) indicates which variables participate most in the variation of the data and groups the samples according to their distribution among these variables. In both Abies alba samples (Fig. 8) and Fagus sylvatica samples (Fig. 9), a clear separation of class 4 samples can be observed. This grouping mainly corresponds to a difference between the percentage of water and bark in the sample and the measured respiration, a separation that is very evident in the case of the beech deadwood samples. Variables such as temperature and soil water content remain secondary. The separation of classes by PCA confirms that the methodology used for sample selection was correct, while temperature and soil moisture remain secondary.

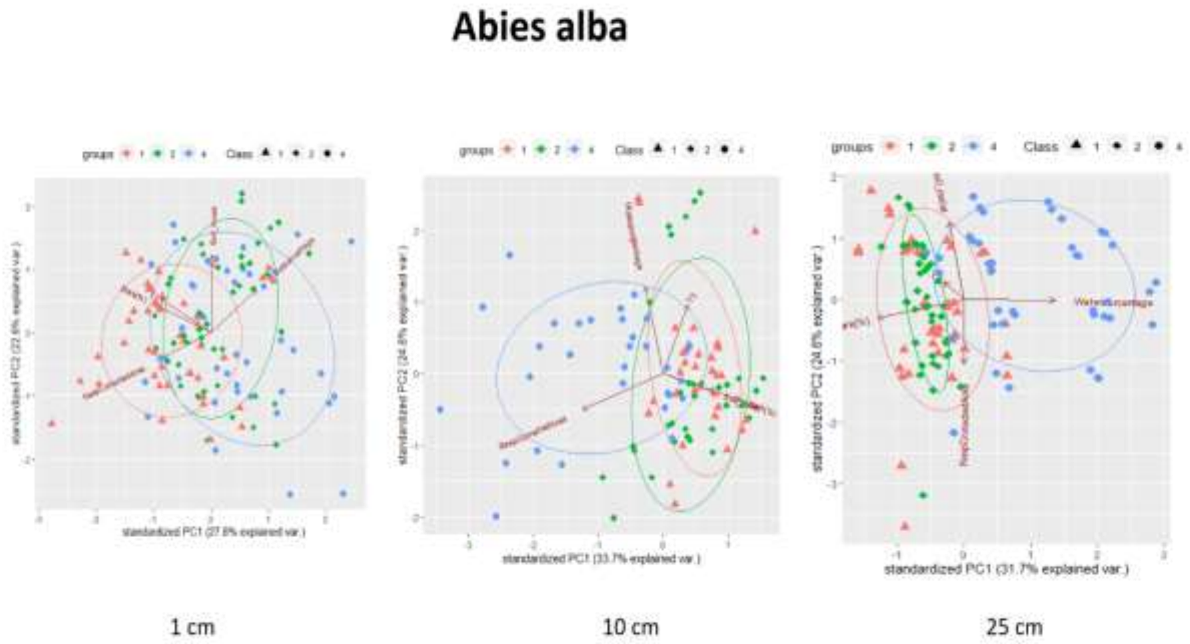


Figure 8. Principal component analysis for fir.

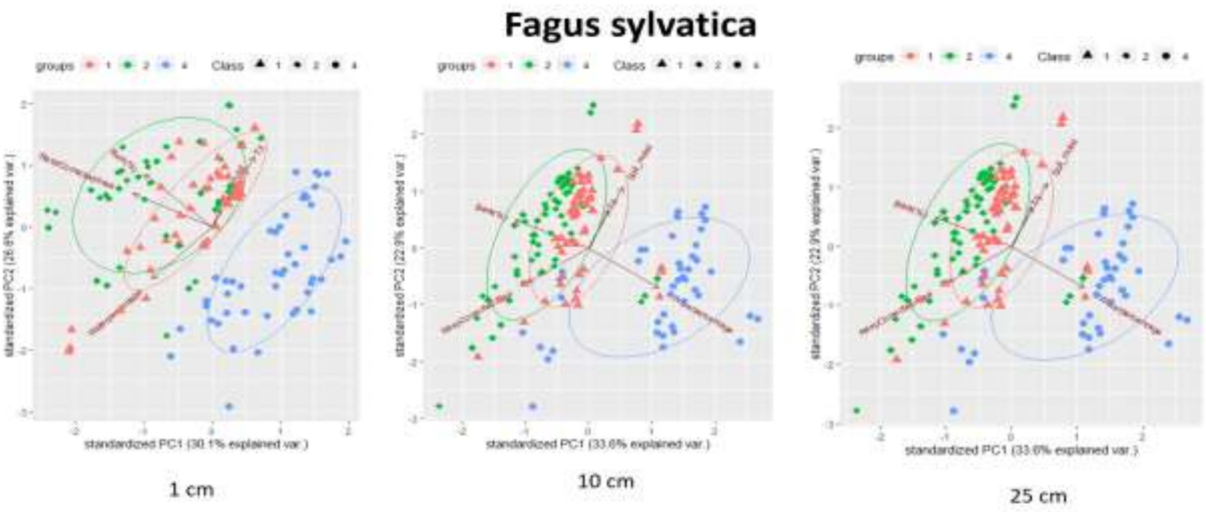
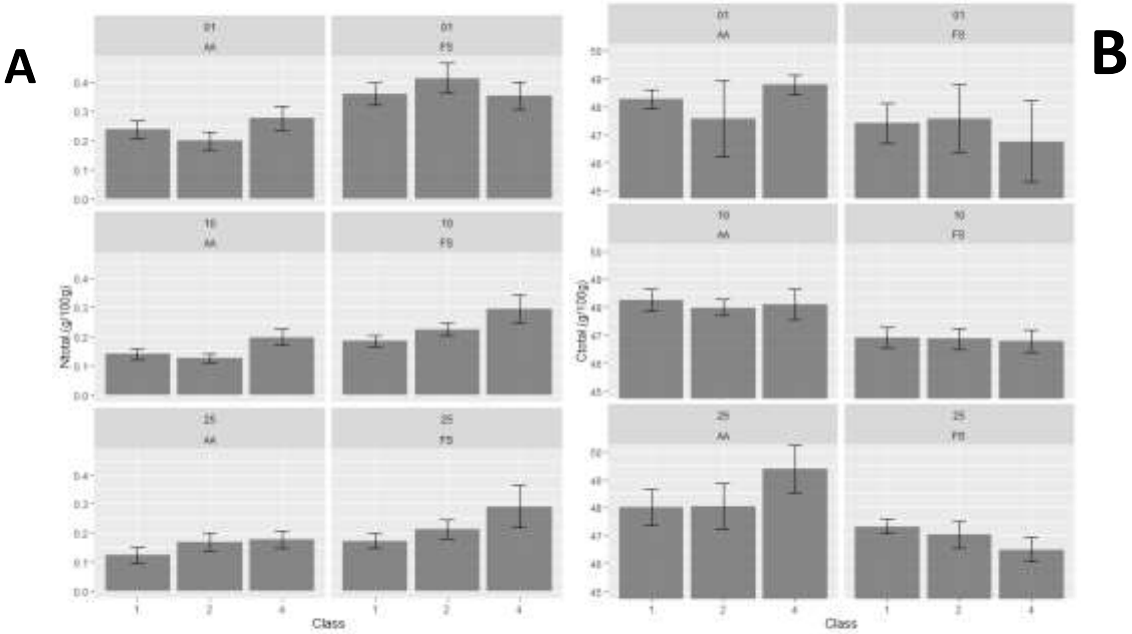


Figura 9. Principal component analysis for beech.

Both the density and pH of the wood depend on several variables during the life of the tree, but after the tree dies and falls to the ground, bacteria and fungi, which will consume the components stored in the wood, will cause a loss of material and therefore a reduction in the density of the wood, while the environment acidifies as a result of enzymatic action. In terms of pH, a similar pattern to density was found, i.e. an acidification of dead wood as the wood decays, with no notable differences between classes 1 and 2, while, as expected, class 4 is the most acidic in both species. The classification of the pieces of wood into the three decay classes was done visually, based on external characteristics of the wood established by several researchers through careful inspection. This selection process ranged from the general strength of the wood to the loss of bark, the development of bryophytes and fungi and even the accumulation of water or partial burial of the piece of wood in the soil. The results of our study so far show that the selection process cannot be limited to characteristics such as density or pH and that a more detailed study should be made (e.g. lignin, C/N contents, ergosterol, cellulose,...) when trying to standardise the chemical properties of different classes of dead wood decay.

Carbon, Nitrogen and C/N ratio

Once the piece of dead wood is colonised, it begins to be consumed by decaying organisms. Bacteria, fungi and arthropods, mainly, will use the nitrogen and incorporate it into their own biomass, while the carbon stored in the wood will be used for metabolic support and released as CO_2. The carbon and nitrogen remaining in the wood is therefore an important marker of microbial activity and the relationship between the two chemical elements, usually expressed by the C/N ratio, is a reliable indicator of the stage of decomposition.



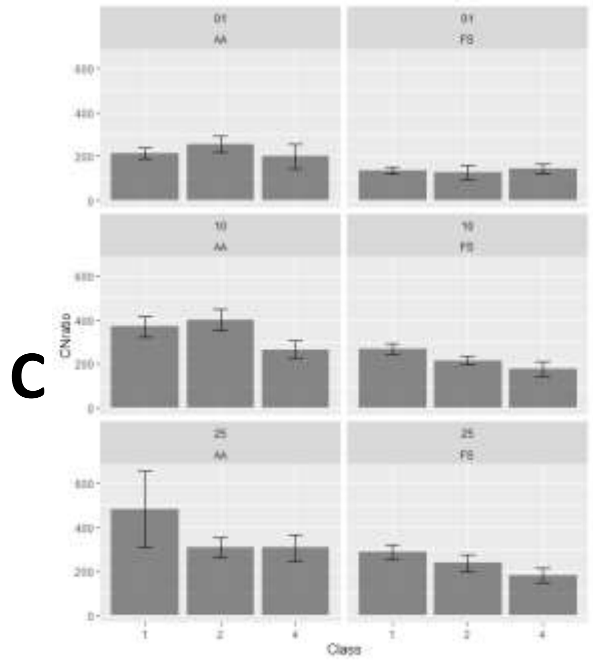


Figure 10.

- ***A.*** *Total nitrogen (g/100g deadwood)*
- ***B.*** *Total carbon (g/100g deadwood)*
- ***C.*** *C/N ratio from deadwood*

All three graphs are plotted separately by species: fir (Abies alba -AA) and beech (Fagus sylvatica -FS), by the three deadwood diameter classes (1, 10 and 25 cm - top to bottom) and by decay classes (1, 2 and 4 - left to right).

In general, beech had a higher amount of nitrogen per gram of dead wood compared to fir, and a lower amount of carbon, respectively (Fig. 10). This is one of the main differences that can be found between angiosperms and gymnosperms, which is also reflected by differences in the C/N ratio, decay rate (see below) and wood density (see above) of the two species. The C/N ratio shows how differently the two species decompose. As time passes, dead beech wood (right) shows a more stable and continuous reduction in C/N ratio, while dead fir wood (left) shows a huge difference between one class and a stabilisation in the following classes. Further results will confirm this difference in decay rate.

Indicators of results: The results presented in this section were presented at two international conferences - oral presentations:
-Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Petritan AM, Petritan IC. Dynamics of Chemical Traits of Downed Dead Wood in a Temperate Old-Growth Forest. INTERNATIONAL SCIENTIFIC CONFERENCE Forest science for people and societal challenges The 90th "Marin Drăcea" INCDS Anniversary.
-Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Petritan AM, Petritan IC. Dynamics of Chemical Traits of Downed Dead Wood in a Temperate Old-Growth Forest. International Scientific Symposium MODERN TRENDS IN THE AGRICULTURAL HIGHER EDUCATION in the Republic of Moldova. P
In addition, the results presented in this section will be included in a scientific article in preparation: Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Petritan AM, Petritan IC. Dynamics of Chemical Traits of Downed Dead Wood in a Temperate Old-Growth Forest. In preparation.

2.4. Decomposition of dead wood in relation to biotic decomposers (fungi, saproxylic insects)

2.4.1. The role of saproxylic insects in the decomposition of dead wood

After the two insect collecting seasons (June-October 2021 and April-September 2022), 44007 beetles were collected, belonging to 213 species in 41 families. Most specimens were caught in Barber traps (40657 specimens), belonging to 66 species in 15 families. In wing traps, 3350 individuals were caught, from 170 species (41 families). Of the total number of beetle families identified in the Șinca forest, 12 are represented by at least 5 species, the Carabidae family being the best represented (30 species) (Figure 11).

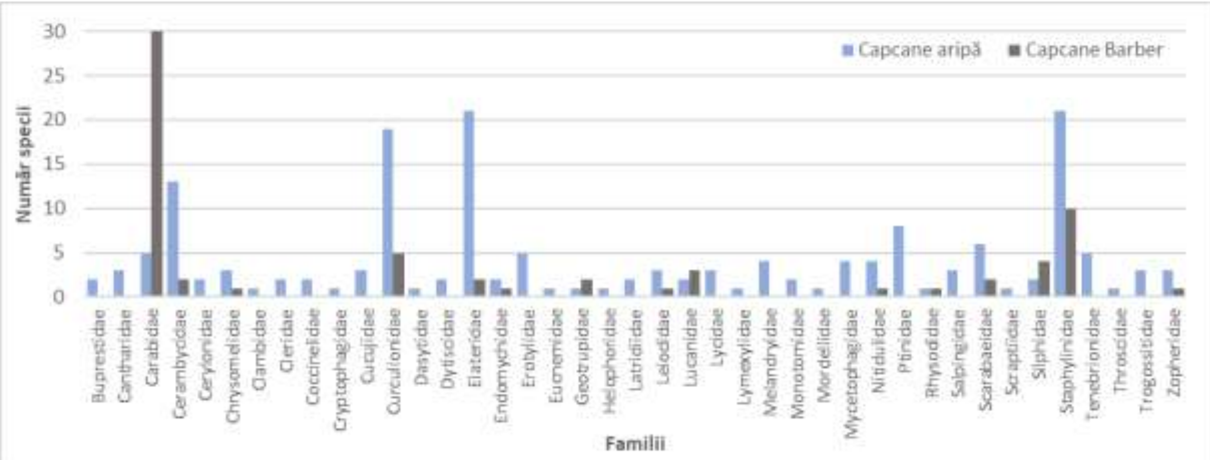


Figura 11. Distribution of beetle species numbers by family and trap type

In wing traps, most beetles (more than 500 individuals/family) belong to the families Elateridae and Curculionidae, while in Barber traps, most individuals belong to the families Silphidae, Carabidae and Geotrupidae (Figure 12).

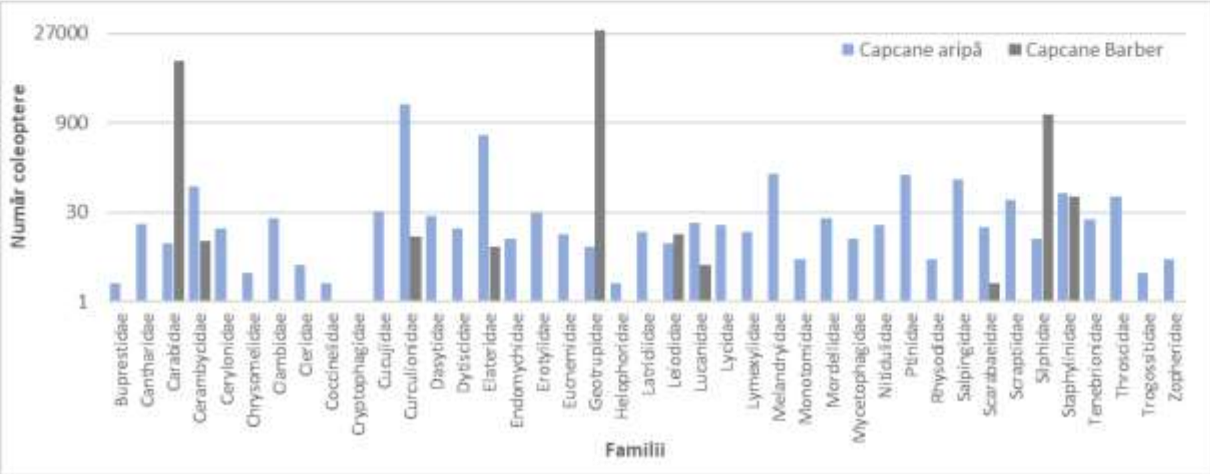


Figure 12. Distribution of numbers of Coleoptera beetles caught by family and trap type.

However, there are also families that were represented by only 1-10 individuals, of very rare species, related to the presence of dead wood in forests, most of which were caught in wing traps. In terms of food preference of the beetles captured, the most frequently encountered species were entomophagous (63 species, 30%), xylophagous (41 species, 19.5%) and myctophagous (33 species, 15%). In terms of percentage of individuals, saprophagous species accounted for 68% of all specimens captured, entomophagous about 18%, while xylophagous species accounted for 2% (Fig. 13).

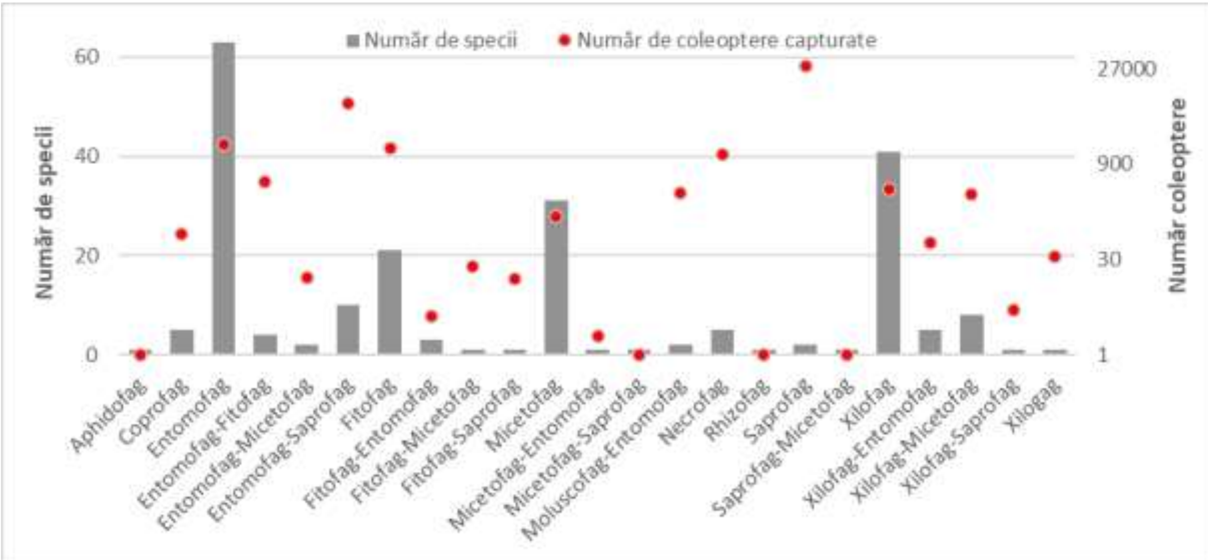


Figure 13. Distribution of the number of species (left axis) and the number of beetles caught (right axis) by foraging preference.

The volume of deadwood in the 15 sample areas installed in the Șinca Forest ranged from 28.6 m3/ha (S3) to 653.9 m3/ha (S1), with two areas where beech deadwood was missing (S12 and S15) and areas where beech deadwood exceeded 100 m3/ha (S4, S1, S10 and S7). As for dead fir wood, it was present in all sample areas, with volumes ranging from 0.6 m3/ha (S5) to 510.2 m3/ha (S1). The distribution of deadwood by species and decay classes also varied from one area to another, with the largest amounts of deadwood of fir being identified in classes C2-C5, while for beech significant amounts were identified in classes C1, C3 and C4 (Fig. 14).

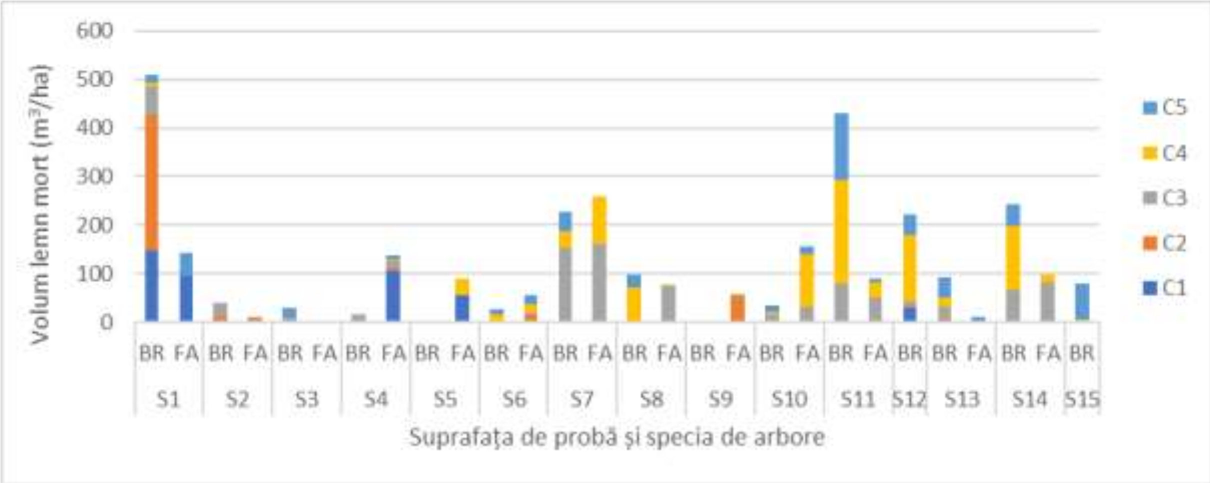


Figure 14. Distribution of dead wood volume by species and decay class.

The relationship between the catches of xylophagous and mycetophagous insects with the volumes of dead wood is close especially in the case of mycetophagous species, the number of coleopterans in this category correlating positively and significantly with the volumes of dead fir wood from degradation classes C1 and C2, but also with the total volume of dead fir wood. However, there is a weak, negative relationship between the number of xylophagous insects caught and the volume of dead fir wood in the case of C1 and C2 decay classes, and with the volume of dead beech wood in the C1 and C5 decay classes, respectively (table 2).

Table 2. Correlation coefficients matrix (Pearson): Number of myctophagous or xylophagous beetles correlated with the volume of dead wood per hectare by species and decay class.

Deadwood species	Fir						beech						Beech+fir					
Decay class	C1	C2	C3	C4	C5	Total	C1	C2	C3	C4	C5	Total	Total	C1	C2	C3	C4	C5
Micetofag	**0,53**	**0,53**	0,29	0,12	0,14	**0,53**	0,17	-0,009	-0,19	-0,16	0,43	-0,04	0,42	0,40	**0,53**	0,04	0,03	0,28
Xilofag	-0,27	-0,30	0,30	0,15	0,30	0,01	-0,04	0,12	0,31	0,18	-0,33	0,22	0,09	-0,18	-0,28	0,32	0,22	0,18
P - values:																		
Micetofag	**0,03**	**0,03**	0,28	0,65	0,61	**0,04**	0,53	0,97	0,48	0,56	0,11	0,88	0,11	0,13	**0,04**	0,87	0,89	0,29
Xilofag	0,32	0,26	0,27	0,57	0,27	0,96	0,87	0,65	0,25	0,51	0,22	0,41	0,73	0,51	0,31	0,23	0,42	0,51
Determination coefficient																		
Micetofag	0,28	0,28	0,08	0,02	0,02	0,28	0,03	0,0001	0,03	0,02	0,18	0,001	0,17	0,16	0,28	0,001	0,001	0,08
Xilofag	0,07	0,09	0,09	0,02	0,09	0,001	0,002	0,015	0,09	0,03	0,11	0,052	0,009	0,03	0,07	0,107	0,049	0,03

The entomological study carried out in the Șinca Secular Forest indicates an impressive diversity of insects, supported by the presence of 74 xylobiont species (xylophagous + myctophagous). These species are directly dependent on dead wood, a fact confirmed by the correlations identified between the number of captures and volume, at least in the case of dead pine wood. The positive correlation (in most cases) of the number of xylobiont insect species catches with the decay classes of dead wood clearly indicates the role of these species in wood decay and their direct dependence on the presence of dead wood in forest ecosystems.

Indicators of results:

All the results presented in this section have been presented at several national and international conferences:

-Dragomir. I.M., Isaia, G., and Duduman, M-L.-Study on the diversity of beetles captured in unbaited traps in Codrul secular Șinca, Brasov County, Romania-Preliminary results". 5 th Edition of the

International Conference "Integrated Management of Environmental Resources", 29 October, Suceava, Romania (http://www.silvic.usv.ro/imer2021/).

-I.M.Dragomir, G-A.Isaia, M-L.Duduman, I-C. Petrițan.- Study on the Diversity of Beetles Captured in Unbaited Flight Intercept Traps in Codrul Secular Șinca, Brasov County, Romania. National Session of Student Scientific Communications on Forestry and Environmental Protection. Edition VII, Brasov, Romania, 3-4 June, 2022.

-Patrașcu, A. - Study on the diversity of beetles captured at Barber's traps in the Șinca Secular Forest. National Session of Student Scientific Communications on Forestry and Environmental Protection. 7th Edition, Brasov, Romania, 3-4 June 2022.

-I.M.Dragomir, G-A.Isaia, M-L.Duduman, I-C. Petrițan, A.Patrașcu. Study on Coleoptera from the Șinca Secular Forest, Brasov, Romania. National Symposium of Entomology. Edition XXXI. 7 May 2022.

-I.M.Dragomir, G-A.Isaia, M-L.Duduman, I-C. Petrițan. Study on the Diversity of Beetles Captured in Unbaited Intercept Traps in Codrul Secular Șinca, Brasov County, Romania. 10th International Symposium Forest and Sustainable Development Brasov, Romania, 14-15 October 2022.

-Isaia, G., Duduman LM, Dragomir, I, Petritan IC. The influence of dead wood on the diversity of ground beetles in the Șinca Old-Growth Forest. SCIENTIFIC CONFERENCE Forest science for people and societal challenges The 90th "Marin Drăcea" INCDS Anniversary, 2-5.10.2023, Bucuresti. Poster.

-Isaia, G., Duduman LM, Dragomir, I, Petritan IC. Deadwood and saproxylic beetles in the Sinca Old-Growth Forest. 6 th Edition of the International Conference "Integrated Management of Environmental Resources". 23-24.11.2023. Suceava. Oral presentation.

-Isaia, G., Stoica, I. Study on the involvement of different species of saproxylic insects in the degradation of beech and fir wood in the Șinca Old-Growth Forest. NATIONAL SESSION OF STUDENT SCIENTIFIC COMMUNICATIONS ON FORESTRY AND ENVIRONMENTAL PROTECTION - 8th Edition, Vatra Dornei, 26-27 May 2023. Oral presentation.

În plus, rezultatele prezentate în această secțiune au fost incluse într-un articol științific ce a fost deja publicat și într-unul care se află în pregătire.

-Isaia, G., Dragomir, MI., Duduman, LM. 2023. Diversity of beetles captured in pitfall traps in Șinca Old GrowthForest, Brașov County, Romania: forest reserve versus managedforest. Forests 14.

-Duduman M.L., Isaia G., Dragomir, I., Petrițan C.: Coleoptera diversity in mature managed and old-growth beech-fir forests from Șinca, Brasov county, Romania. Forest Ecology and Management. În prep.

In addition to the articles and conferences mentioned above, 6 bachelor and master theses have been produced at the Faculty of Silviculture and Forest Engineering, Transivania University Brasov.

2.4.2. The role of xylophagous fungi in the decomposition of dead wood

Silver fir (*Abies alba*, AA) was found to host significantly richer and more diverse fungal communities compared to beech (*Fagus sylvatica*, FS). Fungal richness increased with decomposition stage as well as with wood object diameter, it was particularly high in the last decomposition stage (Fig. 15). A significant interaction between tree species and decomposition stage indicates that the influence of tree species on fungal diversity varies across different decomposition stages, suggesting a more complex relationship between the wood type and its decomposition phase in the structuring of fungal communities.

Fungal communities in deadwood samples were dominated by the members of the phylum Basidiomycota (57.1% in average in *A. alba* and 42.8% in average *in F. sylvatica*) and Ascomycota (19.5% in average in *A. alba* and 32.1% in average in *F. sylvatica*). At the genus level, distinctions in fungal community composition were more pronounced in the initial decomposition stage (Fig. 16), while two later decomposition classes tended to be more similar (Fig. 16). Dominant genera showed specificity not only to the tree species but also to certain decomposition stage and diameter class. Notably, saprotrophic genera *Amylostereum* (Basidiomycota, white-rot), *Mycena* (Basidiomycota) and *Xenopolyscytalum* (Ascomycota) were predominantly found in *A. alba*, while saprotrophic genera *Mycetinis* (Basidiomycota) and *Phlebia* (Basidiomycota, white-rot) were more prevalent in *F. sylvatica*, particularly in larger diameter trees (Fig. 16).

.

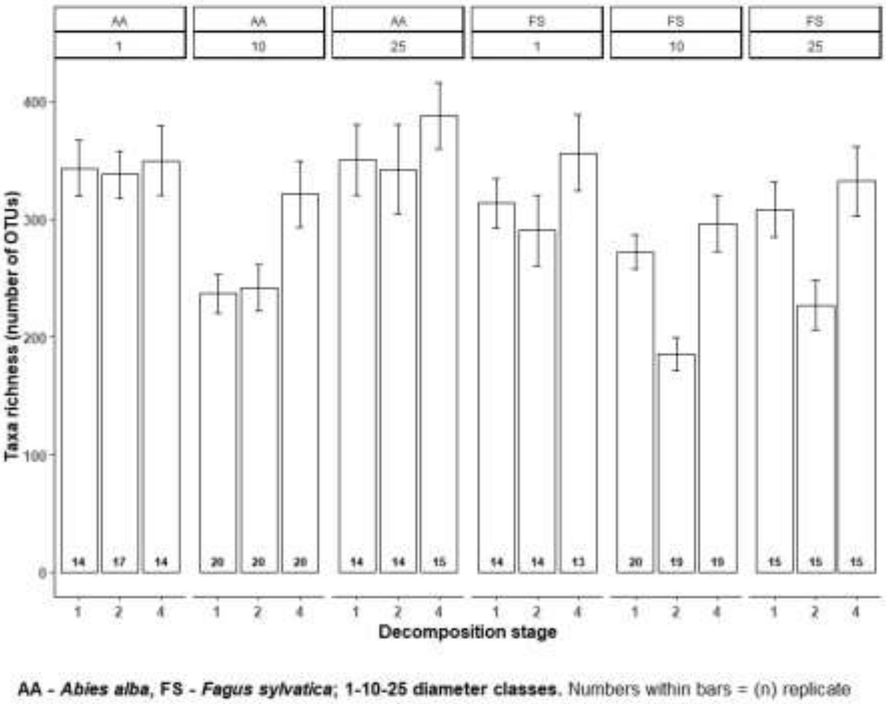


Figure 15. Fungal taxa richness in two tree species: AA (*Abies alba*) and FS (*Fagus sylvatica*).

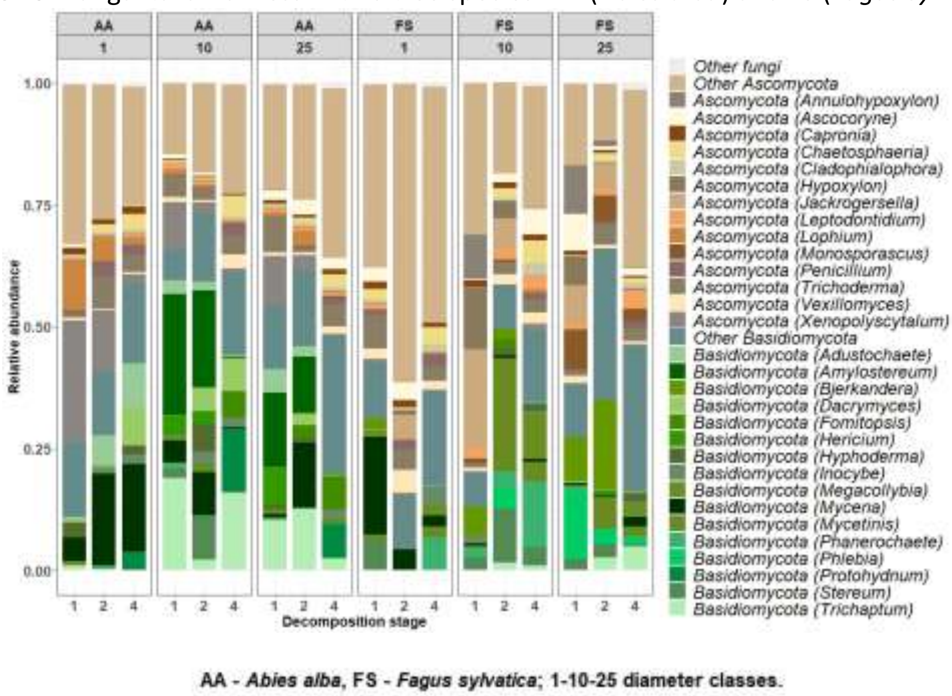


Figure 16. Relative abundance of the 20 most abundant genera in Abies alba and Fagus sylvatica decomposing wood.

The identified genera were mainly saprotrophs, more specifically white-rot fungi, and to a lesser extent brown-rot fungi which were more prevalent in later stages of *A. alba* decoposition (Fig. 17). An interesting pattern emerged with the relative abundance of white-rot fungi in *A. alba*, which decreased with each decomposition class, while in *F. sylvatica*, they peaked at decomposition class 2. Additional taxa, including plant pathogens and ectomycorrhizal fungi, were also observed. These fungi, commonly found in living trees, probaly use deadwood as a nutrient source.

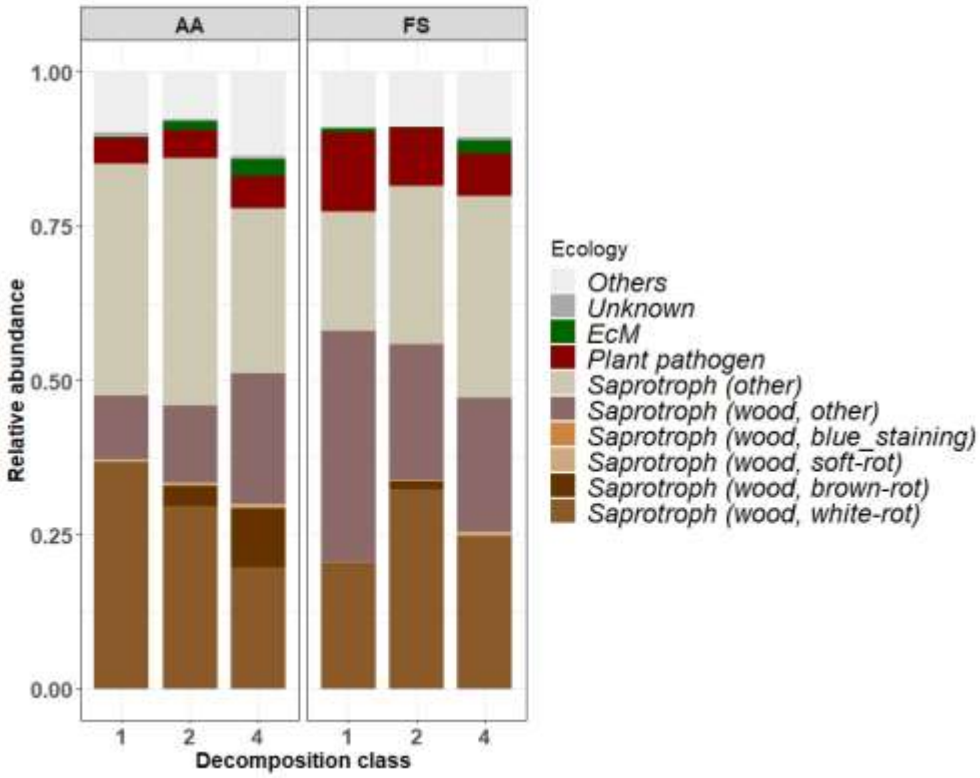


Figura 17. Relative abundance of fungal ecological guilds in decomposing wood of two tree species: AA (*Abies alba*) and FS (*Fagus sylvatica*).

The genus-level community composition showed high diversity and heterogeneity within the fungal communities. Individual sample comparisons from the same decomposition stage for each tree species revealed that dominant genera in certain samples are absent in other samples of the same type. This heterogeneity is likely due to size variability, microenvironmental differences, or stochastic community assembly processes on newly formed deadwood. While some genera persisted across all decomposition stages, others were limited to specific stages, supporting the successional development of fungal communities on deadwood (Lepinay et al., 2021).

While dominant fungal taxa are shared between the two tree species, the diversity and composition of fungal communities are influenced by all three studied factors: tree species, decomposition stages, and deadwood object diameter. This underlines the ecological significance of rare fungal species, which may predominantly be specialists with tree species-specific associations. These findings enrich our understanding of fungal biodiversity and its crucial role in forest decomposition processes.

Indicators of results:

The results from this section will be included in a scientific article:

-Martinovic T.. Baldrian P., Buezo-Bravo J., Medina N, Heres AM, Petritan IC, Ciocîrlan E, Curtu, AL., Petritan AM, Curiel-Yuste J. Fungal diversity in deadwood is depending by tree species, tree size and decay class. In prep.

2.5. The role of the bryophytes inhabiting on dead wood in its decomposition.

CO2 emissions from 10 cm wood samples with and without bryophytes were analysed for each season. The samples separately followed the already known trend, with low, almost non-existent emissions in the autumn and winter months and a peak in summer. For each of the species and degradation classes, bryophytes exerted no significant effect compared to controls. However, there seems to be a trend that dead wood covered with bryophytes has different effects depending on the species, especially during the summer season. The presence of bryophytes appears to decrease CO2 emissions from DWD in fir, while the opposite effect is observed in beech (Fig. 18).

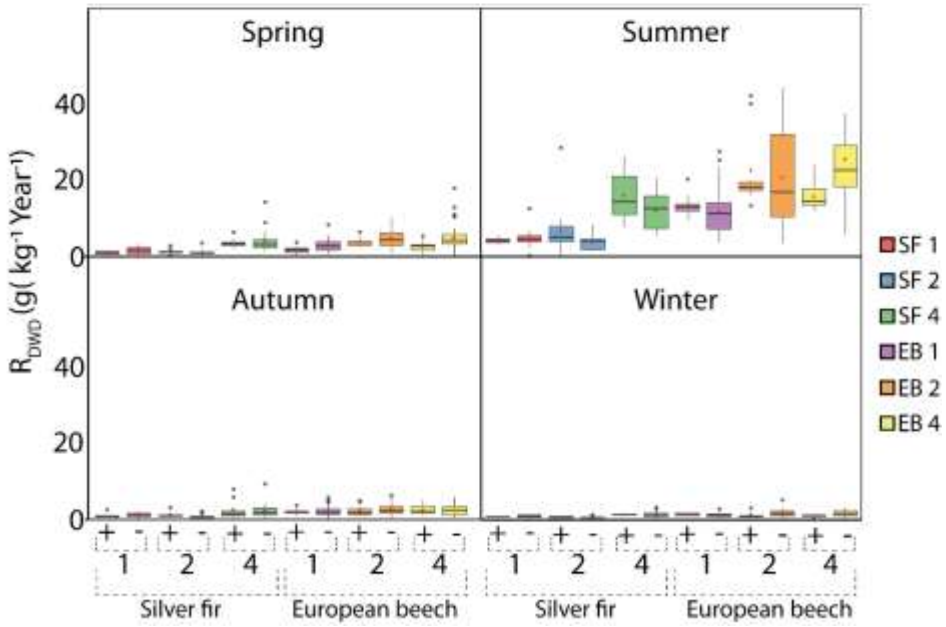


Figura 18. Seasonal variability of deadwood respiration with and without bryophytes.

To further investigate the effects of bryophytes, we used a linear mixed-effects model. The model was previously used and validated for Buezo et al. 2023 (accepted in STOTEN). In this case, the model excluded diameter and incorporated bryophyte status as yes or no, along with associated interactions. Consequently, the following model was finally chosen: RDWD ~ Tair + SWC + Density + Species + DC + bryophyte + Species*SWC + Species*Tair + Species*Density + Species*Class + Species* bryophyte + bryophyte *Tair

When RDWD was estimated for both species in different DCs (1, 2 and 4). The higher respiration rate in the DC holds according to the model, however, no statistically significant differences can be found when the bryophyte-covered RDWD (+) was compared to the control conditions (-). In this case, a promising trend can be observed in DC 4 of both species. DC 4 of silver fir shows an increasing trend in emissions when bryophytes are present, while DC 4 of European beech shows a decreasing trend in their respiration (Fig. 19).

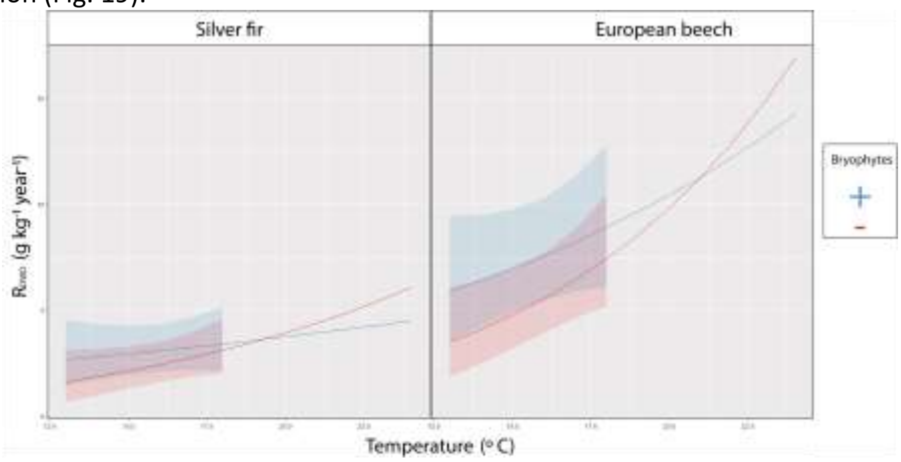
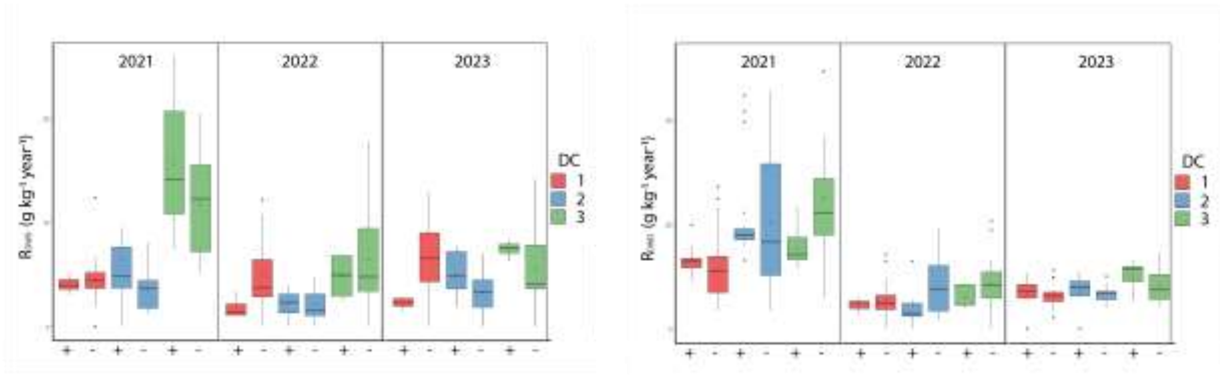


Figure 19. Modelling deadwood respiration as a function of temperature, species and presence/absence of moss. When estimating RDWD as a function of temperature, no differences were found according to the presence of bryophytes.



Abies alba Fagus sylvatica

Figura 20. Deawood respiration over 3 study years, with and without bryophytes.

In general, bryophytes do not seem to play a significant role in RDWD, but a trend can be observed in high DC and, interestingly, this trend varies by species (Fig. 20). Wood decay is a prolonged process, and this is also true for the life cycle of bryophytes. Complex and dynamic interactions may occur during the course of the processes, depending on climatic and intrinsic factors. Bryophytes have the ability to regulate moisture and temperature conditions within the DWD while attracting various scavenger species. Previous research has shown that the RDWDs of different species may respond differently to these environmental factors. Therefore, depending on the origin of the DWD, the impact of bryophytes may either increase or decrease the RDWD. According to existing data, it seems that these effects will only become visible and significant after several years of decomposition in the forest floor.

Indicators of results:

The results from this section will be included in a scientific article:

- Medina N ., Buezo-Bravo J., Heres AM, Petritan IC, Petritan AM, Esteban R., Curiel-Yuste J. Can Bryophites presence alter the decomposition rates of deadwood in a virgin mixed beech -silver fir forest? In prep.

2.6. **Carbon stock dynamics in Sinca forest**

2.6.1. Development of a model for the response of dead wood decay to climate fluctuations

Respiration rates are higher the larger the diameter of the piece of dead wood, which makes sense because the wood acts as a shelter for different species of decomposers (Fig. 21). A larger piece of dead wood allows more diverse and richer decomposer communities to colonise it, which in turn causes higher respiration rates.

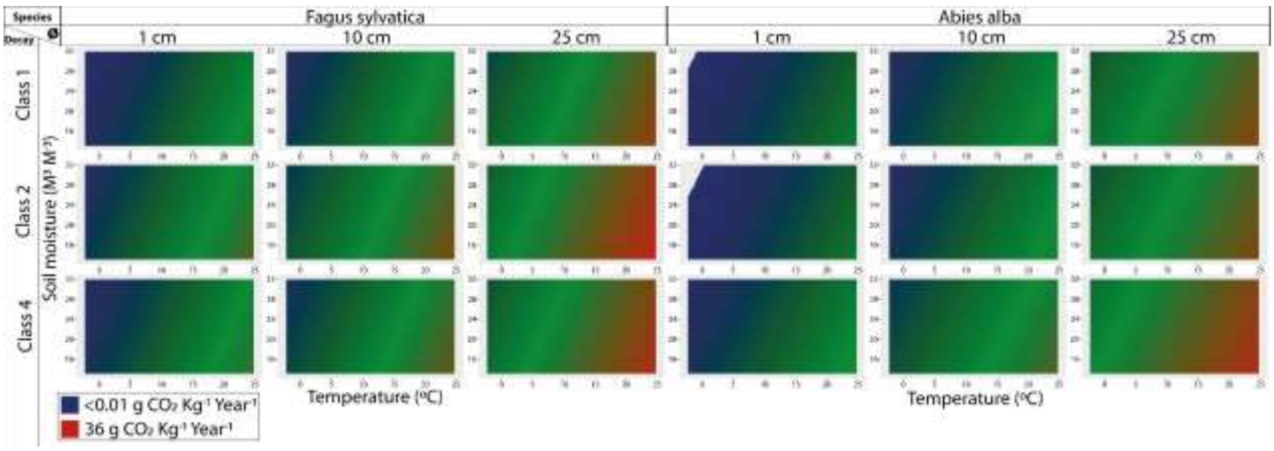


Figure 21. Contour plots of deadwood respiration prediction for beech and fir 1, 10 and 25 cm in diameter and for decay classes 1, 2 and 4.

Also, dead beech wood has a higher respiration rate, which is already known, as angiosperms tend to have higher decay rates, due to the fact that their wood is easier to decompose, while gymnosperm wood has a higher content of lignin and antimicrobial sap, which prevents the early proliferation of microorganisms. This may also explain why dead beech wood in the 2nd decay class has the highest respiration rate, while dead fir wood in the 4th decay class has the highest CO2 emission rate. It is generally accepted that high temperatures and humidities cause a higher respiration rate, but in our study humidity has a negative effect on respiration for both species, and for all diameter and decay classes. This effect is rare compared to results obtained in other ecosystems and may be the result of the already high average humidity of the studied forest, presented and explained above. The high average moisture value in the studied forest may lead to anoxia or leaching of enzymes and nutrients from dead wood, resulting in lower overall respiration. This interaction may also be responsible for the lower CO2 emissions detected in spring.

2.6.2. Deadwood Carbon stock dynamics over last 10 years (2013-2023)

The reinventory of dead wood on the ground in 2023 showed an increase in carbon from 10.3 t/ha in 2013 to 12.8 t/ha in 2023, 10 years later. Although fir in the first decay class (freshly dead wood) was almost absent in both inventory campaigns, beech showed a significant increase in carbon content in the first two decay classes, signalling high mortality among individuals of this species during the last decade (Fig. 22).

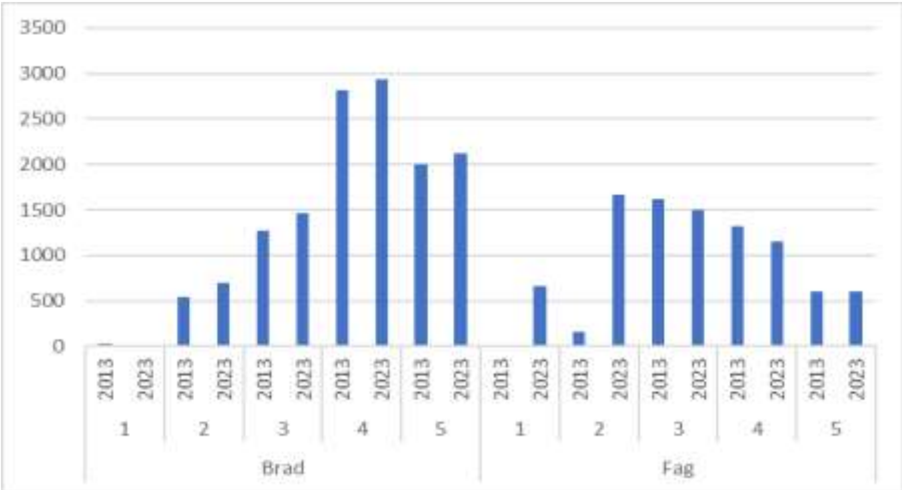


Figura 22. Amount of carbon (kg) stocked in lying dead wood of the virgin forest Șinca in 2013 and 2023.

The related results were partially included in an ACCEPTED scientific article in the prestigious journal Science of the Total Environment (Q1): - Buezo Javier, Medina Nagore, Hereș Ana.-Maria., Petritan Ion Catalin, Cornelissen Hans, Petritan Any Mary, Esteban Raquel, Ilinca elisabeth, Stoian Remus, Curiel Yuste Jorge, 2023. Carbon emissions from downed woody debris in a European temperate virgin forest as a function of species, decay class, diameter and microclimate. Science of The total Environment. ACCEPTED 3/12/2023.

3.**Main results, their estimated impact and dissemination**

The main goal of the DEWOOD project was to quantify the role of deadwood in the carbon cycle of the Sinca Forest ecosystem and thus to gain a better understanding of how the interactive effects of climate (temperature, humidity), wood characteristics (wood density, wood chemical properties), decomposers (xylophagous fungi, saproxylic insects) and organisms inhabiting on deadwood (mosses) influence the decomposition process of deadwood.

Studies dealing with variations in deadwood dry density for different decay classes in European temperate virgin forests are very rare, mainly because of the scarcity of such forests. For this reason, the

DeWood project is among the few such investigations carried out at European level, mainly due to the fact that Romania still preserves a significant area of virgin forests.

Our study suggests that a local estimation of deadwood density by species and decay classes is necessary for a more accurate estimation of deadwood necromass, as volume may not be the best variable to express carbon stock unless a satisfactory conversion is made using density as a conversion factor. Our project showed that deadwood density decreases during the decay process for both studied species, with a more pronounced reduction for beech. The dry density of beech was significantly higher than that of fir in the early decay classes for both deadwood types (still standing and lying deadwood), while for deadwood in the most advanced decay classes there were no significant differences between species.

Our study can also help quantify C stocks in other virgin forests and for other species. Furthermore, our study could serve as a methodological basis for specific research to find out the potential influence of different forest management practices on the dry density of deadwood.

Using more precise data on how wood density varies for different species and degrees of decay, coupled with studies of C emissions associated with deadwood decay and the environmental factors that control it (e.g., climate, biodiversity), will help us understand the role of deadwood in the carbon cycle in forest ecosystems.

The most significant result obtained in the DEWood project and published in Science of the Total Environment is the one related to explaining the variability of the CO2 flux released from deadwood by climatic factors (temperature and humidity), but also by wood intrinsic factors (species, decay stage, size). This result provides further insight into the critical function of deadwood in determining the carbon uptake capacity of virgin forests. These factors define the degradation potential of deadwood and decay rates, which subsequently influence the carbon cycle of forest ecosystems. Thus, the study provides new insights into deadwood decay processes through a distinct and varied model of deadwood respiration for two dominant species (beech and fir) found in temperate forests, given the well-established relationship between wood traits, climate and deadwood CO2 emissions. CO2 emission from deadwood shows a high sensitivity to seasonal and spatial fluctuations in temperature and soil water content. Spatial variability of soil water content played a key role in influencing the spatial variability of deadwood respiration, outweighing the impact of other factors such as species or decay class. Our study also showed that air temperature and soil water content can serve as effective proxies for deadwood temperature and water content. In addition, we showed that deadwood respiration can be partially explained by intrinsic physical or chemical differences between the 2 species. However, these species-specific differences are gradually reduced as the deadwood decays. Although, due to the intrinsic physico-chemical characteristics of dead wood, beech showed higher respiration rates in the early stages of decay, respiration rates of dead wood tend to converge with the respiration rates of fir for advanced stages of decay. The size of the dead wood (diameter) had a significant impact on the decay rate, with larger diameters of fir deadwood pieces leading to higher C emissions per gram than smaller diameter dead wood pieces. In conclusion, even though virgin forests are considered substandard C sinks due to low net productivity and high microbial community adaptation and diversity, which in turn cause a high annual deadwood respiration rate, we can think of this virgin forest as a low annual emitter of CO2.

DeWooD project can be considered as a starting point for the consolidation of a multidisciplinary research group in functional ecology of virgin forests at Transilvania University of Brasov. DeWood benefited from the participation of an international team of several high-level scientists from renowned European research institutions, leaders in their research fields: plant physiology, bryophytes, genetics, entomology, forestry or soil sciences (Jorge Curiel Yuste -BC3 Bilbao, Esteban Raquel - University of Bilbao, Hans Cornelissen - University of Amsterdam, Nagore Medina - University of Madrid), joined by experts from the University of Brasov, Stefan cel Mare University and INCDS Marin Dracea. This research group has established a long-term collaboration, which is a milestone towards an EU-funded (e.g. Horizon Europe) interdisciplinary research project on climate change. Through the joint research

activities carried out in the framework of the DeWood project, an even stronger coagulation of the research team has been achieved by running its own internal mechanisms, thus contributing fully to an increased capacity to successfully apply for European and national funding instruments by the project team. Some of the team members are already involved in a Horizon project (Holisoils, 2021-2025), with another PCE research project proposal submitted in the 2023 call launched by UEFISCDI and currently under evaluation. The involvement of MSc students (2), as well as a PhD student whose thesis was developed entirely on data obtained in the project, demonstrates the engagement of junior researchers in high-level research activities, being able to benefit from the expertise of senior members of the research team, training, strengthening and expanding their scientific knowledge and skills. The DeWood project also benefited from the contribution of a student from the University of Nancy in France, who completed a 6-month internship in our project. Innovative, multi- and trans-disciplinary approaches have provided accurate estimates of carbon stocks in temperate virgin forests, as well as predictions of wood decay rates and forest ecosystem vulnerability to future climate change. This novelty in the methodological approach of the present project has ensured the high international visibility of the results obtained in DeWooD, through their publication in high-impact journals and their dissemination at international and national conferences. Furthermore, although DeWooD has a clear focus on ecological research, the results found are relevant for both forest managers and policy makers as they have produced some of the first accurate quantifications of the role of deadwood on the C budgets of representative European temperate virgin forests, which can further contribute to the definition of practical guidelines for the management of forest ecosystems to enhance C sequestration capacity and climate change mitigation. Future LULUCF reports for our country have available the results found in the DeWood project on deadwood density for beech and fir for each of the 5 decay classes, both for still standing and lying deadwood, which will lead to a high accuracy in estimating the carbon stored in deadwood in forest ecosystems.
All information about the DEWOOD project, its implementation and results, can also be found on the following website: https://silvic.unitbv.ro/ro/cercetare/579-proiect-dewood.html

DISsemination

4.1. ISI papers

4.1.1. Duduman, M.-L.; Beránková, K.; Jakuš, R.; Hradecký, J.; Jirošová, A. Efficiency and Sustainability of Ips duplicatus (Coleoptera: Curculionidae) Pheromone Dispensers with Different Designs. Forests 2022, 13, 511. https://doi.org/10.3390/f13040511

4.1.2. Heres, AM., Polanco-Martinez, J., Petritan, IC., Petritan, AM., Curiel-Yuste, J. 2022. The stationary and non-stationary character of the silver fir, black pine and Scots pine tree-growth-climate relationships. Agricultural and Forest Meteorology 325.

4.1.3. Edurne Martinez del Castillo, Christian S Zang, Allan Buras, ..., Petritan, IC..... 2022. Climate-change-driven growth decline of European beech forests. Communications Biology 5, 1-9.

4.1.4. Isabel Dorado-Liñán, Blanca Ayarzagüena, Flurin Babst, Guobao Xu, ,…, Petritan, IC.,...2022. Jet stream position explains regional anomalies in European beech forest productivity and tree growth. Nature Communications, 13, 1-10.

4.1.5. Petritan AM, Petritan IC, Hevia A, Walentowski H, Bouriaud O, Sánchez-Salguero R. 2021. Climate warming predispose sessile oak forests to drought-induced tree mortality regardless of management legacies. Forest Ecology and Management 491, 119097, IF=3.558

4.1.6. Ion Catalin Petritan, Victor-Vasile Mihăilă, Jorge Curiel Yuste, Olivier Bouriaud, Any Mary Petritan, 2023. Deadwood density, C stocks and their controlling factors in a beech-silver fir mixed virgin European forest, Forest Ecology and Management, Volume 539, 2023, 121007.

4.1.7. Isaia, G., Dragomir, I., Duduman, LM. 2023. Diversity of beetles captured in pitfall traps in Șinca Old GrowthForest, Brașov County, Romania: forest reserve versus managedforest. Forests 14.

4.1.8. Buezo Javier, Medina Nagore, Hereş Ana.-Maria, Petritan Ion Catalin, Cornelissen Hans, Petritan Any Mary, Esteban Raquel, Ilinca elisabeth, Stoian Remus, Curiel Yuste Jorge, 2023.

Downed woody debris carbon emissions in a European temperate virgin forest as driven by species, decay classes, diameter and microclimate. Science of The total Environment. ACCEPTED 3.12.2023.

4.2. Conferences

4.2.1. Duduman M.L., Jakus, R., Hradecky, J., Jirosova, A., 2021. Development of dispenser with activity for offspring generations of invasive bark beetle Ips duplicatus; response to synthetic pheromone dispensers with the volatiles releases by wick versus polyethylene foil. Joint meeting of IUFRO Working Groups 7.03.12 - Alien Invasive Species and International Trade, 7.03.07 - Population Dynamics of Forest Insects, 8.02.04 - Ecology of Alien Invasives Biological Invasions in Forests: Trade, Ecology & Management, 20-24 September, Prague (https://iufro.czu.cz/en).

4.2.2. Duduman M.L., Jakus, R., Hradecky, J., Jirosova, A., 2021. Comparison of the synthetic pheromone lures for Ips duplicatus, depending on the used solution for the release of the volatile mixtures. 5 th Edition of the International Conference "Integrated Management of Environmental Resources", 29 October, Suceava, Romania (http://www.silvic.usv.ro/imer2021/).

4.2.3. Dragomir. I.M., Isaia, G., et Duduman, M-L.-Study on the diversity of beetles captured in unbaited traps in Codrul secular Șinca, Brașov County, Romania-Preliminary results". 5 th Edition of the International Conference "Integrated Management of Environmental Resources", 29 October, Suceava, Romania (http://www.silvic.usv.ro/imer2021/).

4.2.4. Petritan IC, Braga C, Mihaila V, Petritan AM. Species-specific deadwood density and its controlling factors in a virgin European beech-silver fir mixed forest in the Southern Carpathians. 5 th Edition of the International Conference "Integrated Management of Environmental Resources", 29 October, Suceava, Romania (http://www.silvic.usv.ro/imer2021/).

4.2.5. Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Stoian Remus, Ilinca, E., Petritan AM, Petritan IC. DOWNED DEAD WOOD IN TEMPERATE OLD-GROWTH FORESTS: NOT JUST CARBON LEFTOVERS. INTECOL 2022: Frontiers in ecology: science and society, Geneva, Evetia, 28.08.2022-2.09.2022.

4.2.6. Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Stoian Remus, Ilinca, E., Petritan AM, Petritan IC. Downed Dead Wood. A Really Complex Carbon Stock. 10TH INTERNATIONAL SYMPOSIUM FOREST AND SUSTAINABLE DEVELOPMENT.

4.2.7. I.M.Dragomir, G-A.Isaia, M-L.Duduman, I-C. Petrițan.- Study on the Diversity of Beetles Captured in Unbaited Flight Intercept Traps in Codrul Secular Șinca, Brașov County, Romania. National Session of Student Scientific Communications on Forestry and Environmental Protection. Ediția VII, Brașov, România, 3-4 Iunie, 2022.

4.2.8. Patrașcu, A. Study on the Coleoptera diversity collected in Sinca virgin forest. National Session of Student Scientific Communications on Forestry and Environmental Protection. Ediția a VII-a, Brașov, România, 3-4 Iunie 2022.

4.2.9. I.M.Dragomir, G-A.Isaia, M-L.Duduman, I-C. Petrițan., A.Patrașcu. Study on Coleoptera insects in Sinca virgin forests, Brașov, România. Simpozionul Național de Entomologie. 7th of May 2022.

4.2.10. I.M.Dragomir, G-A.Isaia, M-L.Duduman, I-C. Petrițan. Study on the Diversity of Beetles Captured in Unbaited Intercept Traps in Codrul Secular Șinca, Brașov County, Romania. 10th International Symposium Forest and Sustainable Development Brașov, Romania, 14-15 October 2022.

4.2.11. Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Petritan AM, Petritan IC. Dynamics of Chemical Traits of Downed Dead Wood in a Temperate Old-Growth Forest. INTERNATIONAL SCIENTIFIC CONFERENCE Forest science for people and societal challenges The 90th "Marin Drăcea" INCDS Anniversary, 2-5.10.2023, Bucharest. Poster.

4.2.12. Isaia, G., Duduman LM, Dragomir, I, Petritan IC. The influence of dead wood on the diversity of ground beetles in the Șinca Old-Growth Forest. SCIENTIFIC CONFERENCE Forest science for people and societal challenges The 90th "Marin Drăcea" INCDS Anniversary, 2-5.10.2023, Bucharest. Poster.

4.2.13. Buezo-Bravo, Javier, Medina, NG., Curiel-Yuste, J., Heres, AM., Petritan AM, Petritan IC. Dynamics of Chemical Traits of Downed Dead Wood in a Temperate Old-Growth Forest. International Scientific Symposium MODERN TRENDS IN THE AGRICULTURAL HIGHER EDUCATION in the Republic of Moldova. Poster.

4.2.14. Petritan IC. Deadwood carbon dynamics over 10-years in a temperate virgin forest. 6 th Edition of the International Conference "Integrated Management of Environmental Resources". 23-24.11.2023. Suceava. Oral presentation.

4.2.15. Isaia, G., Duduman LM, Dragomir, I, Petritan IC. Deadwood and saproxylic beetles in the Sinca Old-Growth Forest. 6 th Edition of the International Conference "Integrated Management of Environmental Resources". 23-24.11.2023. Suceava. Oral presentation.

4.2.16. Isaia, G., Stoica, I. Study regarding implication of different saproxylic insects into deadwood decomposition of beech and fir in Sinca virgin forest. National Session of Student Scientific Communications on Forestry and Environmental Protection - Ediția a VIII-a, Vatra Dornei, 26-27 mai 2023. Oral presentation.

4.2.17. Isaia, G., Portasa, G, Influence of deadwood on Carabidae insects diversity from Sinca virgin forest. National Session of Student Scientific Communications on Forestry and Environmental Protection - Ediția a VIII-a, Vatra Dornei, 26-27 mai 2023. Oral presentation.

4.3. PhD, Bachelor, and Master theses

4.3.1. Ghinea Paul. Dewood decomposition of silver fir (Abies alba) and growth patterns in the last years of life. Master programm: Multiple purpose forestry. Multiple purpose forestry. Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov. Iunie 2021

4.3.2. Dragomir Ionuț-Marian. Study on the diversity of beetles captured in unbaited intercept traps in Codrul Secular Șinca, Brașov County, Romania. Master program: Multiple purpose forestry. Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov. June 2022.

4.3.3. Patrașcu Alexandru Study on the Coleoptera diversity collected in Sinca virgin forest. Bachelor programm: Silviculture. June 2022.

4.3.4. Stoian Remus. Influence of abiotic factors on deadwood decomposition process in a virgin mixed beech-fir forest. Master thesis. June 2022. Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov.

4.3.5. Chelemen George Marian. Influența lemnului mort asupra diversității coleopterelor capturate la capcane aripă instalate în codrul secular Șinca. Bachelor thesis. June 2023. Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov.

4.3.6. Portasa George. Influence of deadwood on Carabidae insects diversity from Sinca virgin forest. Bachelor thesis. June 2023. Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov.

4.3.7. Stoica Ionut Georgian. Study regarding implication of different saproxylic insects into deadwood decomposition of beech and fir in Sinca virgin forest. Master thesis. June 2023. Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov.

4.3.8. I.Dragomir. Impact of forest management on beetle biodiversity in beech-fir mixtures. PhD thesis. Ongoing.

The data and results obtained during the 3 years of the DEWood project were published in 8 ISI articles, were disseminated in the form of 17 oral and poster presentations at international and national conferences, but also constituted the material for 7 bachelor and master theses and a PhD thesis defended at the Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov. Another 4 articles are in progress and will be submitted for publication in the near future.

Brașov, 06/12/2023

Director proiect,
Ion Cătălin Petrițan

Petritan