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CARBON STORAGE IN FOREST STANDS ON DEGRADED LANDS

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Abstract

In the context of expanding environmental degradation processes, degraded lands represent potential areas for forest plantations that help reduce soil erosion, increase carbon storage and biodiversity. Research conducted in 2025 aimed to determine the carbon stock (in soil, litter, forest biomass and deadwood) and the annual carbon sequestration capacity in forest stands established on degraded lands in the Curvature Subcarpathians region. The results indicate that soil and living biomass are essential components for storing organic carbon. Soil carbon stock is relatively stable (between 70 and 120 t/ha), while carbon in living biomass shows greater variation (between 45.78 and 258.24 t/ha). The distribution of carbon in soil, litter, forest biomass and deadwood reflects the influence of environmental conditions and stand structure on carbon storage dynamics. The results demonstrate that forest plantations on degraded lands represent an effective tool for carbon storage and for mitigating the effects of climate change, capable of providing significant ecosystem and socio-economic services.

Key words*: carbon storage, degraded lands, forest biomass, stands.*

INTRODUCTION

Beyond their traditional production and protective roles, forests play an important part in carbon storage and mitigation of greenhouse gas (GHG) concentrations, functions that have gained particular importance in Romania following its accession to the Kyoto Protocol (1997). In recent years, the role of forests in carbon storage and the mitigation of greenhouse gas emissions (GHG) has emerged as a global priority, as emphasized in the EU Green Book on forest protection and information (European Commission, 2010). The report highlights that European forests have the capacity to act as efficient absorbers for gases such as CO_2, NH_3 and NO_x but this is not yet fully understood.. Given that substantial reductions in GHG emissions are difficult to achieve in the short term, carbon sequestration is increasingly considered as a viable long-term solution.

Forests represent the most important terrestrial ecosystem in the carbon (C) cycle and also play a key role in carbon storage (Schulze et al., 2010; Konôpka et al., 2025). Phytomass, or tree biomass, by definition, refers to the organic mass of trees (Koch, 2010), and carbon storage in tree biomass has become an effective measure for mitigating climate change (Somogyi et al., 2007). More than 80% of aboveground biomass is stored in forest ecosystems and also accounts for over 70% of the carbon present in soils (Jandl et al., 2007).

Therefore, in addition to their traditional production and protection roles, forest ecosystems contribute significantly to carbon sequestration by functioning as important carbon pools.

In the context of ongoing climate change conditions and increasing environmental degradation processes, degraded lands represent potential sites for establishing tree plantations (Constandache et al., 2023). Afforesting degraded lands can provide multiple benefits, such as biodiversity, strengthening ecosystem stability, preventing soil erosion, offering recreational opportunities, and enhancing carbon storage (Maestre & Cortina, 2004; Semwal et al., 2013; Moscatelli et al., 2017; Oprică et al., 2022). Soil organic carbon dynamics have been widely investigated across different forest ecosystems, with particular attention given to pines species (*Pinus* spp.) due to their significant ecological and economic importance (Dincă et al., 2015; Torres et al., 2021).

Pine species have often been studied both in monocultures and in mixture with other forest

species, offering valuable information on their carbon sequestration potential (Tudor et al., 2025). Studies comparing pure pine stands with mixed-species forests suggest that, while pine stands accumulate substantial amounts of carbon in their aboveground biomass, mixed forests may provide a more even distribution of carbon between belowground and aboveground components (Rodríguez de Prado et al., 2023).

Soil organic carbon is a fundamental component of forest ecosystems (Nadelhoffer, 2004; Batjes, 2014). On a global scale, soils store almost three times more carbon than the atmosphere and about 4.5 times more than the total terrestrial carbon pool in the biosphere (Lajtha et al., 2014), surpassing the combined carbon found in both the atmosphere and vegetation (Jobbágy et al., 2000). Forest soils have significant role in the global carbon cycle, containing roughly 1.5 times more carbon than the biomass of isolated standing trees (Baritz et al., 2010).

Soil carbon also representing a critical factor in the balance of greenhouse gases (GHGs), contributing to the mitigation of rising GHG emissions (Janssens et al., 2003; Jandl et al., 2007; Baritz et al., 2010). However, measuring soil organic carbon stocks over time and space is challenging due to specific local conditions and the differing results obtained in various studies, which makes harmonization of data being difficult for the development of predictive models (Grüneberg et al., 2014; Dincă et al., 2015).

Data from the National Greenhouse Gas Inventory, compiled under the United Nations Framework Convention on Climate Change (UNFCCC), indicate that Romanian forest lands absorbed an average of around 25 million tons of CO_2 equivalent over the last 10 years (2011-2020), accounting about 25% of the total national greenhouse gas emissions (Dragostin et al., 2022).

Given the importance of quantifying carbon dioxide fluxes from forests for greenhouse gas (GHG) inventory reporting (Braga, 2018), and considering that this represents a novel research direction in Romania, it was deemed appropriate to carry out a study focusing on degraded lands as well. The results obtained can provide an initial basis for evaluating the annual carbon dioxide pools from plantations established on degraded lands within the country.

The aim of the research was to quantify the total carbon stored in the soil, litter, aboveground biomass, and deadwood of forest plantations established on degraded lands in the Curvature Subcarpathians region.

MATERIALS AND METHODS

The research was carried out in permanent experimental plots (PEP), located in representative situations of stands on degraded lands in three experimental perimeters (EP) in the Subcarpathian Curvature area (Figure 1): Caciu-Bârseşti (CB), Pârâul Sărat-Valea Sării (PS) located from a phytoclimatic point of view in the hilly storey of sessile oak, beech and sessile oak-beech codified as FD_3 and Livada-Râmnicu Sărat (LV), located in internal forest-steppe site codified as Ssd (Table 1).

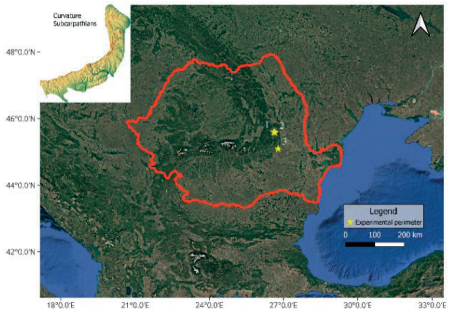


Figure 1. Location of the study (marked on the map with yellow stars: 1 - EP Caciu-Bârseşti; 2 - EP Pârâul Sărat-Valea Sării; 3 - EP Livada-Râmnicu Sărat)

The researches consisted in observations, measurements, field data collection, processing and interpretation regarding the determination of carbon stored in the soil, litter, living biomass and deadwood.

In the laboratory, soil samples were collected from soil profiles at depths of 0-10 cm, 11-20 cm, and 21-40 cm to determine organic carbon (%) and bulk density (BD, g/cm³). Litter samples consisting of dried leaves, fruits, plant residues, and twigs, were collected from each research plot over an area of 1 m² to determine organic carbon content (C%) and mass (g/m²).

To determine the amount of carbon (C) accumulated at different soil depths, the following formula was used:

$$C = SOC\ \% * BD * d * CFst$$

where: C - soil carbon stock (kg/m² × 10 = t/ha); SOC % - soil organic carbon concentration determined in the laboratory (%); BD - bulk density of the soil (kg/dm³);
d - depth or thickness of the analyzed horizon (cm); CFst - correction factor for skeletal fraction (= 1).

Table 1. General information on the studied permanent experimental plots (PEP)

Name/Location		Phyto-climatic zone	Stand composition	Age (years)	Degradation form
EP	PEP				
Caciu-Bârsești (CB)	PEP8	FD_3	93Pi 7Pi.n	50	E3
	PEP11	FD_3	33Pi 67Pi.n	51	E3
Pârâul Sărat-Valea Sării (PS)	PEP1	FD_3	44Pi 48Pi.n 8 Dt	68	E3
	PEP9	FD_3	8Pi 92 Pi.n	70	E1
Livada-Râmnicu Sărat (LV)	PEP10	Ssd	52 Pi 48 Dt	71	E1
	PEP12	Ssd	95 Pi.n 5 Dt	73	E1
	PEP13	Ssd	100 St.r	73	E1
	PEP14	Ssd	81 St.b 19 Dt	73	E1

Legend: PEP - Permanent Experimental Plot; EP - Experimental Perimeter; FD_3 - the hilly storey of sessile oak, beech and sessile oak-beech; Ssd - internal forest-steppe site; Pi - Scots Pine; Pi.n - Black pine; Dt - diverse hardwood species; St.r - red oak; St.b - greyish oak; E3 - very strong erosion; E1 - moderate erosion.

The organic carbon in litter (OC_L) stock was calculated as the product of litter mass and the carbon percentage (C %) determined in the laboratory.
Data collection for trees and deadwood to determine the organic carbon stored in wood, involved inventories of tree numbers by species, dendrometric characteristics of trees (DBH-diameter at the breast height, H- height) or deadwood (DBH, length and so on) and sampling of wood samples using a "Pressler" increment borer to determine wood density.
The organic carbon stored in wood (CW) was calculated by first estimating tree volume (m³) using allometric equations. To convert tree volume (m³) into biomass (t), species-specific wood density (WD) values were used, determined gravimetrically (Chave et al., 2006) based on analyses of wood samples extracted from trees of each species. The carbon stock (C, t/ha) corresponding to aboveground biomass (AGB) and deadwood biomass (DWB) was calculated according to standard recommendations (IPCC, 2003; Penman et al., 2003; Eggleston, 2006; IPCC, 2006). Depending on the species, the carbon content in wood ranges between 46% and 59% of the tree biomass (Thomas & Malczewski, 2007). The carbon content in wood (CW), whether living or dead (C_DW), was assumed to be 50% of the biomass (Innes, 2004) and was obtained by multiplying the total biomass by 0.5.

RESULTS AND DISCUSSIONS

Soil carbon stock

Based on the research data obtained (Table 2), it was found that the highest soil organic carbon stocks at a depth of 0-40 (20) cm ranged between 99.57-120 t/ha. In some cases, particularly on degraded lands, the total soil depth was only 20 cm. These values were recorded in Scots pine plantations mixed with black pine, aged 50-51 years, on very strongly eroded lands. The lowest values (70.96-71.76 t/ha) were recorded in deciduous plantations or in mixed pine (Scots and black pine) and deciduous stands, aged 71-73 years, on moderately to strongly eroded lands.

Table 2. Soil organic carbon stock, by depth intervals and total values

PEP-EP	Soil depth	Bulk density	Soil organic carbon	
	Cm	g/cm³	%	(t/ha)
PEP8-CB	0-10 cm	1.058	3.74	39.54
	10-20 cm	1.406	2.31	32.48
	20-40 cm	1.627	1.48	47.98
	Total		**7.52**	**120.00**
PEP11-CB	0-10 cm	1.121	4.41	49.39
	10-20 cm	1.483	1.25	18.47
	20-40 cm	1.613	0.98	31.72
	Total		**6.64**	**99.57**
PEP1-PS	0-10 cm	1.224	2.39	29.27
	10-20 cm	1.308	1.26	16.50
	20-40 cm	1.520	0.89	26.89
	Total		**4.54**	**72.67**
PEP9-PS	0-10 cm	1.251	3.13	39.15
	10-20 cm	1.501	1.43	21.39
	20-40 cm	1.485	0.93	27.73
	Total		**5.49**	**88.27**
PEP10-LV	0-10 cm	1.029	4.01	41.30
	10-20 cm	1.266	2.39	30.28
	Total		**6.41**	**71.58**
PEP12-LV	0-10 cm	1.224	3.33	40.71
	10-20 cm	1.185	2.62	31.05
	Total		**5.95**	**71.76**
PEP13-LV	0-10 cm	1.324	1.98	26.26
	10-20 cm	1.511	1.13	17.08
	20-40 cm	1.469	1.10	32.26
	Total		**4.21**	**75.60**
PEP14-LV	0-10 cm	1.065	2.16	23.04
	10-20 cm	1.109	1.36	15.09
	20-40 cm	1.237	1.33	32.84
	Total		**4.85**	**70.96**

In the soil profile, the highest carbon content values were generally recorded in the upper 10 cm (Figure 2).

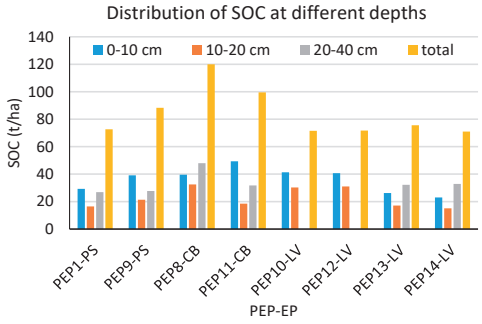


Figure 2. Distribution of soil organic carbon (SOC) stock

In the first 10 cm of the soil profile, carbon stock values ranged between 23.04 t/ha and 49.39 t/ha, whereas in the 10-20 cm layer they ranged from 15.09 t/ha to 32.48 t/ha. The minimum and maximum values by soil horizon were recorded in the same plots/stands as for total carbon stock. In a previous study conducted on eutricambosol soils (Dincă et al., 2012), the following organic carbon stocks were determined by geometric horizons: 42 t/ha (0-10 cm), 26 t/ha (10-20 cm), 33 t/ha (20-40 cm), and 40 t/ha (>40 cm), giving a total of 140 t/ha. For soils in Germany of the cambisol class, Grüneberg et al. (2014) compared periodic values of carbon stock in the mineral layer at a depth of 30 cm, finding 68.3 ± 2.2 t/ha, which is lower than the average value determined in Romania. Batjes (2002) reported that cambisol soils in central and southern Europe have a carbon stock of 69 t/ha for the first 30 cm and 118 t/ha at 100 cm depth. The same author (Batjes, 2014) determined a global carbon stock of 88 t/ha in eutricambosol soils for the first 100 cm.

Compared with values reported by the aforementioned authors, the average carbon stock in soils on degraded lands in the studied plots was 36 t/ha (0-10 cm), 23 t/ha (10-20 cm), and 33 t/ha (20-40 cm), which is lower (in the first 20 cm) or similar (20-40 cm) to those determined for eutricambosols.

According to the guidelines elaborated by ICPA (Dumitru et al., 2011), in the soils analyzed on degraded lands, carbon content in the upper 20 cm is considered good to very good (3.65-6.41%) in all pine-containing stands, and medium (3.11-3.52%) in deciduous stands (oaks). The total carbon stock (throughout the entire soil depth) is generally classified as medium in most of the analyzed cases.

Litter carbon stock

Litter represents the organic matter on the soil surface, which, due to its characteristics, is an ecologically important component.

The determination of the total litter quantity, such as the organic carbon stock in litter for the analyzed research plots, revealed differences between plots depending on stand composition, age, and the degree of land degradation. According to the summary data (Table 3), the highest litter carbon stock (OC_L) values (12.24-13.04 t/ha) were recorded in pine stands (Scots pine or black pine) mixed with deciduous species, aged 71-73 years, on moderately to strongly eroded lands. Lower values were found in deciduous stands (4.99-7.9 t/ha) and in pine stands on very strongly to excessively eroded lands (4.72-8.60 t/ha), (Table 3).

Table 3. Organic carbon stock in litter (OC_L)

PEP - EP	Litter horizon	C %	Mass t/ha	OC_L t/ha
PEP8 - CB	OL	42.54	5.17	2.20
	OF+OH	24.99	10.07	2.52
	Total		15.24	4.72
PEP11 - CB	OL	51.06	10.08	5.15
	OF+OH	32.97	10.48	3.46
	Total		20.56	8.60
PEP1 - PS	OL	47.76	4.41	2.10
	OF+OH	31.99	14.26	4.56
	Total		18.67	6.67
PEP9 - PS	OL	56.16	6.82	3.83
	OF+OH	25.02	6.26	1.57
	Total		13.08	5.40
PEP10 - LV	OL	36.24	7.40	2.68
	OF+OH	29.63	34.97	10.36
	Total		42.36	13.04
PEP12 - LV	OL	47.70	8.41	4.01
	OF+OH	29.90	27.53	8.23
	Total		35.94	12.24
PEP13 - LV	OL	38.88	6.83	2.66
	OF+OH	23.94	9.74	2.33
	Total		16.57	4.99
PEP14 - LV	OL	42.60	11.56	4.93
	OF+OH	25.12	11.82	2.97
	Total		23.38	7.90

Legend: PEP - Permanent Experimental Plot; EP - Experimental Perimeter; C - organic carbon stock (%); OL - organic horizon of litter; OF - fermentation horizon; OH - Humification Horizon; OC_L - organic carbon in litter.

Carbon Stock in Tree Biomass

Research indicates that carbon stock in biomass on degraded lands varies depending on stand age, species composition, stand structure, and the type of degradation. It is determined by the accumulated wood volume of the different

species, as well as by the wood density or specific gravity. For the studied plots (Table 4), in pine-containing stands, carbon stock in biomass ranged from 45.78 t/ha in a Scots pine plantation mixed with black pine, aged 50 years, on very strongly to excessively eroded land, up to 213.45 t/ha in a predominantly black pine plantation mixed with Scots pine, aged 70 years, on moderately eroded land.

In deciduous stands, biomass carbon stock was 135.44 t/ha in a late pedunculate oak (*Quercus pedunculiflora*) stand and 258.24 t/ha in a red oak (*Quercus rubra*) stand, both aged 73 years and located on moderately eroded land.

Table 4. Carbon stock in tree biomass (CW)

PEP-EP	SP	WD, kg/mc	WD, t/mc	V, mc/ha	AGB, t/ha	CW, t/ha
PEP8 - CB	Pi	45.84	0.45	190.00	86.23	43.11
	Pi.n	471.71	0.47	11.28	5.32	2.66
	total			**201.28**	**91.55**	**45.78**
PEP11 - CB	Pi	413.87	0.41	118.60	49.08	24.54
	Pi.n	471.41	0.47	237.85	112.12	56.06
	total			**356.45**	**161.21**	**80.60**
PEP1 - PS	Pi	522.97	0.52	137.84	72.09	36.04
	Pi.n	687.90	0.69	159.98	110.05	55.03
	total			**297.82**	**182.14**	**91.07**
PEP9 - PS	Pi	522.97	0.52	64.70	33.84	16.92
	Pi.n	531.04	0.53	740.17	393.06	196.53
	total			**804.87**	**426.90**	**213.45**
PEP10 - LV	Pi	404.71	0.40	418.04	169.18	84.59
	Dt	669.12	0.67	45.79	30.64	15.32
	total			**463.83**	**199.82**	**99.91**
PEP12 -LV	Pi.n	452.47	0.45	494.46	223.73	111.86
	St	669.12	0.67	4.84	3.24	1.62
	total			**499.30**	**226.97**	**113.48**
PEP13 - LV	St.r	600.52	0.60	**860.06**	**516.48**	**258.24**
PEP14 - LV	St.b +Dt	669.12	0.67	**404.83**	**270.88**	**135.44**

Legend: PEP - Permanent Experimental Plot; EP - Experimental Perimeter; SP - species; WD - wood density; V - volume per hectare; AGB- aboveground biomass; CW - carbon stock for living biomass of the tree; Pi - Scots pine; Pi.n - black pine; Dt - diverse hardwood species; St - common oak; St.r- red oak; St.b - greyish oak.

The results indicate that the rate of carbon accumulation in living biomass of the tree increases proportionally with wood density (WD) and unit volume (V). The exponential model used captures the nonlinear nature of carbon stock growth (Figure 3), suggesting that substantial amounts of carbon can be accumulated as tree diameter increases. Moreover, the model parameters allow efficient estimation of the carbon accumulation rate in relation to both tree diameter and species.

In comparison, in the internal forest-steppe site (EP Livada - Râmnicu Sărat), deciduous species (greyish oak - St.b; red oak - St.r) exhibit higher carbon accumulation than conifers (Scots pine - Pi; black pine - Pi.n), due to higher wood density (WD) and favorable dimensional characteristics (DBH, H), which promote greater biomass growth (Figure 3).

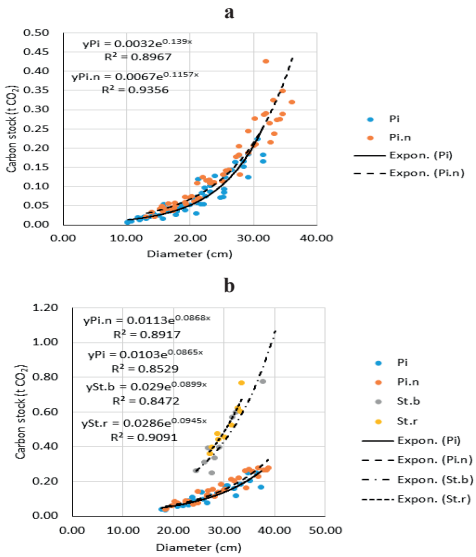


Figure 3. Distribution of soil organic carbon stock in relation to diameter at breast height (DBH) for the main species within the experimental perimeter: **a** - EP Caciu Bârseşti and EP Pârâul Sărat-Valea Sării; **b** - EP Livada-Râmnicu Sărat (**Legend**: Pi - Scots pine; Pi.n - Black pine; St.b - greyish oak; St.r - red oak)

Carbon Stock in Deadwood

To evaluate the biomass derived from deadwood (DWB), the volume of deadwood in the analyzed plots was considered, determined according to the dimensions of the identified pieces by species, along with the average values of deadwood density (WD_m) determined for different decay classes (Weggler et al., 2012). These values range from 315.42 to 481.04 kg/m³ for pine species and 534.24-558.55 kg/m³ for manna ash (*Fraxinus ornus*). Scots pine (*Pinus sylvestris*) shows higher wood density and slower decay compared to black pine (*Pinus nigra*), which has lower wood densities and faster decay across the classes.

The carbon stock in deadwood (C_DW) ranges from 17-18 t/ha (Table 5), representing 16-17% of the carbon stock in living tree biomass in the analyzed plots. This is explained by the high proportion of damage (such as drying and

breakage) in pines caused by abiotic stress factors, including drought and wind.

In the analyzed experimental plots where deadwood was identified (Table 5), coniferous species (Scots pine and black pine) represent the main source of deadwood biomass, while the contribution of deciduous species (manna ash) is low, representing less than 5% of the total. This distribution reflects a forest structure dominated by pines, with deadwood accumulation primarily from these species.

The differences observed between the two analyzed plots are associated with stand composition, stand density, the history of ecosystem disturbances and the decay stage of the wood, with slightly higher carbon storage in deadwood from stands dominated by black pine.

Table 5. Carbon stock per hectare in deadwood

PEP - EP	SP	DWB (t/ha)	C_DW (t/ha)
PEP10 - LV	Pi	32.38	16.19
	Mj	1.68	0.84
	Total	**34.06**	**17.03**
PEP12 - LV	Pi.n	35.47	17.74
	Mj	0.17	0.09
	Total	**35.64**	**17.83**

Legend: PEP- Permanent Experimental Plot; EP -Experimental Perimeter; DWB - deadwood biomass; C_DW - Carbon stock in deadwood; Pi - Scots pine; Pi.n - black pine; Mj - manna ash.

Total Organic Carbon Stock (Soil, Litter, Living and Dead Biomass)

The data summarized in Figure 4 reveal considerable variations in carbon stocks across the permanent experimental plots (PEPs).

Higher total carbon values were recorded in PEPs dominated by species with high productive potential relative to environmental conditions (land degradation), such as black pine and xerophytic oaks. These results are consistent with accumulated living biomass, stand age, forest structure and vegetation conditions.

The contribution of soil carbon remains relatively stable, ranging between 70 and 120 t/ha, whereas litter carbon exhibits greater variability. The highest litter carbon stock (13.04 t/ha) was observed in well-balanced pine with deciduous mixtures of older age (PEP10-LV), likely due to more substantial accumulation of organic matter.

Experimental plots with pine stands (PEP10 and PEP12-LV) in the internal forest-steppe site (Ssd) are notable for the presence of a significant deadwood component (~17.00 t/ha), which further contributes to total carbon stock. In contrast, in other plots, deadwood is absent or insignificant, indicating either low tree mortality dynamics or rapid decomposition of deadwood.

Overall, total carbon stock is primarily determined by living biomass and soil carbon, highlighting the influence of stand composition and structure (depending on pedological conditions) on carbon storage capacity.

From the graphical analysis (Figure 4), the following characteristics emerge:

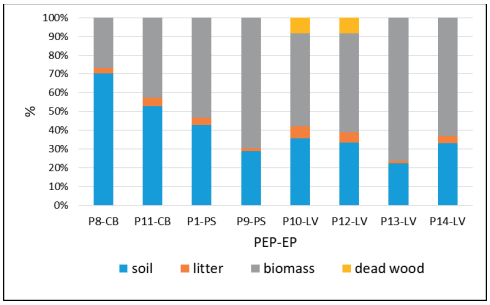


Figure 4. Carbon Stock Structure (%) by component (soil, litter, biomass, deadwood) for different experimental plots

- Pine stands store more carbon in the soil than deciduous (quercine) stands. Conversely, deciduous stands accumulate more carbon in the aboveground living biomass;
- Stands from internal forest-steppe site (Ssd), particularly pine stands, accumulate more carbon in litter and deadwood compared to stands from the hilly storey of sessile oak, beech and sessile oak-beech (FD_3) phytoclimatic level;
- Pines on very strongly eroded lands in the FD_3 level accumulate less carbon in the aboveground living biomass, with a greater proportion stored in the soil. In contrast, pine stands in internal forest-steppe site (Ssd) on moderately eroded lands accumulate more carbon in the aboveground living biomass.

CONCLUSIONS

The determination of organic carbon stock in forest plantations on degraded lands involved quantifying carbon accumulated in the main storage compartments of forest ecosystems: soil, litter, living tree biomass and deadwood.

Higher values of soil carbon stock were determined in younger pine stands on very heavily

eroded lands, compared to older deciduous stands on moderately eroded lands. In the litter, the largest amount of carbon was accumulated by mixed pine and deciduous trees of older ages, on moderately-severely eroded lands.

The carbon stock in tree biomass varies depending on the age, composition, structure of the stands and the degree of soil degradation, being almost 5 times lower in younger stands on heavily eroded lands (45.78 t/ha) compared to those of older age and on moderately eroded lands (>200 t/ha).

The carbon stock in dead wood differs according to species and phytoclimatic zone, with higher values being recorded in pine stands in the forest-steppe zone, as a result of damage caused by abiotic factors.

Total carbon stock is generally given by living biomass and soil carbon. The proportion of carbon stored in dead wood and litter becomes significant only in certain ecological contexts, such as the case of stands in the hilly forest-steppe area.

The complexity represented by environmental conditions revealed differences between the analyzed areas, highlighting the role of stand structure and composition in carbon storage. These results highlight the importance of species diversity and forest structure for the carbon sequestration capacity of forest ecosystems.

The aim of the study to know the total carbon stock in stands on degraded lands was achieved, this being limited to stands in the Curvature Subcarpathian area with the possibility of being used in similar situations. The results obtained make an important contribution to the assessment of the carbon stock in forests and the monetization of their ecosystem services, reflecting the importance of forest ecosystems in carbon sequestration and climate change mitigation.

In the next stage, new research is needed to determine the annual carbon flux, which is a dynamic, variable and complex process in relation to the characteristics of the stands, the silvicultural works applied, the impact of damaging abiotic factors, etc.

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