Environmental Sciences Proceedings

MDPI

*Proceedings*

# Carbon Stock in Forest Stands of Ukrainian Eastern Forest-Steppe: Forest Monitoring Data†

**Volodymyr Pasternak [1], Tetiana Pyvovar [2] and Volodymyr Yarotsky [3,*]**

[1] Ukrainian research institute of forestry and forest melioration named after G.M. Vysotskiy; Pasternak65@ukr.net
[2] Ukrainian research institute of forestry and forest melioration named after G.M. Vysotskiy; pyvovartatiana@gmail.com
[3] Ukrainian research institute of forestry and forest melioration named after G.M. Vysotskiy; suerlay@ukr.net
* Correspondence: Pasternak65@ukr.net.com; Tel.: +380-57-707-80-44
† Presented at the 1st International Electronic Conference on Forests, 15–30 November 2020; Available online: https://sciforum.net/conference/IECF2020

Published: 25 October 2020

**Abstract:** In Ukraine carbon stocks in forests are assessed by gain-loss method, since the national forest inventory is under development now. For evaluation of main pools of oak and pine forest stands, typical for Forest-steppe of Ukraine, stock-difference method was used for data of repeated observations on 18 intensive forest monitoring plots. The average carbon stock in the phytomass is 94.1 ± 10.5 tC $ha^{-1}$ and 93.4 ± 12.6 tC · $ha^{-1}$, in dead wood - 8.8 ± 3.8 tC · $ha^{-1}$ and 5.3 ± 4.2 tC · $ha^{-1}$ for oak and pine forest stands respectively. By age classes pine stands due to it higher productivity in general have higher C stock in phytomass comparing to oak. C stock changes in trees phytomass is the highest in younger stands, and it decreases with age; while in dead wood it increases. At age 81-100 years oak forest stands have higher carbon storage capacity than pine (total stock in main pools (phytomass, mortmass and soils (30-cm layer)) is 191.7 t C $ha^{-1}$ for oak and 175.4 t C $ha^{-1}$ for pine stands). Trees phytomass carbon prevails among other pools (50.3 % in oak forests, and 57.6 % in pine).

**Keywords:** carbon pools; phytomass; dead wood; carbon stock changes; oak stands; pine stands; age classes

## 1. Introduction

In many countries for greenhouse gases (GHG) emissions estimates, especially carbon, in forest sub-sector national forest inventory (sample based) (NFI) data are used [1]. In Ukraine the NFI system is under development now, so by the moment the source of data for GHG reporting is data of stand wise forest inventory [2, 3]. So methodology of carbon stocks calculations testing on forest monitoring plots is important for development of NFI in Ukraine.

## 2. Materials and Methods

The study was held in Eastern part of Ukraine (Kharkiv and Sumy regions), in ecological zone of temperate forests (Forest-steppe zone) [4]. The data was collected at 18 intensive forest monitoring plots with fixed area at two consequent observations with 4-year interval. These monitoring plots are located at Scots pine (4 plots) (*Pinus sylvestris* L.) and English oak (14 plots) (*Quercus robur* L.) forest stands, which are typical for Forest-steppe zone in the eastern part of Ukraine. Studied oak stands are represented mainly by natural coppice stands with admixture of other deciduous species (*Fraxinus excelsior* L., *Acer platanoides* L., *Tilia cordata* Mill. etc.) on dark gray forest soils, pine stands –

are artificial monodominant Scots pine forests on sandy sod-podsolic soils. The age of these stands varied from 44 to 144 years old, the average age of pine stands was 68 years, oak – 99 years.

All trees with DBH ≥12 cm (living and dead) on these monitoring plots were mapped, measured and their sanitary condition was estimated. The litterfall type and thickness, as well as soil type were determined. All dead logs with diameter ≥7 cm and stumps with diameter >14 cm were measured; their decomposition stage were evaluated.

Carbon (C) stock was evaluated for two observations at trees phytomass and deadwood mortmass (dead trees, dead logs and stumps) by IPCC formulas [1], taking into account basic wood density of trees species [5] and decomposition stage of deadwood [6, 7]. For estimation of carbon dynamics on studied monitoring plots by carbon pools the stock-difference method was used [1].

Data was analyzed for pine and oak forest stands, in general and by 20-years age classes, as the age influences on process of trees growth and carbon accumulation [8]. For comprehensive evaluation of main carbon pools at plots level additionally data on average soil carbon in 30-cm soil level and litter carbon stocks from [9] for the region of study (Forest-steppe) and types of forest stands were used.

## 3. Results

The average carbon stock in trees phytomass was 94.1±19.8 t C $ha^{-1}$ at studied oak stands and – 93.4±12.8 t C $ha^{-1}$ at pine stands (table 1). In all types of stands, the phytomass C stocks increased with age, just at one plot at oak stand (age 61-80 years) it decreased due to significant trees mortality caused by biotic damage. The average deadwood C stocks at studied oak stands was 8.8±7.3 tC $ha^{-1}$, while in pine stands – 5.3±4.3 t C $ha^{-1}$.

**Table 1.** Carbon stocks (t $ha^{-1}$) and dynamics (t $ha^{-1}year^{-1}$) in phytomass and mortmass of studied oak and pine stands.

| Forest type and age class | C stock in trees phytomass | C stock in deadwood mortmass | Averge C change in trees phytomass | Average C change in deadwood mortmass |
|---|---|---|---|---|
| Oak 41-60 years | 91.1 | 5.0 | 2.7 | 1.1 |
| Oak 61-80 years | 60.2 | 11.9 | -2.0 | 0.3 |
| Oak 81-100 years | 96.5±23.0 | 4.4±4.0 | 1.6 | 0.1 |
| Oak 101-120 years | 98.5±17.4 | 8.6±6.8 | -0.3 | 1.8 |
| Oak >120 years | 97.6±10.5 | 15.7±7.4 | -1.9 | 0.5 |
| **Average Oak** | **94.1±19.8** | **8.8±7.3** | **0.2** | **0.6** |
| Pine 41-60 | 71.9 | 1.0 | 2.9 | 0.0 |
| Pine 61-80 | 100.3±4.4 | 4.2±2.4 | 1.4 | 0.8 |
| Pine 81-100 | 101.1 | 11.8 | -0.9 | 2.7 |
| **Average Pine** | **93.4±12.8** | **5.3±4.3** | **1.2** | **1.1** |

Data showed (see Table 1), that both pine and oak stands at age 41-60 years have the highest C change due to their intensive growth. The oldest stands have negative trees phytomass C change and positive deadwood C change due to slow growth and increased mortality.

According to the combined calculation at studied forest stands obtained on the base of our observations on C stock in stands and deadwood and data from [9] on C stock in soils and litter at age class 81-100 in oak forest the total carbon stock in main carbon pools was 191.7 t C $ha^{-1}$ (phytomass – 96.5, mortmass – 4.4, soil – 88.0, litter – 2.8 t C $ha^{-1}$) and at pine stands – 175.4 t C $ha^{-1}$ (phytomass – 101.1, mortmass – 11.8, soil –50.9, litter – 11.6 t C $ha^{-1}$).

## 4. Discussion

Results showed that the average carbon stocks in trees phytomass and mortmass of studied oak stands are higher than in pine stands, which is associated with a difference in age structure (oak stand were older then pine). Our results are lower than average values calculated for modal oak and pine stands (104 and 101.3 t C $ha^{-1}$, respectively) for the Forest-steppe zone of Ukraine at the same age according to [2]. For these calculations gain-loss method was used.

The results showed, that deadwood C stock at oak stands is higher than in pine stands, due to higher mortality rates and longer decomposition period of the oak deadwood.

So our data proved, that in general, at age 81-100 years oak stands have higher carbon storage capacity, than pine stands. Among other pools trees phytomass plays the most significant role in C sequestration (50.3 % and 57.6% of total carbon stock in oak and pine stands, respectively), the second important pool is forest soil (45.9 and 29.0%, oak and pine stands, respectively), while the deadwood and litter pool are the smallest (3.8% and 13.3 %, oak and pine stands, respectively).

However, these results are preliminary, and just show general trends and illustrate the methods used. Of course, implementation of NFI and soil monitoring at the country level will allow obtaining more detailed estimates in these carbon pools values for different forest types and age groups, and just after two repeated NFI observations it will be possible to obtain modern data on carbon budget in forests of Ukraine.

**Author Contributions:** V. Pasternak – **c**onceptualization, methodology, formal analysis, data analysis, validation, investigation, writing—review and editing; T. Pyvovar – methodology, writing—original draft preparation; V. Yarotsky – investigation (field work), data analysis.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, IPCC 2014. Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland. Available online: URL https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html (accessed on 29.09.2020)
2. Shvidenko, A., Lakyda, P., Schepaschenko, D., Vasylyshyn, R., Marchuk, Yu. Carbon, climate, and land-use in Ukraine: Forest sector: A monograph. FOP Gavrishenko V.M.: Korsun-Shevchenkivskyi, Ukraine: 2014; 283 p.
3. Buksha, I.F., Butrim, O.V., Pasternak, V.P. Inventory of greenhouse gases in the land use and forestry sectors: A monograph. KhNAU: Kharkiv, Ukraine, 2008; 232 pp. (in Ukrainian).
4. Didukh, Y.P., Fitsailo, T.V., Korotchenko, I.A., Iakushenko, D.M., Pashkevich, N.A. Biotopes of forest and forest-steppe zones of Ukraine. LLC MACROS: Kyiv, Ukraine, 2011; 288 pp. (in Ukrainian).
5. Lakida, P.I., Vasylyshyn, R., Lashenko, A., Terentiev, A. Standards of evaluation of components of aboveground trees biomass of trees of the main forest-forming species of Ukraine. ECO-inform: Kyiv, Ukraine: 2011; 192 p.
6. Avramchuk, O.O., Bilous, A.M., Golyaka, D.M., Ischenko, M.B., Kyslytsya, P.S. Evaluation of logs in pine plantations of Kyiv Polissya. Proceedings of the National University of Life and Environmental Sciences of Ukraine. Forestry. Decorative Gardening, 2015. 219, 11-18. (In Ukrainian).
7. Yarotskiy, V. Yu., Pasternak, V. P., Nazarenko, V. V. Deadwood in the oak forests of the Left Bank Forest steppe of Ukraine. Folia Forestalia Polonica, Series A - Forestry. 2019. 61. 4, 247–254. https://doi.org/10.2478/ffp-2019-0024
8. Pregitzer, K,S, & Euskirchen, E.,S. Carbon cycling and storage in world forests: biome patterns related to forest age. Global Change Biology. 2004, 10(12):2052 – 2077. DOI: 10.1111/j.1365-2486.2004.00866.x
9. Buksha, I.F., Raspopina, S.P., Pasternak, V.P. Assessment of organic carbon stock in soil and litterfall in forests of Ukraine. Forestry & Forest melioration. 2012, 120, 106–112. (in Ukrainian).