Seasonal carbon accumulation by groundcover in the Central Siberian subtaiga forest-steppe zone

Sevinch Mamedova*, *Andrey* Vais, *Alexandra* Melnik, *Svetlana* Chanchikova, *Pavel* Mikhaylov, and *Artem* Nepovinnykh

Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, Russian Federation

Abstract. The research is dedicated to comparing the above ground living vegetation carbon stock in various site conditions. The study was carried out in the Karaul'noe forestry located near Krasnoyarsk, Russia. We placed the research plots in stands of varying density (0.34-1.06) and landforms. Seven research plots are of the closed type (the groundcover develop under the canopy) and three research plots are of the open type (the bank of the Yenisei River, hayfield, area under power lines). Open (forestless) plots (the bank of the Yenisei River, hayfield, area under power lines) and pine forests with forest floor dominated by ferns/tall grasses were of the maximum above ground living vegetation carbon stocks values (from 2.01 to 2.46 tonnes of carbon per ha). A significant carbon sequestration was observed in the pine forest of lingonberry/moss type (1.58 tonnes of carbon per ha) since the moss layer makes a significant contribution to the groundcover carbon accumulation.

1 Introduction

The biological productivity of lower vegetation layers, in particular above ground living vegetation, has not been sufficiently studied in taiga forest ecosystems [1-3]. In this regard, regional research are highly relevant. Usoltsev stated [4] that the lack of data on phytomass and annual production generates serious uncertainties in carbon budget estimates.

Carbon stock in dry plants biomass (phytomass) varies from 45 to 53 % [5]. Carbon, being a basic organic matter element, is of inactive migration ability. Most of carbon in the biological cycle stocks for a long time in the phytomass of woody plants [6]. Above ground living vegetation, unlike trees, accumulates and releases most of the carbon within one year [7].

Herbs/shrub and moss layers act as indicators of forest conditions. They also regulate microclimatic and microbiological processes in forest communities. Thus, herbs/shrub and moss layers play an important role in the accumulation of organic matter in forest ecosystems [8].

* Corresponding author: mamedova_ceva@mail.ru

2 Materials and methods

The study was carried out in the Karaul'noe forestry located near Krasnoyarsk, Russia (Figure 1). The study area belongs to the Central Siberian subtaiga forest-steppe zone [9].

We conducted field study during the period of maximum plant growth (2022), that is, between the stages of flowering and fruiting (July-August).

We used the mowing method [10] to assess the groundcover phytomass. We placed 0.25 m^2 quadrats evenly distributed on each research plot. The number of quadrats depended on the plant community-forming species diversity. A frame (0.5 × 0.5 m), a tape measure and scissors were used as additional tools. In quadrats we asseses species composition and area covered with each species. All plants were cut with scissors at ground level and sorted into the following groups: herbs, mosses, shrubs, ferns.

We weighed the samples in an air-dry state. To determine the moisture content, samples were stored for 8 hours (at 105 °C) in a drying cabinet until they became absolute dry. Then the samples were weighed on an electronic scale with an accuracy of 0.01 g. Absolute dry weight of the above ground living vegetation was calculated using these absolute dry and air-dry state weights.

To convert the absolute dry weight of the above ground living vegetation (tonnes per ha) to its carbon stock values (tonnes of carbon per ha), we used a converting coefficient of 0.484 [11].

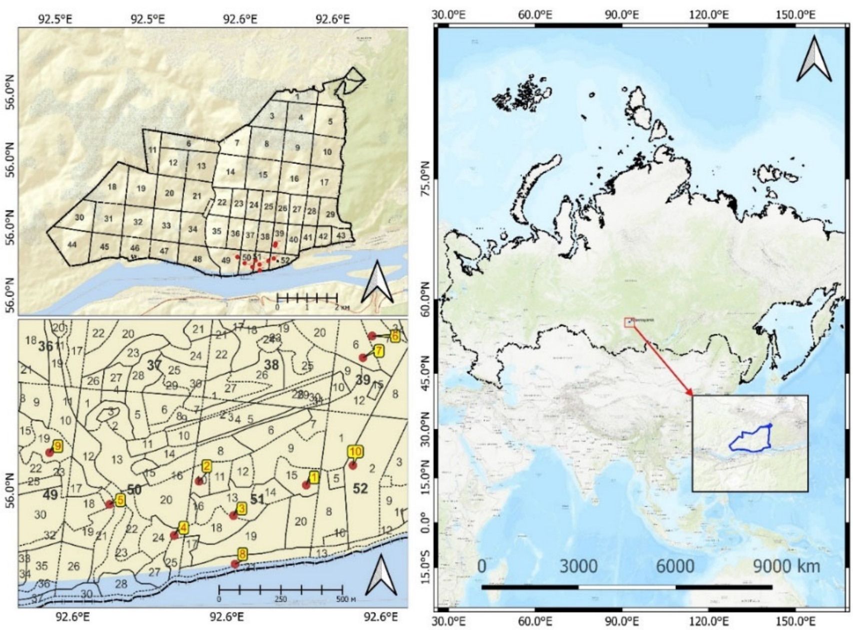

Fig. 1. Study locations: left – research plots; right – the Karaul'noe forestry.

CO_2 sequestration and O_2 release depend not only on the type of plan community and its age, but also on individual components of forest ecosystems, including the above ground living vegetation. In this regard, we used a volume-conversion approach [12-13].

The volume-conversion approach implies the estimation of the groundcover carbon stock using the conversion coefficient, calculated using the following formula:

$$CC = \frac{M_{C\,lgc}}{M_s}, \quad (1)$$

where CC is the conversion coefficient of the above ground living vegetation carbon stock;

$M_{C\,lgc}$ is the above ground living vegetation carbon stock, tonnes of carbon per ha;

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M_S is the forest stand growing stock, m^3 per ha.

All quantitative indicators of phytomass and carbon stock were calculated using Microsoft Excel and STATGRAPHICS softwares.

3 Results and discussion

The selected research plots were referent for the study area and reflected all the variety of site conditions. We conducted forest inventory in the research plots using visual and instrumental measurements (Table 1) and assesses the above ground living vegetation.

The groundcover growth depends on insolation [14], that is why we placed the research plots in stands of different density (0.34-1.06) and landforms [15]. Seven research plots are of the closed type (the above ground living vegetation was formed under the canopy) and three research plots are of the open type (the bank of the Yenisei River, hayfield, areas under power lines).

Data on the above ground living vegetation carbon stock for all the research plots are summarized in Tables 2 and 3. It was found that open (forestless) plots and pine stands with forest floor dominated by lingonberry, green mosses and ferns (L/M, F/TG) were of the maximum groundcover carbon stocks values (Figure 2).

Table 1. Silvicultural and forest inventory of the studied forest stands.

No.	**Reseach plot**	**Forest stand composition**		**Age, years**	**Diameter, cm**	**Height, m**	**Relative density**	**GS, m^3 ha^{-1}**	**Aspect: slope**
		Scots pine	Birch						
1	Pine forest, lingonberry/moss-covered forest floor (L/M)	100 %	-	130	32	25	0.92	370	SE:10^0
2	Pine forest, *Pyrola*/moss covered forest floor (P/M)	100 %	-	100	26	29	1.06	504	SE:10^0
3	Pine forest, sedges/herbs-covered forest floor (S/H1)	100 %	-	130	30	27	0.76	331	SE:22^0
4	Pine forest, bracken-covered forest floor (B)	100 %	< 2 %	130	38	25	0.83	333	SE:7^0
5	Pine forest, sedges/herbs-covered forest floor (S/H2)	90 %	10 %	100	35	28	0.56	254	S:2^0
6	Pine forest, ferns/tall grasses-covered forest floor (F/TG)	100 %	< 2 %	80	41	30	0.34	168	E:9^0
7	Pine forest, bracken/tall grasses-covered forest floor (B/TG)	60 %	40 %	80	45	30	0.91	447	E:16^0
8	The bank of the Yenisei River (Bank)								S:4°
9	Hayfield								SE:10°
10	Area under power lines (PL)								SE:5°

Note: Scots pine - Pinus sylvestris L.; Birch - Betula pendula Roth; here we present the average stand-wide values of age, diameter and height; GS – growing stock, m3 per ha

Table 2. The groundcover carbon stock.

No.	Research plot	Unit of measurement	Herbs	Mosses	Shrubs	Ferns	Total carbon stock
1	Pine forest, lingonberry/moss-covered forest floor (L/M)	t C ha-1	0.2981	1.1438	0.1336	-	1.5755
		%	19.0	73.0	8.0	-	100.0
2	Pine forest, Pyrola/moss covered forest floor (P/M)	t C ha-1	0.3630	0.3315	-	-	0.6944
		%	52.0	48.0	-	-	100.0
3	Pine forest, sedges/herbs-covered forest floor (S/H1)	t C ha-1	0.2068	0.2137	0.2179	-	0.6384
		%	32.0	34.0	34.0	-	100.0
4	Pine forest, bracken-covered forest floor (B)	t C ha-1	0.1705	-	-	0.4554	0.6259
		%	27.0	-	-	73.0	100.0
5	Pine forest, sedges/herbs-covered forest floor (S/H2)	t C ha-1	0.4015	0.0186	0.0030	0.0708	0.4940
		%	81.0	4.0	1.0	14.0	100.0
6	Pine forest, ferns/tall grasses-covered forest floor (F/TG)	t C ha-1	2.0500	0.0089	-	0.2277	2.2866
		%	89.6	0.4	-	10.0	100.0
7	Pine forest, bracken/tall grasses-covered forest floor (B/TG)	t C ha-1	0.5788	-	-	0.1161	0.6949
		%	83.0	-	-	17.0	100.0
8	The bank of the Yenisei River (Bank)	t C ha-1	1.9921	0.0154	-	-	2.0075
		%	99.0	1.0	-	-	100.0
9	Hayfield	t C ha-1	2.4583	-	-	-	2.4583
		%	100.0	-	-	-	100.0
10	Area under power lines (PL)	t C ha-1	1.6958	-	-	0.3383	2.0341
		%	83.0	-	-	17.0	100.0

Table 3. The above ground living vegetation conversion coefficient.

Indicators	**L/M**	**P/M**	**S/H 1**	**B**	**S/H 2**	**F/TG**	**B/TG**	**Bank**	**Hayfield**	**PL**
Forest stand growing stock, m^3 ha^{-1}	370	504	331	333	254	168	447	-	-	-
The above ground living vegetation carbon stock, t C ha^{-1}	1.5755	0.6944	0.6384	0.6259	0.4940	2.2866	0.6949	2.0075	2.4583	2.0341
Conversion coefficient, t C m^{-3}	0.0043	0.0014	0.0019	0.0019	0.0019	0.0136	0.0016	-	-	-

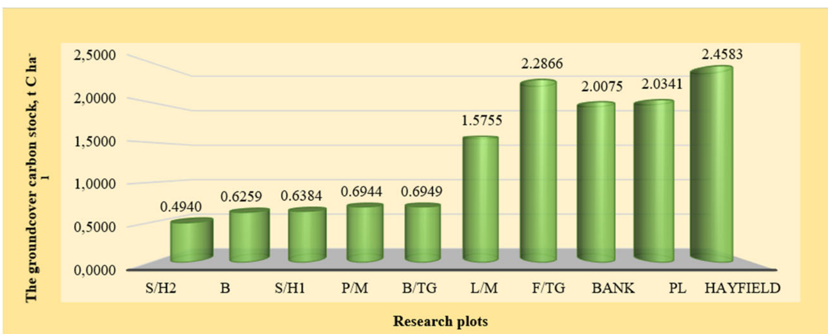

Fig. 2. The groundcover carbon stock.

In low-density pine stand with ferns/tall grasses-covered forest floor, the total above ground living vegetation carbon stock is 2.29 tonnes of carbon per ha. This value exceeds the carbon stocks in other research plots by an average of 66.0 %.

On the research plots 1, 2 and 3, the moss layer makes a significant contribution to the organic matter accumulation. For instance, in the pine stand with lingonberry/moss-covered forest floor, moss layer took 73.0 % in the total groundcover carbon stock; in the pine forest of *Pyrola*/moss type, mosses took 48.0 %; in the pine stand with sedges/herbs-covered forest floor, mosses took 34.0 %. Green mosses growing on the research plots included Schreber's big red stem moss (*Pleurozium schreberi* (Willd. ex Brid.) Mitt.), glittering woodmoss (*Hylocomium splendens* (Hedw.) Bruch et al.), and the big shaggy-moss (*Rhytidiadelphus triquetrus* (Hedw.) Warnst.).

In the bracken-dominated pine forest (research plot 4), common bracken (*Pteridium aquilinum* (L.) Kuhn) took 73.0 % in the total above ground living vegetation carbon stock. Bracken also took the following share in the total groundcover carbon stock on other research plots: 17.0 % in the area under power lines, 14.0 % in the pine stand of sedges/herbs-covered forest floor (research plot 5), and 17.0 % in the pine forest of bracken/tall grasses type. Ferns growing in the pine stand with ferns/tall grasses-covered forest floor included two species: the lady fern (*Athyrium filix-femina* (L.) Roth) and common bracken. The lady fern took 8.9 % in the total above ground living vegetation carbon stock (0.2042 tonnes of carbon per ha) on this research plot, and common bracken took 1.1 % (0.0234 tonnes of carbon per ha).

According to Nikitin [16], the above ground living vegetation carbon stock ranged from 0.03 to 3.26 tonnes of carbon per ha in pine plantations (Belarus), which is comparable to the absolute values of carbon stocks in the Karaul'noe forestry.

Table 3 shows the calculation of the conversion coefficients for the above ground living vegetation in various forest types. The conversion coefficients ranged from 0.0014 to 0.0136. The coefficients indicate how much of the groundcover carbon is stocked in one cubic meter of stem wood.

The difference in conversion coefficients and the presence of open spaces indicate the possibility of dividing the data into two groups: the absolute groundcover carbon stock values (open spaces and pine forests with significant carbon stocks, namely lingonberry/moss and ferns/tall grasses forest types) and a group of relative values (conversion coefficients of pine stands of various forest types).

4 Conclusion

The research let us draw the following conclusions:

- The above ground living vegetation varies widely in pine stands depending on the forest type.
- Open (forestless) plots (the bank of the Yenisei River, hayfield, area under power lines) and pine stand with forest floor dominated by ferns/tall grasses were of the maximum groundcover carbon stocks values (from 2.01 to 2.46 tonnes of carbon per ha). What is more, a significant carbon sequestration was observed in the pine forest of lingonberry/moss type (1.58 tonnes of carbon per ha).
- The moss layer makes a significant contribution to the carbon accumulation in groundcover. For instance, moss took the following share in the total above ground living vegetation carbon stock: 73.0 % in the pine stand with lingonberry/moss-covered forest floor; 48.0 % in the pine forest of *Pyrola*/moss type; 34.0 % in the pine stand with sedges/herbs-dominated forest floor.
- Seasonal accumulation of the above ground living vegetation carbon is related with the stands density and forest type.
- Relative density may be used as a factor limiting the above ground living vegetation growth. Hence, the relative density may act as a variable for determining both absolute and relative values of the groundcover carbon stock in allometric equations.

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References

1. S. G. Prokushkin, A. P. Abaimov, A. S. Prokushkin, O. V. Masyagina, Contemporary Problems of Ecology **2**, 131-139 (2006)
2. M. V. Zaprudina, Bulletin of the Samara Federal Research Scientific Center of the Russian Academy of Sciences **12**, **1(3)**, 876-879 (2010)
3. I. S. Grozovskaya, L. G. Khanina, V. E. Smirnov, M. V. Bobrovsky, M. S. Romanov, E. M. Glukhova, Russian Journal of Forest Science **1**, 63-76 (2015)
4. V. A. Usoltsev, *Eurasian forest biomass and primary production data* (Ural Branch of Russian Academy of Sciences, Yekaterinburg, 2010), 570

5. D. Zamolodchikov, Sustainable Forestry **4(29)**, 15-22 (2011)
6. P. Havas, E. Kubin, Ann. Bot. Fennici **20**, 115-149 (1983)
7. E. Mälkönen, Communicationes Instituti Forestalis Fenniae, Helsinki **91**, 1-35 (1977)
8. V. V. Tuzhilkina, Plant Resources **48**, 1, 44-50 (2012)
9. Order of the Ministry of Natural Resources of Russia dated August 18, 2014 No. 367 *On Approval of the List of Forest Site Zones of the Russian Federation and the List of Forest Districts of the Russian Federation*. https://docs.cntd.ru/document/420224339)
10. V. B. Golub, L.F. Nikolaychuk, Diversity of plant world **1(8)**, 30-50 (2021)
11. Forests carbon balance assessment in the Republic of Belarus based on the coeeficients of carbon dioxide emission/absorption from above ground phytomass, forecast for an increase in greenhouse gases absorption by forests until 2030 and until 2050, preparation of a list of measures to increase the absorption of greenhouse gases in forestry: report, Minsk, Belarus, 65 (2017)
12. M. N. Ignatieva, A. N. Ivanov, in Proceedings of the Seventh All-Russian Scientific and Practical Conference with International Participation, *Actual Problems of Economics and Management*, October 15–16, 2019, Yekaterinburg, Russia, 161-165 (2019)
13. D. G. Zamolodchikov, A. I. Utkin, G. N. Korovin, Russian Journal of Forest Science **3**, 84-93 (1998)
14. I. N. Artemyeva, Spatial distribution, phytomass and annual production of the lower vegetation layers in the northern taiga lichen pine forests of Khanty-Mansiysk Autonomous Okrug-Yugra (Yekaterinburg, 2022)
15. A. V. Lebedev, Landscape inventory of plantings, Mechanization and Electrification of Agriculture, 148 (2022)
16. A. N. Nikitin, Proceedings of the Belarusian State Technological University. Series 1. Forestry **11**, 95-97 (2003)