

Evaluating stumps volume in managed, protective pine stands of the subtaiga forest-steppe region of Middle Siberia

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Abstract. The article evaluates the stump reserves in pine forests of the subtaiga-forest-steppe region of Central Siberia. It was found that in stands with high density (relative density above 1.0) and high productivity (I–II productivity classes), the stump stock ranged from 0.23 to 2.21 m³ per ha⁻¹. The proportion of stump wood in the total timber stock ranged from 0.04% to 0.44%. The majority of stumps (39.1%) were in the 2nd decay class, indicating that the silvicultural practices used in the area were implemented over a decade ago. The mass of stumps ranged from 0.07 to 0.70 t per ha⁻¹, while the stump carbon reserve varied from 0.04 to 0.35 t C per ha⁻¹.

1 Introduction

A stump is a remaining part of the trunk (after a tree has been felled or broken) with the roots still in the ground; it may be alive or dead [1].

The study of global post-fire and post-logging carbon pools in large woody debris (LWD include snags, downed logs, stumps) in Russia allowed Zamolodchikov to reveal a number of patterns [2]. The average carbon pool in LWD is 13.0 t C per ha⁻¹; 15.8% of all newly formed debris occurs in post-fire forests and 14.3% of LWD occurs in post-logging forests. The Asian Russia accounts for 90% of all post-fire detritus emissions. Aleynikov, Tyurin, Grabarnik, Efimenko [3] compared two post-fire forest communities (80 and 120 years after the fire) and found that both forest stands were dominated by deciduous trees, with a small proportion of conifers. A detailed analysis of the main structural indicators revealed some differences. However, according to most of them, these communities do not differ significantly for the forest stand and the deadwood, and characterize approximately the same type of recovery dynamics. Mukhortova and Vedrova [4] state that felling leads to a significant increase in LWD volume, both on the ground and in the soil (roots). The rate of LWD decay in taiga pine forests is significantly lower than in fir forests. This is due to a number of factors, including the qualitative composition of the wood of these species, the hydrothermal regime and soil conditions. In undisturbed fir forests, as well as in pine forests, the contribution of LWD to the total phytodetritus is 34–38%. Bobkova and Likhanova [5] analyzed the amount of carbon removal and mineral nutrition during the clear-cutting of

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spruce forests in the Middle Taiga. Sergienko and colleagues [6] analyzed the accumulation dynamics of woody debris following logging of varying intensities. The study was carried out in managed and protective uneven-aged coniferous and mixed forests located in the Leningrad Oblast. The analysis of tree mortality dynamics has enabled the establishment of indicators for forest ecosystems in the taiga zone. These indicators are used to determine the volume of deadwood removal during selective logging. The article presents data on the average annual mortality and defines deadwood categories in spruce forests of different ages, previously subjected to logging of varying intensity. The analysis focused on mortality data and the distribution of LWD based on decay classes and deadwood categories. It has been established that the main loss of timber stock, particularly in deadwood, occurs in spruce, which is the dominant species. In uneven-aged stands, it is recommended to carry out felling of moderate and moderate-high intensity (25% and 35% of the growing stock) and remove up to 10% of woody debris.

After clear cutting, a large number of stumps remain in the forest. Old stumps provide a favorable habitat and food for living organisms. However, such stumps can be dangerous for surrounding plants as they are hosts for spores of wood-destroying fungi and stem pests (in particular, pine shoot beetle (*Tomicus piniperda* L. u *T. Minor* Hart.) outbreaks can occur on pine stumps).

Stumps can be used as fuel. In addition, stumps hinder high quality automated reforestation.

The aim of the present study is to evaluate the stump reserves in managed protective high-density pine forests, in order to assess the carbon emission processes from stumps and plan reforestation measures for stands damaged by various types of pathogens.

2 Materials and methods

Preparatory measures to determine detritus reserves in a forest management unit can be carried out simultaneously with forest inventory or during the inter-inventory period.

The stock of stumps was assessed using the 'Methodology for determining the reserves and mass of woody detritus based on forest inventory data' [7].

Three or more temporary research plots measuring 20x20 m or with a radius of 12.6 m were placed in forest sites that are representative of the study area.

Measurement data is recorded in a special field form. For stumps, the diameter and height at the middle of the stump are measured.

To create a comprehensive inventory of deadwood, it is recommended to use research plots for various purposes, such as training and studying growth progress.

The reserves of stumps per hectare are determined by processing data from temporary research plots and measurements of detritus. Primary data processing is carried out on a PC, with volumes are determined with an accuracy of 0,001 m³.

When processing on a computer, one may use any of the available software products such as Excel or Access.

Coarse woody debris (CWD) is a crucial component in the decomposition system of deadwood and the carbon balance of forest ecosystems [7, 8]. The formation of CWD can be caused by various factors, ranging from natural and insignificant ones such as competition, diseases, and plant aging, to accidental and massive ones such as blowdown, pest outbreaks, and fires [9].

CWD comprises snags, downed logs, and stumps with a diameter of at least 10 cm – dead woody material (mortmass) in all stages of decomposition prior to becoming humus [7, 10].

Data on CWD were collected from 18 reference forest sites. In each forest mapping unit, three circular plots with a radius of 13.75 m ($S = 594.0344$ m²) were placed. The research plots were evenly distributed across the entire mapping unit. The collected data included the

number of tree, species, and the category of deadwood (stumps), as well as their diameters and heights.

To calculate the mass of detritus, we utilized the specific gravity (p) as an indicator of the deadwood decay class. The formula used for this calculation is:

$$p = \frac{M_{d.m.}}{V}, \quad (1)$$

where $M_{d.m.}$ – mass of dry wood, t per ha-1;

V – timber volume, m³ per ha-1.

The mass of detritus was determined using the following formula:

$$M = V_d \cdot p, \quad (2)$$

where M – mass of detritus, t per ha-1;

V_d – volume of detritus, m³ per ha-1;

p – specific gravity.

The specific gravity values for the dominant species, Common pine (*Pinus sylvestris* L.), were obtained from the reference material on detritus [7]. Therefore, the specific gravity (p) of coniferous wood, specifically pine stumps, is 0.316. To convert detritus mass into deadwood carbon stock, a standard conversion factor of 0.5 was used.

In the study area, it is important to note that the stumps are of anthropogenic origin. In most cases, stumps formed when tree trunks were removed during thinning and sanitation cutting.

3 Results and discussion

The study analyzed LWD in high-density pine forests located in the Karaul'noe forestry, which is an Educational and Experimental Forestry of the Reshetnev Siberian State University of Science and Technology. The studied stands are pure. The age of the pine varied from 85 to 150 years. The average tree height ranged from 23.6 to 26.3 m. Average tree diameter varied from 27.2 to 37.3 cm. The basal area ranged from 21.9 to 52.95 m² per ha⁻¹. The basal area and relative density values suggest a high density of the original forest stands. The stands are of high productivity, falling within the I-II productivity class. The growing stock ranged from 235 to 643 m³ per ha⁻¹. The typological structure is quite diverse, with all pine forests belonging to the herb-rich group of forest types, including sedges/herb-rich pine forest, meadowsweets/sedges pine forest, and pasqueflowers/sedges pine forest (steppe).

Table 1 shows the main silvicultural and forest inventory details from our studies, including age, average diameter, and average height.

Table 1. The average diameter and height of pine trees in the studied stands.

Forest compartment / mapping unit	Age, years	Average height, m	Average diameter, cm
48/13	85	23.7	27.2
49/2	110	23.6	34.6
49/4	130	24.3	33.6
49/7	110	25.4	34.1
49/9	150	25.3	31.8
49/12	120	24.0	37.3
49/24	85	25.2	33.9
49/28	110	24.9	33.2
49/31	110	26.3	35.7

Table 2 presents the calculations for stumps volume.

Table 2. Initial list of stumps measurements and determination of stumps volume (fragment).

Species	Deadwood category	Decay class	Diameter, cm	Stump height, m	Stump volume, m ³
Forest compartment No. 48 Mapping unit No. 13					
Pine	stump	4	35.0	0.6	0.058
Pine	stump	5	24.0	0.4	0.018
Pine	stump	4	25.0	0.5	0.024
Pine	stump	3	21.6	0.4	0.014
Pine	stump	4	32.8	0.8	0.067
<i>Total</i>					0.182
<i>Per ha</i>					1.024
Forest compartment No 49 Mapping unit No. 28					
Pine	stump	4	40.2	0.8	0.101
Pine	stump	3	23.5	0.5	0.021
Pine	stump	3	17.2	1.2	0.027
Pine	stump	2	40.2	1.2	0.152
Pine	stump	2	30.5	0.8	0.058
Pine	stump	3	28.2	0.5	0.031
<i>Total</i>					0.393
<i>Per ha</i>					2.206

The stock of stumps per hectare ranged from 0.231 to 2.206 m³.

The bar graph in Figure 1 displays the structural features of stumps according to their decay classes.

In pine stands, stumps are mainly represented by the 2nd (39.1%) and 4th (36.3%) decay classes. The proportion of 1st and 5th decay classes combined was 6.2% of the total. This suggests that the forest management practices in the study area were implemented over a decade ago.

To summarize the results, Table 3 presents a summary of the data on stumps.

The total growing stock ranged from 235 to 643 m³ per ha⁻¹ across the individual forest sites. The stock of stumps was negligible, ranging from 0.23 to 2.21 m³ per ha⁻¹ (Table 3).

A histogram was created (Figure 2) to illustrate the ratio between the growing stock and the stock of stumps.

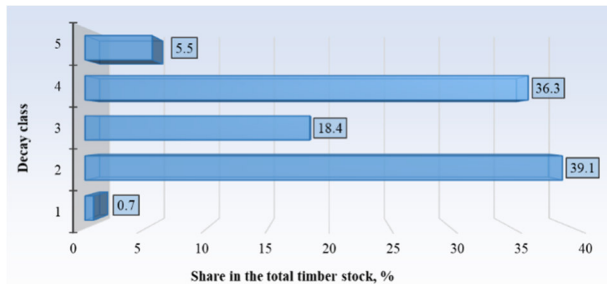


Fig. 1. Diagram showing the distribution of stump stock by decay classes.

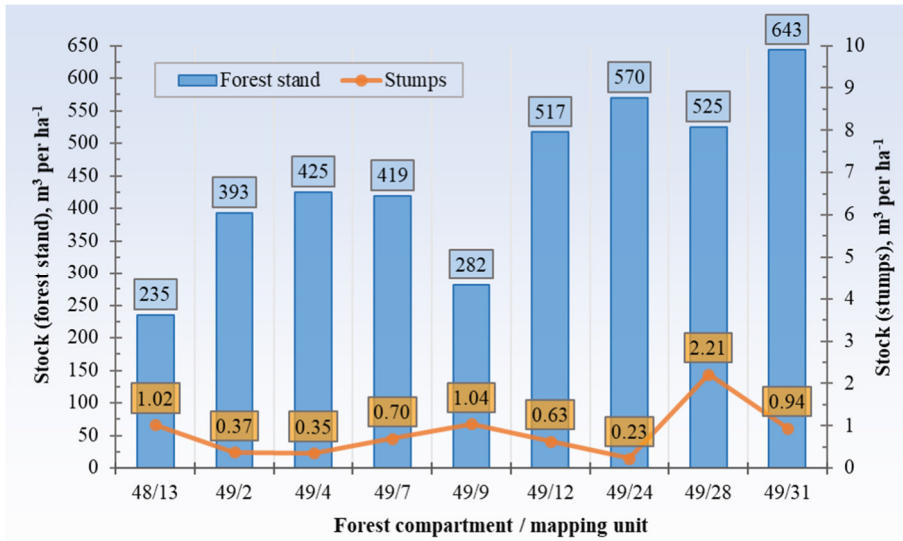


Fig. 2. The ratio of growing stocks to stumps in the pine stands.

According to Table 3 and Figure 2, the proportion of stumps in the overall timber stock ranged from 0.04% to 0.44%.

Table 4 presents the calculated mass and carbon content of deadwood. It can be stated that the mass of stumps varied from 0.07 to 0.70 t per ha⁻¹.

The carbon pool in the stumps ranged from 0.04 to 0.35 t C per ha⁻¹.

The quality of CWD, especially stumps, is crucial. Wood decay affects microbial processes, mineralization, soil enrichment, and biodiversity conservation. The deadwood decomposition process affects the total content of organic carbon (C) and nitrogen (N) and the soil's microbial activity. It has been established that deadwood directly increases the activity of soil enzymes and microbial biomass [11].

C and N concentrations are important factors that influence the decay of deadwood. CWD is crucial for forest productivity, nutrient cycling, carbon decomposition and sequestration, and forms a significant carbon pool in the forest ecosystem [12]. Soil, mulch, and downed logs are significant carbon pools that should be considered in programs aimed at reducing carbon emissions in arid regions [13].

Table 3. Ratio of dead stumps wood stock to growing stock.

Forest compartment / mapping unit	Growing stock, m³ per ha ⁻¹	Stumps wood stock	
		m³ per ha ⁻¹	%
48/13	235	1.02	0.44
49/2	393	0.37	0.09
49/4	425	0.35	0.08
49/7	419	0.70	0.17
49/9	282	1.04	0.37
49/12	517	0.63	0.12
49/24	570	0.23	0.04
49/28	525	2.21	0.42
49/31	643	0.94	0.15

Table 4. Estimating the mass and carbon reserves of stumps.

Forest compartment / mapping unit	Forest type	Age, years	Stump biomass, t per ha ⁻¹	Stump carbon pool, t C per ha ⁻¹
48/13	meadowsweets/sedges pine forest	105	0.32	0.16
49/2	meadowsweets/sedges pine forest	130	0.12	0.06
49/4	meadowsweets/sedges pine forest	150	0.11	0.06
49/7	sedges/herb-rich pine forest	130	0.22	0.11
49/9	sedges/herb-rich pine forest	170	0.33	0.16
49/12	sedges/herb-rich pine forest	140	0.20	0.10
49/24	sedges/herb-rich pine forest	105	0.07	0.04
49/28	pasqueflowers/sedges pine forest	130	0.70	0.35
49/31	sedges/herb-rich pine forest	130	0.30	0.15

Dose-response models have been developed to describe the effects of soil temperature, soil moisture content, and soil water-holding capacity on the decomposition of wood samples in contact with soil [14].

Depending on the direction and degree of change in temperature and humidity (climatic gradients), their combined influence on the intensity of gas exchange (CO₂-O₂) can either strengthen or weaken it [15].

Note that the decomposition process is time-consuming. According to an exponential model that displays biomass loss over time since death, *Fagus Sylvatica* L. trunks with a diameter of 50–90 cm decompose the slowest, taking 51 years. *Picea Abies* L. and *Abies alba* Mill. decompose in 71 and 72 years, respectively [16].

Foreign scientific literature emphasizes the processes of wood decomposition as an integral part of carbon emissions from the forest ecosystem.

It is important to note that the amount of stump carbon in the study area is minimal and has an insignificant impact on emission processes.

4 Conclusion

The research yielded the following main conclusions:

- the pine forests under study were found to have high density and productivity, suggesting a minor disturbance of the stands;
- the total growing stock ranged from 235 to 643 m³ per ha⁻¹ across the individual forest sites. The stock of stumps was negligible, ranging from 0,23 to 2,21 m³ per ha⁻¹;
- the pine stands studied show a predominance of stumps in the 2nd (39.1%) and 4th (36.3%) decay classes. This suggests that the silvicultural practices employed in the area were implemented over a decade ago;
- the mass of stumps varied from 0,07 to 0,70 t per ha⁻¹;
- the stumps carbon reserve varied from 0,04 to 0,35 t C per ha⁻¹.

Compensatory reforestation in pine forests affected by pathogens and secondary insect pests is possible after 15 years or more, once the stumps have reached the 4th or higher decay class.

Stump wood decomposition processes play a crucial role in forest productivity, nutrient cycling, carbon decomposition and sequestration, and form the forest ecosystem carbon pool.

The research was carried out within the project «Restoration of Central Siberian Taiga Forests Disturbed by Insect Pests» (№ FEFE-2024-0029) within the framework of the state assignment, set out by the Ministry of Education and Science of the Russian Federation, for the implementation by the Scientific Laboratory of Forest Ecosystem.

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