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PREREQUISITES FOR UPDATING THE CARBON ASSESSMENT OF RUSSIAN FORESTS

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Abstract

Forests play a vital role in capturing and storing carbon dioxide through various mechanisms. Accurately measuring the carbon sequestration capacity of woody biota is critical to mitigating climate change and developing effective forest management strategies. However, existing methods for accounting for carbon sequestration by woody plants are considered imperfect. Leaf uptake through photosynthesis, carbon storage in trunks, branches and roots, and storage in soil and litter are the main pathways for carbon sequestration in forest ecosystems. The distribution of carbon stocks in different components of forest ecosystems varies depending on the type of vegetation, the age of the forest stand and climatic conditions. Large-scale commercial timber harvesting and increased natural disasters such as wildfires can significantly change the carbon balance of forest ecosystems. Predicting these changes requires taking into account carbon losses associated with deforestation and emissions associated with wildfires. Reliable assessment of the level of carbon sequestration by woody biota is critical for the development of effective climate change mitigation strategies and sustainable management of forest resources. Improving assessment approaches, understanding different sequestration mechanisms, and predicting changes in the carbon budget are key areas for future research. Updating Russia's forest registry through an inventory of unrecorded forest stands will also contribute to a more accurate accounting of carbon sequestration on a national scale. The economic motive of entrepreneurs may be the possibility of subsequent implementation of the carbon quota.

Keywords: Boreal forests, carbon sequestration capacity, carbon dioxide, carbon sequestration, forest ecosystems, forest rejuvenation

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1. Introduction

Decarbonization is the latest trend of the new century to localize the further saturation of the atmosphere with carbon dioxide. The dynamics of the specific gravity of carbon dioxide in the composition of the atmosphere indicates that the ability of carbon absorption by earth landscapes, including forests, is significantly limited: greenhouse gas emissions are more than twice higher than the potential for absorption of CO2 by the planet. As a result, the concentration of carbon dioxide is approaching the critical point of global environmental sustainability (Ahmad et al., 2024; Singh et al., 2024; Waite, 2024).

2. Problem Statement

The article analyzes the specifics of carbon absorption by forest landscapes of the Russian Federation under various environmental conditions.

3. Research Questions

The gas structure of the atmosphere and reserves of deposited carbon dioxide depend on the area and species composition of forest stands. The forests of the Russian Federation occupy about a quarter of the total area of the planet forest stands and 50% of the boreal forests. The average total wood growth exceeds 1,000 cubic megameters per year.

However, the forests of Russia are extremely differentiated in terms of species and age composition, their natural and climatic confinement, ecological state and exposure to natural processes. Consequently, the quantitative and qualitative parameters of forest stands are characterized by a pronounced spatial scatter. Therefore, the average conversion of standing live wood into the mass of absorbed carbon dioxide with a coefficient of 0.5, which has become noticeably widespread in the country, may turn out to be losing. In this case, Russian forests may be underestimated in terms of carbon absorption potential. Therefore, it is advisable to update the main factors that determine the level of current values of carbon dioxide deposition by forest stands.

4. Purpose of the Study

The main purpose of the work is to update the prerequisites for a reliable assessment of the carbon potential of Russian forests.

5. Research Methods

The following methods were used:

i. complex analysis of scientific literature on global carbon problems and factology;
ii. generalization for the analysis of Russian and foreign approaches to optimizing the global carbon balance;
iii. abstraction to isolate thermal indicators from a variety of forest carbon potential factors;

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iv. comparison in the analysis of the carbon capacity of forest stands in differentiated natural and climatic conditions of Russia.

6. Findings

The carbon storage capacity of forests depends on the intensity of photosynthesis, which increases linearly with increasing light levels, reaching gradual saturation. When lighting is 100 W/m2, the increase in photosynthesis stops. Only when the light intensity is above a certain indicator (depending on tree species), known as the light compensation point, forests absorb more carbon dioxide than they release during cellular respiration (Malysheva, 2017).

To convert solar radiation into organic matter, the forest stand uses no more than 1% of the light energy entering the surface of the foliage. Plants perceive about 1500 cal of solar radiation per 1 m2; therefore, only 15 cal is converted into plant matter (Fedorov, 2014). The process of photosynthesis proceeds most intensively in the thermal conditions from 15º to 25ºC. At higher temperatures, dehydration begins, and the processes of respiration and transpiration of plants prevail over photosynthesis (Lipich & Balahura, 2024; Regnerová et al., 2024; Shumilina & Antsiferova, 2024).

Temperatures below 10ºC are also a stressor for the photosynthesis process. It is no coincidence that the indicators of carbon dioxide fixation in the taiga forests of Eastern Siberia and the Far East are only 0.45–0.7 tons per 1 ha (Zamolodchikov et al., 2018). At the same time, some weakening of the thermal limiting factor can be predicted due to a pronounced trend in the growth of the average annual temperature in the Russian North. The result of this trend may be an optimization of the relative humidity gradient. The continuation of this trend should increase the carbon potential of boreal forests.

An important indicator of the photosynthetic capacity of forests is the leaf area index, which expresses the ratio of the total area of the illuminated foliage surface to the area occupied by the forest stand. During the formation of 1m leaves, the carbon dioxide absorption equivalent varies between 1.7–1.84. Deciduous species absorb about 63 tons of carbon-containing organic substances per year per 1 ha (Krasutsky, 2018).

Deciduous natural plantations are characterized by higher assimilation rates and the highest parameters of biological productivity. A significant number of leaves also compensates for other factors that limit the intensity of wood pulp formation. The largest debit of net production corresponds to a leaf area index close to 4. This means that the illuminated surface of the leaves is 4 times higher than the area occupied by the stand. The maximum gross production for mature deciduous forests is achieved at an index of 8–10 (Fedorov, 2014).

The real increase in dead and live phytomass is characterized by the NEP (net ecosystem production) indicator. If the NEP is positive, the forest "binds" CO_2 and the carbon system functions as a sink for atmospheric carbon. If it is negative, the forest works as a supplier of carbon dioxide.

On average, there are 1.83 deposited carbon dioxide per ton of live wood at the root. In the most extensive temperate zone, where the main forest massifs of Russia are localized, the annual growth of forest stands is estimated at an average of 8.2 m^3 with a specific weight of wood of 0.65 (Krasutsky, 2018). Therefore, if these indicators are multiplied by the area of forests, it is possible to reveal a reliable

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volume of oxygen release and carbon dioxide uptake by the forest stand. For different forests, quantitative indicators may be different.

The carbon situation should be studied by the scheme for calculating the deposited CO_2 proposed by Gavrikov and Khlebopros (2013) density of freshly cut wood → dry wood content in wet → carbon content in dry wood, carbon content in its dioxide → mass of carbon dioxide. The applied function of the harvested forest stand in the carbon mechanism is the maximum long-term retention of already bound carbon.

The results of the carbon assessment based on the two schemes can be tracked by mapping online carbon balance calculations using the satellite imagery and neural networks that have already been implemented in other environmental projects in Russia.

When assessing the carbon sequestration by forests, the concepts of increment and stock of timber are shifted. Logically, mature wood is harvested and its felling reduces the reserves of the forest fund. The NEP decreases by the amount of annual losses of the reduced photosynthetic potential of old-growth felled trees on an annual basis. Therefore, the carbon absorption balance on such lands remains a positive indicator.

After industrial logging, a fairly viable, well-lit natural undergrowth remains. At the initial stages of its rehabilitation, the size of the primary phytomass (P) exceeds the cost of respiration of young forests (R). Therefore, the P/R ratio is higher than 1. Young growth removes carbon dioxide from the atmosphere more efficiently, rapidly forming biomass with minimal carbon release due to the small amount of waste. Young forests assimilate CO_2 3–6 times more intensively than overgrown forest stands. This necessitates the introduction of special correction factors for carbon dioxide deposition in accordance with the current age of trees (Ryaboshapko & Revokatova, 2015). However, the implementation of this task is problematic, since the secondary forest stand is extremely heterogeneous in terms of age gradation, species and category composition. The derivation of this coefficient could be done by carbon polygons, which are now being formed in the Russian Federation.

As the young forest gradually develops, the P/R coefficient tends to be 1. This coefficient can be taken as a reliable indicator of the maturity of the forest community. A natural mature forest that has reached a balance between the death of old and the emergence of young generations is not a pronounced carbon absorber: the size of gas deposition is comparable to the volume of its release during breathing (Kokorin, 2018). Therefore, the carbon function of the old forest is to isolate the carbon dioxide removed from the atmosphere.

In the complex mechanism of the carbon cycle, a dilemma in adopting the carbon strategy arises: purposeful preservation of the maximum areas of mature forest stands saturated with carbon dioxide or its renewal with the most “gluttonous” fast-growing young stands. The managerial choice among alternative strategies will depend on the pace of formation of the global civilized carbon market.

In terms of carbon stock per unit area of forests, the leading position is occupied by the North Caucasus, the forest stand of which is mainly represented by mountain trees. Under the high transparency of the atmosphere, increased intensity of gas exchange is observed. The thermal stressor exerts a depressing effect on the mechanism of carbon dioxide uptake under the vertical zoning. Nevertheless, the deposition of CO_2 by the mountain forest per 1 hectare reaches 85–95 tons. For comparison, the reserves

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of fixed carbon in the forests of the Far East per unit area vary within 31–34 tons (Figure 01). Consequently, predominantly hardwood forests of the North Caucasus are more carbon-intensive and characterized by a significant wood density with comparable volumetric reserves.

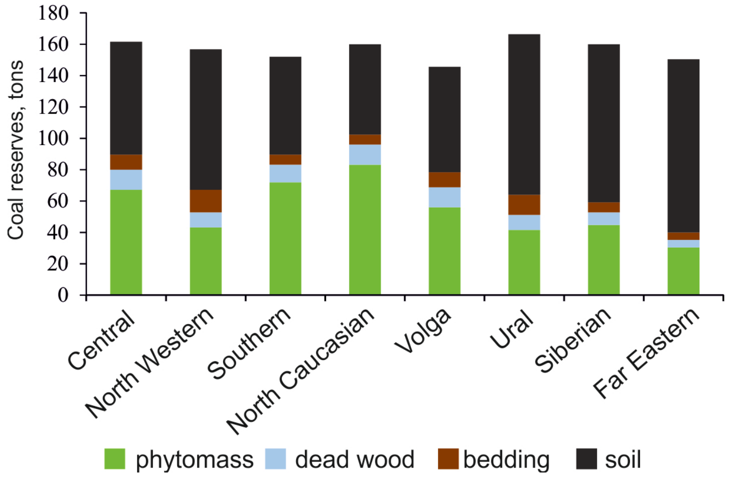

Figure 1. Average reserves of carbon dioxide within the forest areas of the federal districts of Russia (Zamolodchikov et al., 2018)

The reserve for increasing the comprehensive carbon assessment of Russian forests is the inclusion of reserve stands (about 1/3 of all forests), forest-steppe and forest-tundra landscapes of the Russian Federation, former agricultural lands (about 18 million hectares) overgrown with forests in the post-Soviet period in the forest register. However, the proposed change in the functions of post-agricultural lands may be limited by the excessive formal requirements of the Ministry of Natural Resources, which formally exclude forestry on overgrown lands (Dokuchayeva et al., 2024; Tang & Yang, 2024).

The carbon assessment of forests largely depends on the state of forest stands, which are characterized by productivity, phytopathological indicators, resistance to external influences, the degree of environmental disturbance, the ability to self-repair, etc. These parameters are tested for strength by various natural phenomena. Defending the true role of Russian forests in the global problem of carbon conservation may be complicated by the growing scale of forest fires.

The problem of annual mass destruction of forests can be mitigated by leasing forest stands with a high risk of natural impacts to investors. In this case, the economic interest of investors should be focused on the reliable protection of forests from pests and fires, followed by the possibility of implementing a carbon quota. We proceed from the fact that income from the sale of quotas will prevail over the costs of forest management, ensuring a high economic profitability of the project.

7. Conclusion

The differentiated forest areas, the vast areas of agricultural land taken out of circulation can become a sustainable capacity for conserving millions of tons of carbon dioxide, which gives Russia a chance to be a leader of the global carbon agenda (Ivanova, 2021).

Due to a pronounced increase in the average annual temperature in the Russian North, there will be an adjustment in the relative humidity of the air. This trend will increase the carbon potential of boreal

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forests. The dynamics of the carbon capacity of forest stands should be monitored by mapping the current online calculations of the carbon balance using satellite imagery and neural networks.

An unconventional reserve for increasing the carbon potential of Russian forests can be the lease of forest blocks to investors for targeted protection from natural impacts. The economic motive of entrepreneurs may be the possibility of subsequent implementation of the carbon quota.

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