Functional classification of forests: study of carbon sequestration

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Abstract. The article substantiates the relevance of developing a functional classification of forests based on the effectiveness of their performance of ecosystem functions. Using the example of nine types of coniferous-deciduous forests that dominate the European part of Russia and operate in autonomous positions of the landscape, we demonstrate a possible approach to assessing their function of regulating the carbon cycle based on the relationships between informative indicators of vegetation composition, soil macrofauna and ecosystem processes associated with sequestration soil carbon. The lowest level of soil carbon accumulation is characterized by coniferous-deciduous forests on sandy soils, characterized by low functional diversity and low earthworm biomass. A high stock of soil carbon is demonstrated by forests with a more uniform distribution of functional groups of plants with rapidly and slowly decomposing litter within the vegetation. This is explained by the creation of trophic and topical conditions favorable for the functioning of earthworms - active processors of litter in coniferous-deciduous forests. Large-scale assessment of the relationships between vegetation, soil biota, and ecosystem processes that shape the carbon cycle regulation function of Russian forests is an urgent scientific task in connection with climate change issues. Based on an assessment of the effectiveness of the performance of various ecosystem functions by forests of different types, identified in Russia using vegetation classifications, a functional classification of forests can be created.

1 Introduction

The primary objective of forest science is to develop a classification of forest types with predictive capabilities. Current approaches to forest typification are founded on dominant or indicator plant species characterizing the growing conditions within the forest, as well as on habitat condition types. For the forests of European Russia, a unified vegetation classification system has been established, integrating the dominant approach with ecological-coenotic and floristic analysis [1].

L.B. Zaugolnova and V.B. Martynenko have developed an electronic Identifier of Forest Types in European Russia, which provides a means to characterize the typological diversity of forests based on both domestic and foreign traditions of vegetation classification. This Identifier allows for the differentiation of approximately 160 forest

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types in the zone of coniferous-deciduous forests of the European part of Russia. In alignment with Russian soil classification, over 50 soil types are distinguished within forests, with at least 15 types emerging in the coniferous-deciduous forest zone.

Understanding the functional relationships between vegetation and soil is of great importance, particularly for evaluating the multifunctionality of forests [2]. Recent developments have emphasized the concept of forest multifunctionality, recognizing that forests simultaneously serve the functions of providing (wood, fiber), regulating (climate, hydrology), supporting (habitats, soil fertility), and cultural (recreation, health). Thus, there is a growing need to establish a functional classification of forest ecosystems.

While approaches to identifying functional groups or types of plants and soil biota have been advancing, the task of creating a functional classification for forests remains challenging. Although all forests are multifunctional, the extent to which they fulfill specific functions varies. By assessing the performance of functions within different forest biogeocenoses classified in Russia using vegetation classifications, it becomes possible to develop a functional classification of forests.

Forests in the Chechen Republic represent an important natural resource and have a diverse natural environment.

2 Research Methodology

Here are the key indicators used to assess the functionality of forests in carbon regulation (fig.1):

1. Projective Coverage of Functional Groups in Tier A [3]:

- Conifers: This group includes plants that produce litter with specific characteristics.
- Deciduous with Rapidly Decomposing Litter: Another group of deciduous plants that produce litter that decomposes quickly.
- Deciduous with Slowly Decomposing Litter: Deciduous plants that produce litter with a slower decomposition rate.

2. Projective Coverage of Tier B:

- Coniferous: The proportion of coniferous trees and shrubs in the canopy.
- Deciduous: The proportion of deciduous trees and shrubs in the canopy.

3. Projective Coverage of Layer C:

- Woody Plants (CS): This includes the projective cover of shrubs, shrubs, and trees in layer C that produce litter with low-quality characteristics.
- Herbaceous Plants (HH): This group includes the projective cover of herbaceous plants, such as grasses and sedges, with high-quality litter.

For a comprehensive assessment, 11 geobotanical descriptions (20 x 20 meters) were conducted in each forest type [4]. The goal was to understand the distribution and participation of plants with different litter quality in these forests. Here are some key findings across different forest types and regions:

Sandy Soil-Forming Rocks (SB):

- The share of deciduous plants with rapidly decomposing litter in the layer A cover varies slightly from 19% to 21%.

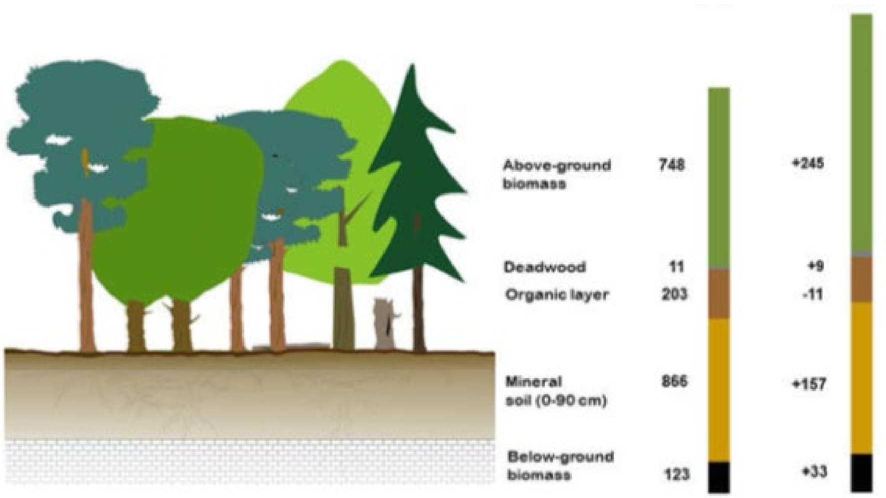

Fig. 1. Carbon storage [in Tg C] in forests and forest soils in Chechen Republic

- For deciduous plants with slowly decomposing litter, the variations are more significant, ranging from 2% to 31%.

- Conifers constitute a share of 48% to 83% in the layer A cover.

Loams (MOR and SZK):

- In both MOR and SZK regions, there are larger variations in the participation of plants with different litter quality.

- The share of deciduous plants with rapidly decomposing litter in the layer A of BP forests ranges from 17% to 97%.

- The share of deciduous plants with slowly decomposing litter in the layer A of BP forests varies from 3% to 59%.

- The share of conifers in the layer A cover of BP forests varies from 0% to 73%.

In general, the distribution of plants with different litter quality varies significantly among different forest types within the three regions. However, it's crucial to consider the distribution of these plant groups within the same sites, as this affects ecosystem processes associated with the carbon cycle [5].

For instance, some forests exhibit clear dominance of plants with rapidly decomposing litter, while others have a more balanced distribution. The lignin:N ratio in aging leaves varies among different tree species, affecting the rate of litter decomposition. This information can provide insights into the functionality of forests in regulating the carbon cycle and is valuable for the development of a functional classification of forests.

3 Results and Discussions

Assessing the effectiveness of forest ecosystems in regulating the carbon cycle involves examining the interaction of various biotic components and ecosystem processes. To create a functional classification of forests based on their carbon regulation capabilities, it's important to identify informative indicators that reflect the involvement of different trophic levels of biota in key ecosystem processes [6]. These indicators can help distinguish forests based on their capacity to regulate the carbon cycle. Below are some of the critical factors to consider when assessing the functionality of forests in carbon regulation (fig.2):

1. Phytomass and Mortmass: The assessment of the effectiveness of organic matter production by vegetation is influenced by factors like phytomass (plant biomass) and mortmass (dead plant material). These indicators are important for understanding the

carbon budget within a forest ecosystem. They can vary among different plant species, groups of plants, and the entire phytocenosis (plant community).

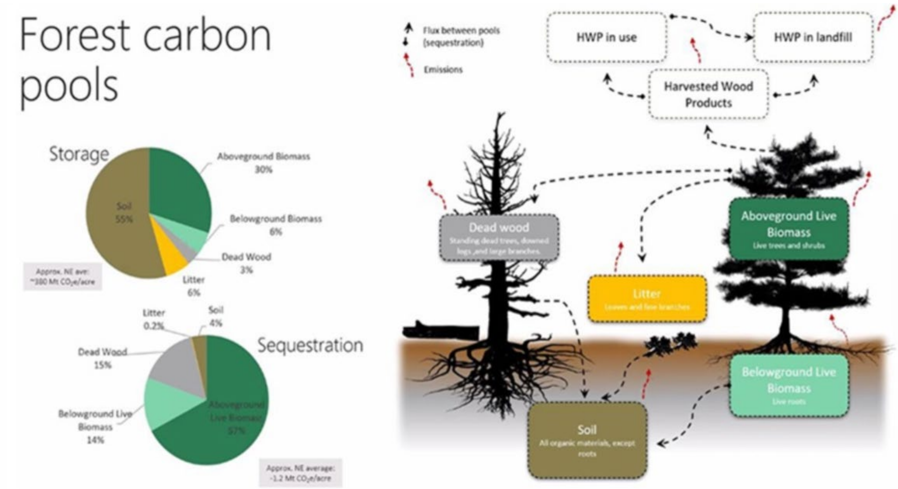

Fig. 2. Forest carbon pools and the approximate breakdown of the percent carbon stored and sequestered.

2. Tree Stand Density and Canopy Structure [7]: The density of tree stands and the overall structure of the canopy can impact the amount of sunlight that reaches the forest floor. This, in turn, affects the development of lower layers of vegetation. Additionally, the canopy structure can influence the penetration of atmospheric precipitation under the canopy, which affects the removal of carbon compounds from the ecosystem.

3. Age Dynamics and Successional Status: The age of plants, plant communities, and their successional status play a significant role in carbon regulation. The age of trees and the stages of forest succession influence various ecosystem functions. For carbon budget assessments, it's important to consider these dynamics.

4. Ecosystem Process Dynamics: To assess the carbon budget, it's necessary to measure the dynamics of key ecosystem processes [8]. This includes factors like the decomposition of litter, the emission of greenhouse gases, the exchange of carbon compounds between biogeocenoses and the atmosphere, and more. These dynamics can vary over different time scales, from long-term to daily and seasonal variations.

5. Litter Quality: The quality of litter, which includes its nutrient content (e.g., nitrogen, phosphorus, potassium, calcium, magnesium) and secondary metabolites (e.g., polyphenols, lignins), influences the rate of decomposition. High-quality litter, with more nutrients and specific ratios (C:N, lignin:N), decomposes faster than low-quality litter. This process has implications for carbon cycling and nutrient availability.

The interplay between these factors, which influence carbon sequestration in soils, is crucial to assess the effectiveness of different forest biogeocenoses in regulating the carbon cycle [9]. Key biotic components include vegetation, soil, and soil biota. Litter, as a connector between these components, plays a pivotal role in regulating carbon cycling and nutrient availability within the ecosystem.

Developing a functional classification of forests based on their carbon regulation abilities can help in forest management, conservation efforts, and climate change mitigation [10]. It's important to consider these factors collectively to gain a comprehensive understanding of forest functionality in carbon regulation.

4 Conclusions

Large-scale studies focusing on the relationships between vegetation, soil biota, and ecosystem processes, both in coniferous broadleaf forests and boreal forests in Russia, offer an opportunity to develop a classification of forests based on the efficiency of their function in regulating the carbon cycle. These assessments can be made using easily measurable indicators and drawing from existing and new data, including:

1. Geobotanical Descriptions: These studies provide insights into the composition of plant communities, including functional groups with different litter quality and decomposition rates. By examining the distribution of these plant groups within forests, their role in carbon cycling can be assessed.

2. Soil Biota Studies: Understanding the composition and activity of soil biota in different forest types helps assess their contribution to carbon cycling. This includes decomposers, nutrient cyclers, and other soil organisms.

3. Relationship Analysis: By analyzing the relationships between vegetation, soil biota, and ecosystem processes, researchers can gain insights into how different forests function in terms of carbon regulation.

4. Abiotic Factors: It's essential to consider abiotic factors such as climate, soil type, topography, and water availability. These factors influence forest functionality in terms of carbon cycling.

The goal is to create a functional classification of forests based on their effectiveness in performing various ecosystem functions. The development of these approaches will provide a more comprehensive understanding of how different forest types contribute to the carbon cycle and overall ecosystem health. This information is valuable for forest management, conservation, and addressing carbon-related environmental challenges.

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References

1. A. A. Daukaev, R. Kh. Dadashev, L. S. Gatsaeva, R. A. Gakaev, IOP Conf. Series: Earth and Environmental Science, 378 (2019)
2. R. A. Gakaev, I. A. Bayrakov, M. I. Bagasheva, Ecological foundations of the optimal structure of forest landscapes in the Chechen Republic. In the collection: Environmental problems. A look into the future. Proceedings of the III scientific-practical conference, 50-52 (2006)
3. R. A. Gakaev, Comprehensive assessment of the current state of the mountain-forest landscapes of the Chechen Republic and measures for their optimization. In the collection: Modern problems of the geoecology of mountain areas, 189-194 (2008)
4. E. Reynard, M. Panizza, Geomorphosites: definition, assessment, and mapping. Geomorphol Relief, 177–180 (2018)
5. EU-Russia Energy Dialogue, Energy Forecasts and Scenarios 2009–2010 Research. Final Report (2021)
6. K. Haegeman, F. Scapolo, A. Ricci, E. Marinelli, A. Sokolov, Quantitative and qualitative approaches in FTA: from combination to integration?, **80**, 386–397 (2021)

7. R. Kh. Ilyasov, Spline modeling and analysis of relationships in the economy with the possible presence of regression switching points, **11(4)**, 165-175 (2018)
8. K. M.-S. Murtazova, Ecological and economic assessment of sectoral agricultural technologies, **3(15)**, 68-71 (2021)
9. A. S. Salamova, Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, **17(1)**, 237-245 (2023)
10. A. S. Salamova, Global networked economy as a factor for sustainable development, 03053 (2020)