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The world's forests are a stabilizing element of the climate system

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Abstract. In addition to climate change bringing high temperatures and drier weather, factors that increased the severity of wildfires or drought-factories caused by climatic change — factors that increase the severity of wildfires and fired forests—the potential of some forests to fully recover from such extreme weather conditions may be hampered or even weakened by past and present land management practices. At the moment, returning to normalcy may be difficult even in areas with occasional wildfires that are an integral part of ecosystem development. The long-term effects from human influenced change disrupt this natural dynamics and can lead to disruption for some reason even in areas where occasional wildfires are an integral part of ecosystem development, as the long-term effects of human-induced climatic change disrupt these natural dynamics. Wildfire intensity can lead to short-term increases in gasoline prices, long-term declines of carbon sequestration capabilities and an unexpected decrease in carbon stocks for the regions that have not experienced fire in the past.

1 Introduction

The phytomass of Russian forests is estimated to contain approximately 75.5 petagrams (Pg), which is equivalent to 75.5 billion metric tons of dry organic matter. In terms of carbon content, this amounts to about 37.5 ± 1.5 Pg of carbon, with an average carbon reserve of approximately 4.56 ± 0.19 kilograms of carbon per square meter (kg C m–2).

The distribution of phytomass is not uniform across Russia [1]:

- The European part of Russia contains roughly one-fourth of the total phytomass, with an average reserve of 5.66 kg C m–2.

- The Asian part of Russia holds the remaining three-fourths of the phytomass, with an average reserve of 4.28 kg C m–2.

In the country as a whole, 57.4% of the phytomass is found in stem wood, 10.3% in crown wood, 22.6% in roots, and 3.5% in leaves/needles. The lower tiers, including undergrowth, undergrowth, and living ground cover, make up a combined total of 6.2% of the total phytomass. Of the total phytomass, 74.6% is above-ground phytomass.

There is a clear zonal gradient in phytomass distribution [2]:

- The average carbon reserve increases from tundra forests (2.83 kg C m–2) to the temperate forest zone (6.74 kg C m–2).

- Southward from the temperate zone, there is a decline in average carbon reserve to 4.23 kg C m–2.

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The structural composition of phytomass shows an increasing share of underground phytomass in northern regions, especially in the Asian part of Russia.

The phytomass of tree stands belonging to the main forest-forming species makes up 97% of the total phytomass in Russian forests, with the following breakdown among key species:

- Pine: 16.5%
- Spruce and fir: 15.3%
- Larch: 30.2%
- Cedar: 7.6%
- Birch: 17.5%
- Aspen: 4.0%

In terms of age categories:

- Young trees make up 5.2%.
- Middle-aged trees contain 26.6%.
- Ripening trees represent 13.2%.
- Ripe trees account for 29.5%.
- Overripe trees contribute 25.5% of the total phytomass.

The passage you've provided highlights the critical role that Russia's vast forests play in terms of carbon sequestration, global climate impact, biodiversity conservation, and the provision of ecosystem services [3]. It also addresses the challenges and threats faced by these forests, particularly due to climate change. Here's a summary of the key points:

1. Importance of Russian Forests: Russia boasts nearly 800 million hectares of forests, which are globally significant due to their size and carbon sequestration capacity. These forests also provide essential ecosystem services and are vital for biodiversity conservation.

2. Management Challenges: Managing such vast forests is complicated, especially in remote and sparsely populated areas with limited infrastructure. The extensive exploitation model of forest management has led to adverse effects, such as a decline in forest quality and changes in species composition.

3. Natural Disturbances:Russian forests face threats from natural disturbances. Each year, around 10-15 million hectares of forest plantations are damaged due to these disturbances. Climate change is expected to intensify these disturbance regimes, including wildfires and insect outbreaks.

4. Carbon Sink and Variability:Russian forests have been acting as a carbon sink, absorbing significant amounts of carbon dioxide. However, this role can vary due to interannual weather variability and disturbances. Notably, some areas, particularly disturbed forests and permafrost regions, may temporarily release carbon.

5. Climate Change Impact:*Russia has experienced substantial warming over the past four decades, at a rate approximately 2.5 times the global average. Precipitation patterns are also changing, with an increase in many regions. Extreme events and hydrological hazards have become more frequent.

6. Future Projections:Climate change projections indicate continued warming trends, with varying patterns of precipitation change across the country. Extreme events and variability are expected to increase, particularly in certain regions.

This passage underscores the need for a systematic analysis of Russia's forest resources, their role in carbon sequestration, and their vulnerability to climate change [4]. It highlights the importance of understanding and addressing the challenges that climate change poses to these critical ecosystems.

2 Research methodology

The passage discusses the various impacts of climate change on Russian forests and emphasizes the need for adaptation measures. Here are the key points [5]:

1. Climate Change Impacts:Climate change is expected to have diverse impacts on Russian forests. Warming temperatures and longer growing seasons are likely to increase net primary productivity, particularly in the northern regions. However, there is a significant threat of increased aridity in the southern ecotone, which poses challenges for forest ecosystems.
2. Natural Disturbances: Climate change is expected to lead to more intense and frequent natural disturbances in Russian forests, such as wildfires and insect outbreaks. These disturbances can result in carbon emissions and disrupt the sustainable carbon cycle in forests.
3. Importance of Adaptation:Adaptation to the risks associated with natural disturbances is crucial for the resilience of Russian forests and the forest sector. Furthermore, efforts are needed to restore forests following such disturbances. These events can also drive changes in forest characteristics, presenting opportunities for adaptation, like modifying species composition to better suit changing conditions.
4. Regional Specificity: Climate change impacts vary regionally, and adaptation measures must be tailored to local conditions.
5. Challenges in the Forest Sector: The passage highlights several challenges in the Russian forest sector, including the decline in the area of productive forests, the negative impact of natural disturbances on timber quality and quantity, and the lack of adequate measures for reforestation.
6. Need for Transformation: Transforming Russia's forest sector is essential, and this transformation should be based on a new forest policy. It should involve sustainable forest management practices, increased investment in the sector, and improvements in forest inventory, monitoring, and protection systems. Additionally, strategies for adapting to predicted natural disturbance regimes should be integrated.
7. Forest Education:To address these challenges, the passage suggests changes to the forest education system. This includes incorporating climate change information and adaptation measures into higher education and retraining programs for forestry personnel.

In summary, the passage underscores the importance of proactive measures to adapt to the changing climate and improve the management and resilience of Russian forests and the forest sector.

3 Results and Discussions

One of the key challenges mentioned is the lack of "ecological information," particularly detailed forest stand inventory data [6]. This ecological information is necessary to ensure the accurate extrapolation of data on phytomass and its annual growth to the entire forested area of a forestry enterprise.

In foreign countries, forest inventory data, including information about individual trees within stands, is combined with assessments of phytomass and carbon pools. These assessments often involve using regression models to estimate phytomass productivity at the tree level, especially in mixed forests [7]. This approach is integrated into international reporting standards like those of the Food and Agriculture Organization (FAO) and the Intergovernmental Panel on Climate Change (IPCC).

However, in Russia, a different forest inventory technology has been historically employed. The elementary unit for forest stand inventory is the taxation unit, which is a relatively homogenous forestry unit characterized by specific taxation indicators. These units, along with orthogonal matrices, serve as the basis for extrapolating data on phytomass from sample plots to the entire forested area of the forestry enterprise and the broader territorial complex.

In summary, the methodology outlined aims to assess carbon content in forest phytomass in a territorial entity. It includes structuring databases, modeling phytomass, and integrating ecological data to ensure accurate assessments, even though the forest inventory approach in Russia differs from some international standards.

Fig. 1. Human impacts on the World Heritage Site Virunga National Park in the Democratic Republic of the Congo: illegal land clearing within the park (left) and farming areas bordering the park (right).

The Landscape-Ecosystem Approach (LEA) is a method for systematically assessing the carbon cycle based on rigorous principles of applied systems analysis. In the context of assessing PUB (Protected Unfragmented Boreal) landscapes, LEA has specific requirements:

1. Use of Strict Definitions and Classification Schemes: LEA requires clear, unambiguous, and formally consistent definitions and classification schemes.

2. Unambiguous Structuring: The computational scheme for assessing the carbon cycle must be structured with clarity in terms of spatial, temporal, and process relations.

3. Calculation of Uncertainties: LEA mandates the calculation of uncertainties at all stages and for all assessment modules.

4. Use of Formally Consistent Algorithms: It employs algorithms that adhere to a formal and consistent methodology.

5. Explicit Representation of Results in Space and Time: The results are explicitly represented in both spatial and temporal dimensions.

To implement LEA, a carbon flow method with elements of a stock change method is used [7]. The completeness and spatial reference of ecosystems and landscapes enable the use of power lines as a structural basis for comparison with other methods.

The information foundation for LEA is an integrated land information system (ISIS), which compiles and organizes various land-related data. ISIS includes data from multiple sources, such as ground and satellite information, in-situ measurements, inventory data (e.g., forest and land records), empirical generalizations, models, and more. It's a multi-layer and multi-scale geographic information system that employs a hierarchical classification of hybrid land cover, with different levels of detail depending on the class's significance in the PUB assessment [8].

For estimating organic carbon stocks in forest ecosystems, the following reservoirs are considered:

1. Phytomass [9]: This includes various components such as trunk, branches, leaves/needles, tree roots, undergrowth, and living ground cover. The stock of phytomass is calculated based on taxation characteristics of forests using multidimensional models.

2. Fallen Wood: This encompasses dead wood, fallen trees, stumps, and dead branches of growing trees. The estimation relies on a variety of data sources.

3. Soil: The calculation of carbon reserves in soil is based on an automated information system, which uses soil maps, typical profiles for soil types, and various environmental factors to estimate the carbon content in both the litter layer and the underlying soil to a depth of 1 meter.

The approach used here combines a wide range of data sources and models to provide comprehensive assessments of organic carbon stocks in forest ecosystems [10]. It ensures that ecological factors, land use, and disturbances are considered in these estimates to provide a detailed understanding of carbon storage and flows within these ecosystems.

4 Conclusions

The provided information outlines the purpose of the World Cultural and Natural Heritage Convention, emphasizing the importance of preserving significant places recognized for their Outstanding Universal Value (OUV). Here are the key points:

1. Convention Objectives: The World Cultural and Natural Heritage Convention aims to protect and preserve the most significant sites on Earth due to their OUV. It provides a mechanism for monitoring the conservation status of sites included in the UNESCO World Heritage List.

2. Reactive Monitoring Procedure: The reactive monitoring procedure involves reporting on the conservation status of identified World Heritage properties that are at risk. These reports help identify specific challenges to the preservation of their OUV, both within the site boundaries and in their immediate vicinity.

3. Role of the World Heritage Committee: The World Heritage Committee, as the governing body of the Convention, reviews and assesses the situation at the relevant sites based on these reports. If necessary, it can decide on specific measures to address systemic issues.

4. Significance of Reports: Since 1979, more than 1,500 State of Conservation reports have been submitted for over 180 natural and mixed sites. These reports are valuable sources of factual information that continue to be used to monitor security concerns under international conventions.

5. IUCN World Natural Heritage Outlook: To comprehensively analyze the status of all natural and mixed heritage properties, the International Union for Conservation of Nature (IUCN), the technical advisory body for natural environmental matters, prepares a report called "IUCN: World Natural Heritage Outlook."

6. Threat Categories: The report mentions a set of threat categories based on the Open Conservation Standards classification. It includes general threat categories such as climate change and extreme weather events, impacts on natural ecosystems (including fires), agricultural production, and biological resource exploitation.

7. Climate Change-Related Threats: Climate change and extreme weather events include subcategories like hurricanes/floods, extreme temperatures, droughts, and range shifts/changes. Severe fires are considered climate change-related threats due to their association with extreme temperatures and droughts.

8. Unsustainable Land Use Patterns: The report combines the categories of agricultural production and biological resource exploitation into the more general term "unsustainable land use patterns" to reflect the broader impact of land uses on World Heritage properties.

Overall, this information highlights the comprehensive approach taken to monitor and address threats to World Heritage sites, especially natural and mixed heritage properties, in the context of the Convention's objectives.

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