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GEOGRAPHY

Assessments of the Forest Carbon Balance in the National Climate Policies of Russia and Canada

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Abstract—This paper examines the role of forests in national climate policies of two countries very rich in woods: Russia and Canada. Canada has made efforts to reduce direct CO_2 emissions in the national economy, intensify forestry, and increase greenhouse gas sequestration by forests. Russia focuses on the verification and recalculation of the carbon sequestration capacity of its forests. Analysis of the Russian and Canadian stationary models used to assess the carbon sequestration capacity of forests (ROBUL and CBM-CFS, respectively) shows that both the Canadian model and the Russian one derived from it reflect the stationary dynamics of forest stands, which inevitably results in a downward CO_2 absorption trend. Even if the forest inventory is updated on a regular basis, the predictive components of such models are unable to take into account the variability of forest ecosystems and their adaptation to climate change. Models that describe global carbon fluxes (e.g., ones using FLUXNET and remote sensing data) provide significantly higher net carbon sequestration values and indicate a nondecreasing net carbon accumulation trend in forests. It is concluded that stationary and remote sensing models should be used together to assess net carbon sequestration and formulate key principles of national climate policies in countries rich in forests.

Keywords: national climate policy, boreal forests, carbon balance, Russian Federation, Canada

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Forests play an important role in the national climate policy of Russia, which places it on a par with other countries rich in woods: Canada, Brazil, the United States, etc. The purpose of this study was to compare the national climate policies of countries with predominantly boreal forests, namely the Russian Federation and Canada, and assess the role of the greenhouse gas (GHG) balance in the forest sector as a factor affecting the national climate policy formation. Negotiations conducted by the Russian Federation under the Paris Agreement, including transboundary carbon regulations and the EU Carbon Border Adjustment Mechanism (CBAM), require a good understanding of the role of forests in national climate policies of countries rich in woods.

Russia ranks first in the world in terms of the total area of its forests, while Canada is in third place after Brazil. The total area of forests in Russia (815 million ha) is 2.3 times larger than in Canada (347 million ha) [1]. According to estimates produced for 2018, the specific GHG sequestration per 1 ha of forest was 0.90 t/ha in Russia and 0.65 t/ha in Canada [14, 15]. Some 90% of forests in Russia and Canada are boreal; almost all forests in both countries are state-owned. Both Russia and Canada include significant areas of reserve forests not used in forestry. The two countries experience similar problems, including extensive forestry techniques, increasing forest fire rates, and outbreaks of forest diseases in recent years as a result of climate change.

In Canada, the priorities of the state climate policy are formulated in a number of government documents (e.g., Canada Action on Climate Change [5]). In Russia, priorities of the state forest climate policy are largely outlined in the Forest Complex Development Strategy of the Russian Federation until 2030 and in the Long-Term Development Strategy of the Russian Federation with Low Greenhouse Gas Emissions until 2050 [4]. These priorities are presented in Table 1 produced on the basis of the above sources.

The main difference between Russia and Canada is in their different understanding of the role of forests in greenhouse gas sequestration (Fig. 1). For instance,

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Table 1. Forest climate policy priorities in Canada and Russia

Forest climate policy directions	Canada	Russia
Increase carbon sequestration	Better forest protection against fires and diseases, dedicated programs to increase GHG sequestration by forests	Better forest protection against fires and diseases
Policy to increase the use of timber and wood products in the national economy	Significantly increase the use of timber in construction, industry, and transport	Wooden housing support program
Biofuel policy	Significant increase in the use of biofuel and bioproducts	Regional support programs to replace diesel fuel with biofuel
Innovative agriculture and forestry	Promotion of innovative forestry practices, including forestry intensification	Better forest restoration and afforestation
Adaptation and resilience	Adaptation to climate change with the focus on increasing the resilience (resistance) of forests to climate change	National and regional forest ecosystem adaptation programs

according to the National Reports submitted to the UN FCCC by Russia [15] and Canada [14], forests absorb some 30% of aggregate GHG emissions in Russia and only 3% in Canada.

It must be noted that the National Inventory Report of Canada estimates GHG emissions from harvested wood products (factor 4G) at some 125 million t CO_2 equivalent; while in Russia, this parameter is estimated at only some 4 million t CO_2 equivalent per year. Such a large difference, most likely, originates from the different techniques used in these countries to assess emissions from harvested wood products. If the net carbon absorption by forested lands in the LULUCF sector and the contribution of harvested wood products (HWP) to the GHG balance are put together, then the difference in net carbon sequestration between Russia and Canada will be 4.4 times, which seems to be more reasonable than 27 times (Fig. 1).

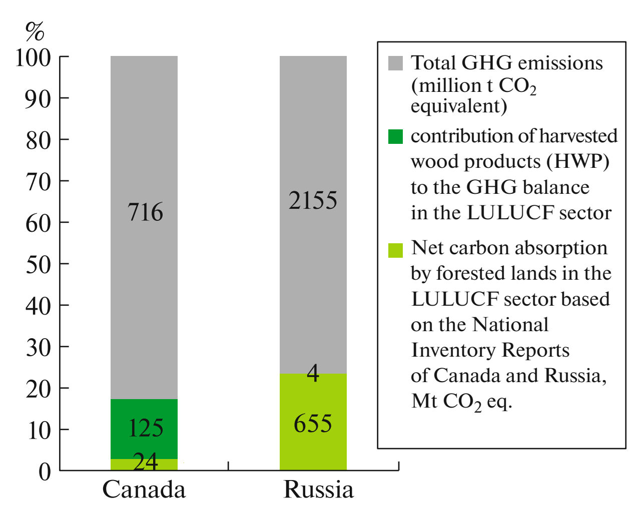

Fig. 1. GHG emissions and net sequestration by forested lands in Russia and Canada in 2017.

The primary objectives of the forest climate policy in Canada are to increase carbon sequestration by forests and adapt forests to climate change. In Russia, even the nationally determined contributions (NDCs) under the Paris Climate Accords rigidly bind the country's obligations to mitigate GHG emissions with the requirement to take into account the carbon sequestration role of Russian forests to the maximum extent. Accordingly, priority in the Russian Federation should be given to carbon sequestration (offset) forest climate projects; the results of such projects can potentially be used to reduce the carbon footprint of industrial companies and reduce the number and area of forest fires in unmanaged forests. In addition, similarly to Canada, it is necessary to put an emphasis on the adaptation of forest ecosystems to climate change; for instance, pure coniferous plantations highly susceptible to fires should be excluded from reforestation practices outside areas leased to forestry enterprises.

Currently, the Russian Federation and Canada use different techniques to assess the GHG sequestration capacity of forests. Russia strives to increase the official estimate of GHG sequestration by forests; for this purpose, methodological guidelines for quantitative assessments of greenhouse gas absorption have been altered without changing forestry practices. According to the Ministry of Natural Resources and Environment of the Russian Federation, the cumulative effect from the methodology correction may amount to an additional 270–450 million t of absorbed CO_2 [2]. The most commonly used models for GHG balance assessment in forests of Russia demonstrate a 4.6-fold data variation (Fig. 2).

It cannot be ruled out that the methodological guidelines were changed to increase the permissible limit of carbon units for the implementation of climate projects under Article 6.4 of the Paris Agreement. Earlier, within the framework of the Kyoto Protocol, the Government of the Russian Federation set the limit for joint projects at 300 million t CO_2 equivalent; apparently, now the goal is to increase it taking into account the introduction of the carbon tax on exported products. In theory, a broader involvement of nonforestry companies in forest climate projects could contribute to the solution of the most difficult and complex forestry issues: reduce the impact of forest fires and diseases, increase woodiness in sparsely forested regions, enhance the quality and efficiency of reforestation and protective afforestation, etc.

Canada's climate policy currently does not aim to revise approaches to the computation of the GHG balance in forests or increase the carbon potential of Canadian forests for implementation of offset forest climate projects. One of the priorities of Canada's forest climate policy is to increase greenhouse gas sequestration by forest ecosystems; this is a conservative but reliable approach. Issues such as increasing forest fire rates and outbreaks of forest diseases are relevant and significant for Canada as well.

The main model used at the state level to compute the carbon balance in Canadian forests is CBM-CFS3 (13); this is the most recent version in the family of models used as a prototype for the ROBUL model created in Russia. It must be noted that computations performed by models of the CBM-CFS type are primarily based on forest inventory data, data on various types of disturbances in the forest cover (fires, pests, felling, etc.), and models calculating biomass accumulation in vegetation and soil for various forest stands under various conditions [12, 17]. The official modeling results [9] indicate a smooth downward carbon absorption trend in managed forests of Canada: from 210 Mt CO_2 per year in 1990 to 150 Mt CO_2 per year. The major portion of the decrease in carbon absorption falls on the years 2000–2007; in this period, large-scale damage was inflicted on forest stands by pests.

The approach based on the traditional forest inventory has a significant drawback: it depends strongly on the quality of the primary data used in modeling (i.e., the inventory quality), and it is difficult to account accurately for processes such as succession and adaptation of ecosystems to new conditions. Models of the CBM-CFS type include four forest biomass growth phases (it is assumed that growth begins after the destruction of the previous stand, i.e., from scratch): regeneration (a very slow mass accumulation rate in the first 20 years of the stand development), growth of immature stands (the highest biomass accumulation rate), growth of mature stands (in fact, a stationary state), and growth of overmature stands (loss of biomass and stand destruction) [11]. Accordingly, forest stand inventories must be performed on a regular basis; otherwise, the CBM-CFS models demonstrate a steady downward carbon absorption trend. During the modeling period (in the case of Canada, some

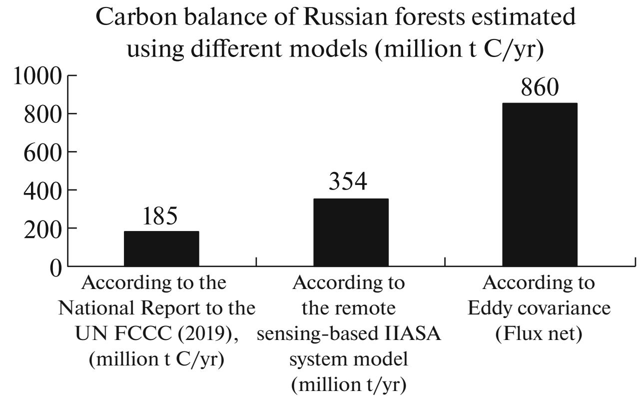

Fig. 2. Carbon balance of Russian forests estimated using different models: IIASA model [16] and Eddy covariance [8].

90 years), the stands could not only die, but also pass through the regeneration phase and already enter the active growth phase. Furthermore, retrospective data indicate a significant dynamics of CO_2 sequestration by forests of Canada. For instance, at the beginning of the 19th century, forests acted as carbon sinks at the level of ~40 Mt; while in 1870, forests turned into carbon emitters at a level of 130 Mt. In 1930, forests again became sinks with a volume of ~200 Mt/yr with a subsequent reduction in absorption to ~57 Mt/yr in 1990 [7]. Although these estimates cannot be treated as accurate, they give an idea of the nonlinear absorption dynamics determined by a significant variability in the state of forest stands over time, including processes such as adaptation and successions of plant communities.

Carbon balance modeling in Russian forests gives a similar picture: taking that the average age of the forest inventory data is 25–30 years or more, many overmature stands have already been transformed into young or middle-aged stands. Numerous researchers obtained similar results at the local level. For instance, remote sensing data indicate that 41% of forests in Tsentral'nolesnoi Biosphere Reserve have changed the dominant species over a period of 30 years as a result of natural processes and adaptation to climate change, and only 21% of overmature stands still retain their initial characteristics. All these changes have occurred without human impacts or major catastrophic events [3].

At the global level, researchers have analyzed changes in the Leaf Area Index (LAI) using remote sensing tools, noted significant adaptation processes in forest vegetation, and registered an overall increase in the LAI and phytomass in the past 35 years. An overall increase in biological productivity by 11.6% has been registered in the northern hemisphere during this period [6], which is consistent with an increase in the C3 photosynthesis productivity caused by the growing CO_2 concentration in the atmosphere.

It can be concluded that the official model currently used in Canada and the Russian model derived from it reflect the stationary dynamics of forest stands, which represents only a part of the reality. Such models will always demonstrate a downward trend in the carbon sequestration capacity of forests. Even if the forest inventory is updated on a regular basis, the predictive components of such models are unable to take into account the forest cover variability and adaptation. Another portion of the carbon balance modeling 'spectrum' is represented by models using remote sensing methods to determine forest types and phytomass growth. Such models often tend to overestimate the absorption capacity of the landscape cover. For instance, the model describing global carbon fluxes in forest vegetation developed by the World Resources Institute [10] estimates the average absorption over 20 years for the entire territory of Canada at 4320 Mt CO_2 per year (and even more for the Russian Federation). For Russia, models using remote sensing and FLUXNET data give a range of 1800–2500 Mt CO_2/yr. A study using both the State Forest Inventory (SFI) data (collected in 2007–2020 during the first SFI cycle) and remote sensing data gives an "intermediate" estimate of ~1270 Mt CO_2/yr [16]. The observed trends are multidirectional: stationary models indicate a decrease in the forest sequestration capacity, while global and regional studies based on remote sensing data indicate an increase in the biological production growth rate and adaptation of forest ecosystems to the elevated CO_2 content in the atmosphere.

The two approaches differ semantically. The stationary model approach implemented by the CBM-CFS family is useful in terms of forestry policymaking. For instance, the Canadian approach based on the national greenhouse gas inventory promotes intensive forest use, longer life of wood products, manufactory of complex durable products, and development of intensive environmentally sustainable forestry models [18]. By contrast, the remote sensing approach demonstrates how the environment adapts to changes in the greenhouse gas content.

Scientific descriptions of processes constituting the greenhouse gas cycle in forest ecosystems and the development of a global climate policy on this basis must take into account the influence of various economic and political factors on the national carbon balance estimates. The results of the current greenhouse gas inventory in Russia can hardly be recognized as comprehensive; however, the adoption of the 'highest' absorption capacity estimates as grounds for administrative and political decisions may cause no fewer problems. To solve them and ensure maximum objectivity, it is necessary to integrate modern approaches (remote sensing and FluxNet data, etc.) into the primary and summarized forest inventory materials, develop a thorough forest management strategy and administrative principles for greenhouse gas balance assessments in forests, and intensify international cooperation to ensure the compatibility and uniform interpretation of the data obtained.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest

The authors declare that they have no conflict of interest.

REFERENCES

1. *Global Forest Resources Assessment 2020* (Food and Agriculture Organization, 2020), pp. 136–142.
2. Ministry of Natural Resources and Environment of the Russian Federation Generated a Decree on Changes in Methodological Recommendations on Quantitative Determination of Greenhouse Gases Adsorption Volume (2021). https://www.mnr.gov.ru/press/news/minprirody_rossii_razrabotalo_rasporyazhenie_o_vnesenii_izmeneniy_v_metodicheskie_ukazaniya_po_kolich/.
3. Yu. G. Puzachenko, I. P. Kotlov, and R. B. Sandlerskii, Izv. Ross. Akad. Nauk, Ser. Geogr., No. 3, 5–18 (2014).
4. Russian Federation Long-Term Development Strategy with Low Level of Greenhouse Gases Emission till 2050. Project. https://www.economy.gov.ru/material/file/babacbb75d32d90e28d3298582d13a75/proekt_strategii.pdf.
5. Canada's Action on Climate Change. Federal Actions for a Clean Growth Economy (2017). https://www.canada.ca/en/services/environment/weather/climatechange/climate-action/federal-actions-clean-growth-economy/highlights.html.
6. J. M. Chen, W. Ju, P. Ciais, et al., Nat. Commun. **10**, 1–7 (2019).
7. W. Chen, J. Chen, and J. Cihlar, Ecol. Modell. **135**, 55–79 (2000).
8. A. J. Dolman et al., Biogeosciences **9** (12), 5323–5340 (2012).
9. ECCC (Environment and Climate Change Canada). National Inventory Report 1990–2018: Greenhouse Gas Sources and Sinks in Canada Part 1 (Government of Canada, 2020). https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/land-based-greenhouse-gas-emissions-removals.html.
10. N. L. Harris, D. A. Gibbs, A. Baccini, et al., Nat. Clim. Change **11**, 234–240 (2021).

11. W. Kurz and M. Apps, Ecol. Appl. **9**, 526–547 (1999).

12. W. A. Kurz and M. J. Apps, Mitigation Adapt. Strategies Global Change **11**, 33–43 (2006).

13. W. A. Kurz, C. C. Dymond, T. M. White, G. Stinson, C. H. Shaw, G. J. Rampley, C. E. Smyth, B. N. Simpson, E. T. Neilson, J. A. Trofymow, J. M. Metsaranta, and M. J. Apps, Ecol. Modell. **220** (4), 480–504 (2009).

14. National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada. Canada Submission to the UNFCC, part 1. https://unfccc.int/documents/194925.

15. National Report on Cadaster of Anthropogenic Emissions and Absorptions for 1990–2018 Years. https://unfccc.int/documents/194838.

16. D. Schepaschenko, E. Moltchanova, S. Fedorov, et al., Sci Rep. **11**, 12825 (2021).

17. C. H. Shaw, K. A. Bona, W. A. Kurz, and J. W. Fyles, Geoderma Reg. **4**, 114–125 (2015).

18. C. E. Smyth, G. Stinson, E. Neilson, T. C. Lempriere, M. Hafer, G. J. Rampley, and W. A. Kurz, Biogeosciences **11**, 441–480 (2014).

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