Regional features of forestry climate adaptation

Sergei Sinkevich[1*]

[1]Forest Research Institute of the Karelian Research Centre RAS, 11, Pushkinskaya St., 185610 Petrozavodsk, Russia

Abstract. A set of measures designed to mitigate and prevent the possible climate change impacts on forestry in the Karelian boreal forest region is proposed based on the analysis of climate dynamics in the study area, the species and age structure of forests and their designated use. The carbon balance was estimated for the forestry fund of ten central forest administrate districts differing in the tree species composition, productivity, and major designated use. Age-related patterns of carbon accumulation in stands formed by major tree species are demonstrated. The article substantiates the importance of tailoring regional carbon balance planning to the specific features of the territory and of applying an integrated approach to the assessment of the ecological potential of forests.

1 Introduction

A key trend in adaptation to climate change is the pursuit of carbon neutrality, attaining which through industrial technology upgrade costs 1.5-2 times more than through reducing emissions due to measures taken in agriculture and forestry [1]. It is argued that such “natural climate solutions” could deliver up to 60% of the needed offset of anthropogenic carbon emissions [2,3]. On the other hand, global forest sector estimates predict the world’s timber demand to grow by 49 percent between 2020 and 2050, chiefly due to demand for commercial roundwood [4], which will definitely have an effect on regions with logging-related economy. This significantly elevates the expert-recognized vulnerability of the world’s forests to the risks associated with climate change [5].

Boreal forests of Russia, which are a source of timber for global markets, are described by scientists from VNIILM institute as an “ecological donor for the planet, contributing to climate change mitigation” [6]. Not contrary to this judgment, an international team of researchers at the EFI has postulated, based on model experiments, that the potential to reach the Paris Agreement targets in Russian forests cannot be achieved without active forest management with a strong focus on natural disturbance prevention and enhancing forest sustainability [7].

The common vulnerability factors for forest land are changes in mean temperature, precipitation regime alteration, and extreme weather phenomena [8]. These factors can induce changes in forest productivity and tree species composition, increase the frequency of forest fires and other events causing forest damage.

[*] Corresponding author : sergei.sinkevich@krc.karelia.ru

The Paris Agreement proclaims that adaptation to the adverse impacts of climate change is a task to be addressed first and foremost at the local and regional levels using available scientific knowledge and local knowledge systems [9], which implies that regional natural and economic conditions are taken into account in adaptation action planning.

Forests of the Karelian boreal forest region, which belongs to the middle taiga subzone, have for nearly three centuries acted as a source of timber for the industry and construction in Northwest Russia, while at the same time being critical for the existence of Europe's largest and purest freshwater bodies. That is why the climatic role of these forests is essential in terms of both carbon deposition and water regulation globally as well as regionally. The diversity of the region's natural settings (geological, hydrological, climatic) requires that adaptation actions are tailored to its substantial specific features, avoiding one-size-fits-all approaches.

2 Materials and methods

The actions in climate policy implementation and conservation of the ecological potential of forests are to be based on information regarding the actually ongoing changes in growth conditions, particularly those during the growing season, when trees are active. Keeping this in mind, the set of adaptation actions was developed using data from long-term climate observations [10], annual digests and forecasts of the Russian Weather Service [11], and published results of regional scientific studies [12,13].

Carbon sequestration by forest stands was estimated following a technique adopted by the state weather service [14,15] using the dataset from forest inventories at the level of central forest administrate districts. The set of adaptation actions was selected in accordance with the standard forest plan form for provinces of the Russian Federation.

3 Results

Mean summer air temperature observed in the city of Petrozavodsk has remained at 15±2°C for 200 years. An increase happening in mean annual temperatures is due to the warmer autumn and winter months, which have no direct effect on growth processes in trees.

Noteworthy however is a steady warming trend (2° over 200 years) for November and December – the months that largely determine the conditions for winter timber harvesting. This trend has been expressed in the past 20 years in frequently alternating periods of thawing and freezing accompanied by lavish snowfall, which results in substantial snow accumulation on tree crowns, affecting their physical resilience.

Continuous temperature logging in a selectively cutted spruce stand during four winter seasons showed that the topsoil did not freeze even at -25ºC. Therefore, the timeframe available for safe selective cutting shrinks and its quality is a priori precarious.

At the same time, mean total summer precipitation has been growing steadily since the 1930s and annual precipitation amounts have increased accordingly [10,11,13]. Considering the overall background of precipitation prevailing over evaporation, this trend directly leads to a degradation of the water regime of soils and, hence, affects the growth conditions of forest stands and their resilience.

The Karelian boreal forest region falls into 3 agroclimatic districts and 4 soil heat supply districts divided by 200 degree steps in the sum of active temperatures [16]. The implications if this division for silviculture are the objectively existing differences in productivity and, hence, in the carbon balance.

This quick overview of the region's climatic parameters is given to prove there are essential details that distinguish the local situation from the global climate change landscape. Consequently, implementation of the climate agenda legislated through regional forest planning needs to be customized. The carbon balance of a region, which is a mandatory forest planning item, depends directly on the forest species and age structure, which can vary notably even within the relatively small Karelian boreal forest region, situated in the middle taiga subzone.

The combination of heterogeneous edaphoclimatic and economic conditions has a significant effect on the average carbon stock of forest stands. Its estimation for ten central forest administrate districts [14,15,17] revealed a variation range of 39–72 Mg C/ha (table 1). This alone makes it clear that the requirements to the carbon sequestration level cannot be the same for the entire forest region.

Table 1. The middle carbon stock in the forest stands with different dominant species in central forest administrate districts of Karelian boreal forest region.

Forest administrate districts	Forest area, thousands ha	Carbon stock, Mg C/ha			
		Pine	Spruce	Birch	Aspen
Suoyarvskoe	916.8	37.9	42.4	41.2	36.4
Kondopozhskoe	399.5	46.1	48.6	53.6	77.0
Medvezhyegorskoe	850.9	37.0	40.4	44.1	66.0
Pudozhskoe	881.8	48.4	49.0	45.4	56.8
Pryazhinskoe	447.6	42.1	49.4	50.5	54.8
Prionezhskoe	327.2	44.8	51.2	53.3	69.2
Olonetskoe	297.4	51.3	68.6	51.1	66.0
Pitkyarantskoe	175.3	52.4	79.7	55.5	60.4
Sortavalskoe	139.8	62.6	87.2	55.8	59.4
Lakhdenpohskoe	137.0	58.9	77.9	44.4	48.1

Correlation analysis revealed a non-linear relationship between the amount of carbon that gets fixed in plant biomass and the previously accumulated carbon stock. If the carbon stock grows to 50 Mg C/ha, its sequestration increases from 0.6 to 0.8 Mg C/ha/yr, where it nearly reaches a plateau and then remains at that level.

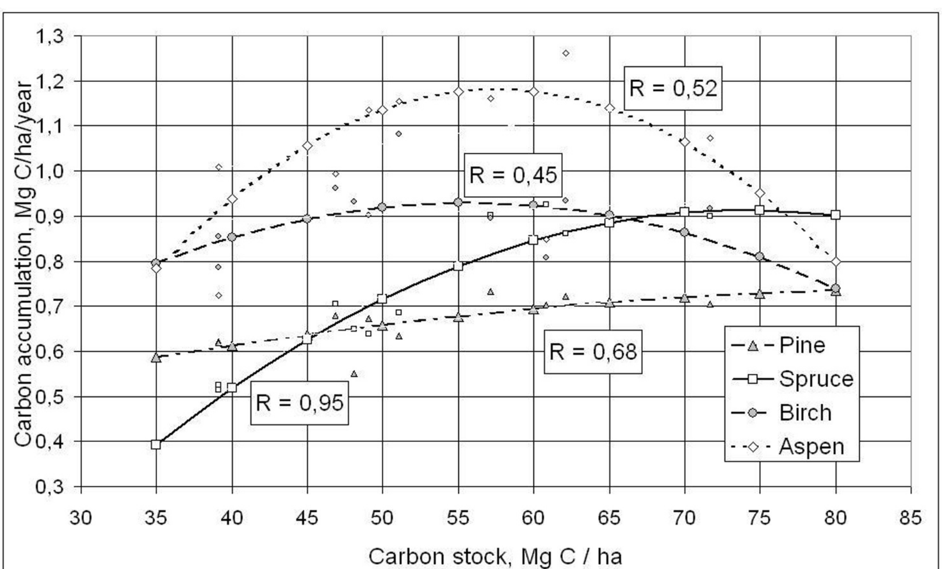

Fig. 1. Carbon stock and accumulation in forest stands with different dominant species.

A more detailed analysis of the numbers given above, taking into account the forest species and age structure, revealed significant differences in how this correlation is expressed in stands dominated by different tree species. Within the above-stated existing carbon stock range, pine stands sequester carbon at 0.6–0.7 Mg C/ha/yr rate and spruce stands at 0.5–0.9 rate (R=0.68 and 0.95, respectively). In stands dominated by deciduous species, carbon fixation grows until 55 Mg C/ha have been accumulated, after which fixation declines. The range of the change is 0.8–0.9–0.8 Mg C/ha/yr in birch stands and 0.9–1.2–1.0 in aspen stands (fig.1).

Our calculation results are similar to the estimates given by VNIILM for boreal forests [6] and demonstrate that the general pattern of carbon fixation by forest stands in southern Karelia is largely governed by the ratio of spruce and aspen contributions to the stand composition. Hence, the approaches to estimating carbon sequestration rates within the Karelian boreal forest region should differ qualitatively.

Carbon fixation from the atmosphere is an important yet certainly not the only aspect of fulfilling the ecological potential of forests. The cornerstones of their ecological functionality are their role in the global biosphere, which depends on the total photosynthesis rate and the corresponding impact on the gas composition of the atmosphere, as well as their critical importance for the regional water balance, quality of water resources, and quality of people's life.

A parameter inextricably linked to the photosynthetic process is transpiration, the rate of which is of paramount significance for offsetting the prevalence of precipitation over evaporation at the regional level [12]. The forest cover is a key element of the water cycle and a regulator of runoff to the numerous brooks and small rivers, whose riparian areas act as biodiversity refugia.

Owing to the interplay of forest and water resources, precipitation is cooled down and falls out, helping stabilize the local and regional climate [18]. The rate of water cycling in forest stands integrally translates into timber increment, which is a major factor for the stability of the regional economy.

The relative weights of the global and regional dimensions of climate policy goals depend on the designated use of the forest in each specific case. In the Karelian boreal forest region, the proportion of protective forests varies among central forest administrate districts from 20 to 100%. Analysis of available data shows that this parameter correlates quite closely (R^2=0.76) with the stand's carbon stock, which can be associated with natural differences between habitats as well as with the management system.

4 Discussion

In view of the above, it appears expedient to implement permanent actions grouped by major sources of climate-related risks.

As the productivity of habitats declines, young deciduous growth needs to be preserved in a substantial part of the felled area during 10-15 years to facilitate the quickest possible recovery of the water balance in the area, which, in turn, raises the costs of tending conifers at the pre-commercial thinning stage. An important thing is to utilize the natural regeneration potential of the stands by retaining advance growth during felling to ensure that the felled sites regenerate as coniferous stands, which are involved in water balance regulation throughout the year.

Simultaneous retention of commercially unwanted deciduous trees will help alleviate the adverse impact on soil and young regeneration; in wet habitats such trees will also hinder paludification. It is certainly necessary to optimize the hydrological regime of the forest land, which requires repairing and renovating the drainage network, which has operated without maintenance for over half a century.

The changes in the species composition observed in recent decades were induced by logging, so interventions in this matter are needed only to conform to the regular silvicultural guidelines with a focus on the growing of uneven-aged mixed stands. All local woody species can grow well in a fairly wide ecological range, so there is no need to introduce specially adapted species.

However, some general biodiversity conservation recommendations have been applied without due adjustment to the Karelian environment, causing a spatial expansion of young aspen stands in the north of the republic, where none of them used to occur, according to state forest inventory data.

Average fire frequency is quite low. As a rule, fires are quickly located and extinguished, but in some years fire-affected area can amount to several thousand hectares. The probability of increased fire frequency is directly related to wider countryside construction, improved transport accessibility, and increased forest visiting.

An additional risk element is the resurgence of outdoor recreation and the declared focus on tourism development in the economy. Collectively, these factors multiply the fire danger, the predominant hazard, statistically, being negligent handling of fire. Dry seasons occur in Karelia with usual predictable periodicity, wherefore the main objective of major measures should be to proactively neutralize anthropogenic factors.

Sources of insect pest propagation can appear only given an adequate increase in food supply. The circumstances described in the climate overview are potentially conducive to the development of pathological processes in the form of a growing number of weakened trees and fungal damage, leading ultimately to increased frequency of pest infections up to the emergence of their propagation sources. Preventive actions should therefore include permanent monitoring of forest stands affected by fires, logging or other factors, as well as prompt clean-up upon catastrophic windthrow events.

A proactive approach to extreme weather events implies, first of all, adherence to silvicultural guidelines as well as enhancement of timber harvesting planning and implementation techniques. Forest stands are to be managed so as to ensure their resistance to windthrow and snow breakage, first of all by means of early thinning of commercially valuable stands in silviculturally required volumes.

To maintain the ecological functionality of protective forests, which constitute a third of the state forestry fund, uneven-aged mixed and multi-layered forest stands are to be formed by means of selective felling [12,19]. To minimize the risk of windbreak and windthrow in commercial forests, the silvicultural principles of selecting trees for thinning and selective felling must be observed.

To avoid disrupting the hydrological regime of soils and the ensuing paludification, operations should be performed by the machines and techniques that minimize strip-road rutting, and the discharge capacity of permanent and temporary watercourses must be restored after logging operations are completed.

The above listing of key directions for climate policy implementation can be extended by adding forest cultivation in idle farmland, which is enabled by latest legislative changes. The studies and estimates for southern Karelia show young forests outrank hayfields in organic carbon accumulation [20].

5 Conclusions

The methods proposed for forestry climate adaptation even within a small forest region should take into account the diversity of its natural and economic conditions. The current level of centralization of the legal framework for forest planning is not quite adequate for such a cause.

Furthermore, the study area is largely a self-regulating "system of organized, systematic and institutionalized economic exchanges" in which "the right of disposal acts as a systemic factor" [20]. In this context, it appears that the implementation of the climate change adaptation policy in application to forest use, conservation, protection, and reproduction should focus on improving legal relations, streamlining the regulation of forest affairs, designing a system of relevant economic incentives.

Acknowledgements

The study was carried out within state assignments to the Karelian Research Centre RAS (Forest Research Institute).

References

1. A.V. Ptichnikov, E.A. Shvarts, G.A. Popova, A.S. Baybar, Bull. RAS **93(1)**, 48–61 (2023)
2. B. Griscom, J. Adams, P. Ellis et al, Proceedings of the National Academy of Sciences **114(44)**, 11645–11650 (2017)
3. S. Roe, C. Streck, M. Obersteiner et al, Nature Climate Change **9**, 817–828 (2019)
4. *Global forest sector outlook 2050: Assessing future demand and sources of timber for a sustainable economy – Background paper for The State of the World's Forests. FAO Forestry Working Paper, No. 31* (Rome, 2022) https://doi.org/10.4060/cc2265en
5. *The FAO Forestry Roadmap: From Vision to Action 2024–2031* (Committee on forestry, Rome, 2024) https://openknowledge.fao.org/server/api/ core/ bitstreams/c2f55a32-f70a-420f-813a-72769d554224/content
6. A.N. Philipchuk, N.V. Malysheva, T.A. Zolina, A.N. Yugov, Forestry inform **1**, 92–113 (2020) http://dx.doi.org/10.24419/LHI.2304-3083.2020.1.10
7. P. Leskinen, V. Lindner, P.J. Verkerk et al, *Russian forests and climate change: What Science Can Tell Us* (European Forest Institute, 2020) https://doi.org/10.36333/wsctu11
8. K. Fritzsche, S. Schneiderbauer, Ph. Bubeck, S. Kienberger, M. Buth, M. Zebisch, W. Kahlenborn, *The Vulnerability Sourcebook Concept and guidelines for standardised vulnerability assessments. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)* (Bonn, 2014)
9. *Paris agreement* (United Nations. Paris, 2015) https://unfccc.int/sites/default/files/russian_paris_agreement.pdf
10. *Scientific and applied reference book on the climate of the USSR. ser.3* (Hydrometeoizdat, Leningrad, Novgorod, Pskov, Kalinin, Smolensk regions, 1988)
11. *Reports on climate peculiarities in the Russian Federation for 2017-2022* (Rosgidromet, Moscow, 2017-2023)
12. Yu.V. Karpechko, N.L. Bondarik, *The hydrological role of forestry and timber industry in the taiga zone of the European North of Russia* (Petrozavodsk, 2010)
13. L.E. Nazarova, Proc. of the KarRC RAS **9**, 114-120 (2015)
14. D.G. Zamolodchikov, *Forest Carbon Budgeting Systems (Science and Education Course)* (Moscow, 2012)

15. *Methodological Guidelines for Quantification of Greenhouse Gas Absorption (approv. by Ministry of Natural Resources of Russia by 30.06.2017 №20-р)* (2017)
16. *Atlas of the Republic of Karelia* (General directorate of geodesy and cartography, Moscow, 1989)
17. *Forest plan of the Republic of Karelia for 2019–2028* (Petrozavodsk, 2018)
18. *Contribution of forestry to FAO's work on climate change and integrated water management* (Committee on forestry, Rome, 2024) https://openknowledge.fao.org/server/api/core/bitstreams/1c5cc4ca-6269-448f-8f11-d003dd339977/content
19. V.A. Ananyev, S.M. Sinkevich, *Recommendations for logging in protective forests of Karelia* (KarNC RAN, Petrozavodsk, 2015)
20. N.V. Genikova, I.A. Dubrovina, A.Yu. Karpechko et al, *Carbon vector of the ontological model of land management economics* (Petrozavodsk, 2023)