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GEOGRAPHY

Indicators in Estimation of Land Degradation Neutrality for Russian Boreal Forests

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Abstract—In this paper, we analyze the applicability of the land degradation neutrality (LDN) concept of the UN Convention to Combat Desertification to the Russian boreal forests. In this regard, it is necessary to adapt three global LDN indicators (land cover, land productivity, and carbon stock) to the assessment of land degradation processes of boreal forests in Russia and around the world. According to the research results, landscapes with different types of forest restoration dynamics can be viewed as an object of forest land dynamic studies. A set of LDN indicators adapted for boreal forests conditions has also been suggested in the course of our research. In order to assess LDN proxies, we calculated the retrospective and projected net carbon balance in the middle taiga zone of the Noshulskoye forest domain (Komi Republic, Russia) using the CBM CFS model. We explored three scenarios of forest net carbon balance under three different felling regimes. The net carbon balance should not be applied as an independent LDN indicator, because it does not take into account changes in species diversity and primary productivity. It is suggested that industrial felling should imitate natural types of restoration dynamics in order to achieve LDN targets. It can be reached through minimization of forest felling at sites with fireless types of succession, which accumulate maximum stocks of dead phytomass matter and serve as forest refuges supporting biodiversity.

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In 2016, the UN Convention to Combat Desertification (UNCCD) developed and published a scientific conceptual framework for Land Degradation Neutrality (LDN) [1]. A minimum set of three global LDN indicators was proposed under this concept. These indicators are considered as major for monitoring the effectiveness of national efforts to achieve the Sustainable Development Goal (SDG) 15.3:[1] (1) *state and changes of land cover*, (2) *land productivity*, and (3) *total organic carbon stock*. The areas correspond to the concept of neutrality if none of these indicators has shown deterioration for a certain time. The Russian Federation supports SDG, and its state policy is aimed at implementation thereof. The UNCCD scope covers not only arid, but also humid landscapes, including forested lands. According to [2], the main way to harmonize the national and global SDG 15.3 system is to supplement the existing national system with global indicators and to use them as general guidelines and criteria to control the objectivity of statistical data obtained by traditional methods.

In relation to forests, the *land productivity* indicator concerns the productivity of forests and shrub—meadow vegetation. Forest productivity is described by the total growth parameter. We offer *biodiversity* as a new LDN indicator for forests. One of the main differences of forests from other land categories is its high level. The Convention to Combat Desertification refers in Strategic Objective 4-2 to the need to understand the distribution and accounting of individual species (plants and animals). In this regard, it is proposed to include the biological diversity level and dynamics in the LDN assessment as an additional indicator (Table 1).

The issues of forest land degradation in humid conditions are considered by the example of a model middle taiga site located in the southern part of the Komi Republic ("Priluzie" model forest). The forestry area is leased for timber felling under commercial forest exploitation. According to Table 2, it can be concluded that the forest is not degraded under humid condi-

[1] SDG 15.3 "Until 2030, it is necessary to combat desertification, to restore degraded lands and soils, including lands affected by desertification, droughts, and floods, and to ensure that the global land condition does not deteriorate."

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Table 1. Approximate ratio of LDN indicators and taxational specifications of forests

State and changes of land cover	Stock
	Forest cover (including burnt areas, felling sites, and forest stands lost due to other causes)
Land productivity	Total forest growth (taking into account overaged wood)
	Biological diversity (for example, Shannon index)
Carbon stocks in soil and forest litter	Estimated indicators per categories of forest areas and forest-forming species

Table 2. LDN indicators and the corresponding parameters in the forestry regulatory framework of the Russian Federation

LDN indicator	Corresponding parameters in the forestry regulatory framework (taxational specifications)	Main trend over the past 15 years
State and changes of land cover	Stock	Increase
	Amount of forests	Permanent
Land productivity	Biological productivity, general growth	Slight increase
Carbon stocks in soil and forest litter	None	Accumulation (except for burnt areas)

Table 3. Proposed LDN indicators for regional humid forests

Dynamics of the middle taiga forest	Proposed LDN indicators
Spruce fire-free dynamics Pine fire dynamics Wetlands (pine forests on peatlands) Fire dynamics with changes in species (pine–spruce and deciduous–spruce subspecies)	• Fire frequency • Biodiversity level (dead wood stock/litter thickness/Shannon index) • Forest stand formula for mature wood • Clear felling area Share of protective forests and specially protected areas (SPA) • “Carbon footprint” (EX-ACT method) • Estimated net carbon balance (ROBUL, ROBUL-M, CBM-CFS) • Slowing of reforestation

tions. Meanwhile, according to many experts, the forest land is degraded in a humid climate due to interruption of natural forest dynamics as a result of massive felling and related forest fires [3]. Felling and fires transform the dynamic cycles and cause a degradation in biological diversity, sustainability, the species–age structure of forests, and other reversible and irreversible changes.

In this regard, we offer a *fundamentally different approach* to the analysis of forest land degradation in humid conditions. Landscapes with various forest dynamics can be an investigation objective. In particular, six types of regenerating forest dynamics can be distinguished in the middle taiga landscapes of the Komi Republic (Table 3).

The *carbon stock* indicator can be estimated through a retrospective and forecast calculation of the C net balance. This approach was applied to the Noshulskoye forest domain (120 780 ha) (Fig. 1)—“Priluzie” model forest—with the help of the CBM-CFS simulation model [4] based on the 1992 taxational specifications of forest types, age and dominant forest stands, growing stocks, carbon stock in the soil, forest categories, and current climate.

This model, which was verified using the similar ROBUL-M model [5], demonstrated good agreement by the Theil coefficient (0.04). CBM-CFS was adapted to three industrial felling scenarios. According to the first scenario (no impact), felling is not carried out until the end of the forecast period (2041). The second scenario (moderate impact) reports the real estimates of felling in the post-Soviet period (1992–1996), after the cessation of felling during the system crisis in Russia (1997–2000), and after resumption of felling from 2001 to date. After reaching the maximum felling rate in 2017 (810 ha per year), according to this scenario, the felling process is terminated. The third scenario is the most realistic (strong impact): it is characterized by maintaining felling at the maximum level from 2018 to the end of the simulation period (2040).

The first scenario demonstrates a gradual decrease in the carbon sink of aging forest stands, while the ecosystem tends to an equilibrium (zero) carbon balance when the recovery follows local successions (Table 2).

According to the second scenario, more active felling in early Russian history quickly reduces the carbon balance to almost zero, and after the termination of felling, the carbon sink into the ecosystem from the atmosphere quickly recovers (in three years), reaching the first scenario.

In the third scenario, after a short period of increasing carbon sink in 1992–2002, it begins to fall and becomes, for the first time, a carbon source for the atmosphere in 2020. Further on, while maintaining the annual felling level, the ecosystem carbon balance fluctuates dynamically around zero. It can be considered as a desired zero degradation state or an analogue

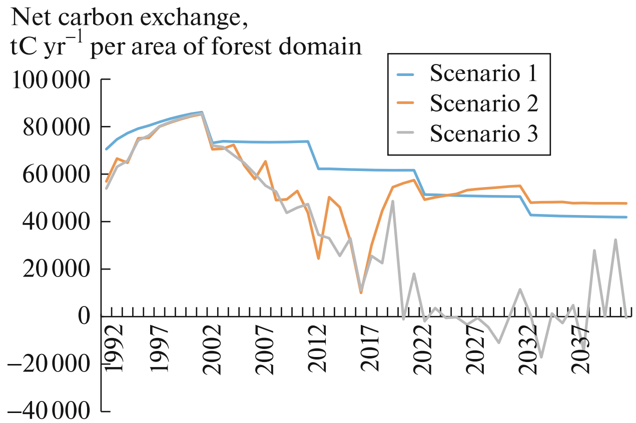

Fig. 1. Retrospective and forecast carbon balance of forests in the Noshulskoye forest domain (Komi Republic), calculated using the CBM CFS model for three forest exploitation scenarios; positive balance values correspond to C sink, while negative values correspond to C source to the atmosphere.

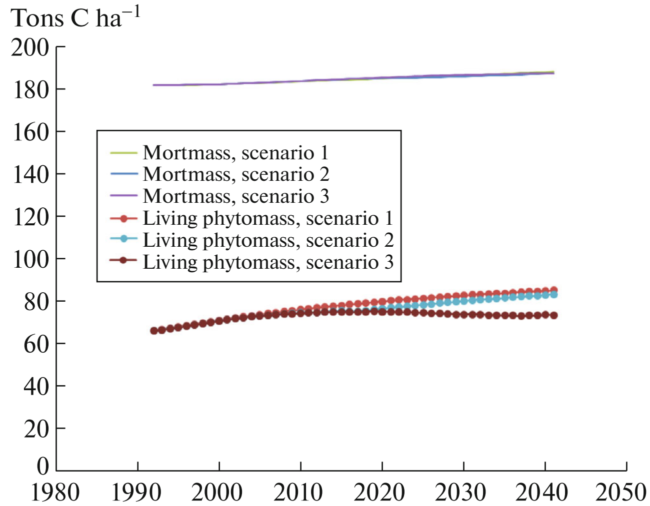

Fig. 2. Retrospective and forecast dynamics of the total living phytomass and mortmass stock in the middle taiga (Noshulskoe forest domain, Komi Republic), calculated using the CBM-CFS model according to three forest exploitation scenarios.

of the estimated cutting area, because the amount of wood removed annually during felling has time to recover through natural growth. However, this indicator does not take into account changes in the species diversity, mortmass, soil carbon, and productivity, which can also serve as indicators of degradation. The second scenario with periodic cessation of felling seems to be more reasonable. In this case, the carbon stock in the soil and the planting productivity are restored. Meanwhile, the species diversity remains debateable. In the third felling scenario, the carbon balance remains near zero, but (Fig. 2) the phytomass stock begins to decline after 2020, which should be considered as a negative indicator. The carbon stock of the mortmass in the forest ecosystem, including soil carbon (Fig. 2), is the least dynamic and slowly growing reservoir in all scenarios; therefore, this indicator should not be considered as sufficiently sensitive.

The optimum impact scenario is the imitation of natural types of forest dynamics in the landscape; it consists in minimizing felling in fireless areas which accumulate and preserve the maximum mortmass reserves, simultaneously being “key biotopes” or refugia supporting the biodiversity of the general forest ecosystem.

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