NEW ESTIMATES OF LIVE BIOMASS AND NET PRIMARY PRODUCTION OF RUSSIAN FORESTS: A FOOTPRINT OF CLIMATE CHANGE?

A. Shvidenko[1], D. Shepashenko[2], S. Nilsson[1], and A. Lapenis[3]

[1]*International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria; shvidenk@iiasa.ac.at*

[2]*Moscow State Forest University, Mytischi, Moscow Region; dschep@mimgroup.com*

[3]*University at Albany, 218AS, 1400 Washington Ave., Albany NY, 12222, USA; andreil@albany.edu*

ABSTRACT

The paper presents new estimates of live biomass (phytomass) and net primary production (NPP) of Russian forests for 1993 and 2003. These indicators are estimated based on forest inventory data and a specially developed semi-empirical modeling system. The latter contains regional models of growth by major forest forming species, multi-dimensional models of phytomass and models of biological production. It is shown that the fractional structure of forest phytomass substantially differs from previous estimates that indicated significant temporal trends of the share of aboveground wood (AGW), green part (GP) and belowground (BG) phytomass. The total forest NPP (of 307 g C $m^{-2}yr^{-1}$ for 2003) is substantially higher than previously reported. These changes may be attributed to climatic change which was dramatic over the last four decades, particularly in Asian Russia.

INTRODUCTION

Live biomass (LB) and NPP are two crucial components of the terrestrial biota full carbon account. Available estimates of LB for Russian forests are obsolete. Data for NPP derived from vegetation models relate to potential vegetation and are biased. Inventory-based estimates of NPP have never been reported. The major objective of this study was to provide a new inventory of these indicators for all Russian forests for 1993 (763.5×10^6 ha) and 2003 (776.1×10^6 ha) aiming at the most accurate assessment that is currently possible, in order to quantify the recent dynamics of the structural component of LB and NPP and try to understand the supposed links of climate change to these dynamics.

METHOD AND MATERIAL

We used forest inventory data in the form of the State Forest Account for 1993 and 2003. These data contain areas and growing stock by dominant species, age, site indexes and relative stocking by ~2000 forest enterprises across the country. In order to convert these data into LB, a system of multi-dimensional nonlinear regression equations has been developed. The equations were calculated based on a database (DB) collected for Northern Eurasia forests (of ~3600 sample plots) that contain field measurements of LB by seven components: stem, branches (both over bark), bark, foliage, roots, understory (US) and green forest floor (GFF) by dominant species and ecoregion. The statistical accuracy of the regressions allowed estimating the forest LB at the national level with uncertainties <5% (confidential interval is 0.9).

In order to estimate NPP, we developed a modeling system for assessing the biological productivity of forest ecosystems based on (1) models of growth and yield (~100 regionally distributed models were used), (2) the above models of LB, and (3) additional set of ecological parameters such as turnover of fine roots, life span of green parts, etc. [*Shvidenko et al*., 2005]. Age dynamics of LB and NPP by fractions are the outputs of this system.

The statistically significant temporal trends in the dynamics of allometric ratios of phytomass components have been reported for Russian forests recently as a footprint of their acclimation to climate change [*Lapenis et al*., 2005]. Using our DB of LB measurements (which were done between mid-1950s and 2003) we calculated the temporal trend of the share of AGW, GP and BG LB to growing stock as a function of the age of stands and the time of measurements. Such models have been developed on a regional basis with four large regions and three groups of species (light coniferous, dark coniferous and deciduous), and in the aggregated form for the entire DB (see Fig. 1, data are normalized by 1983 values).

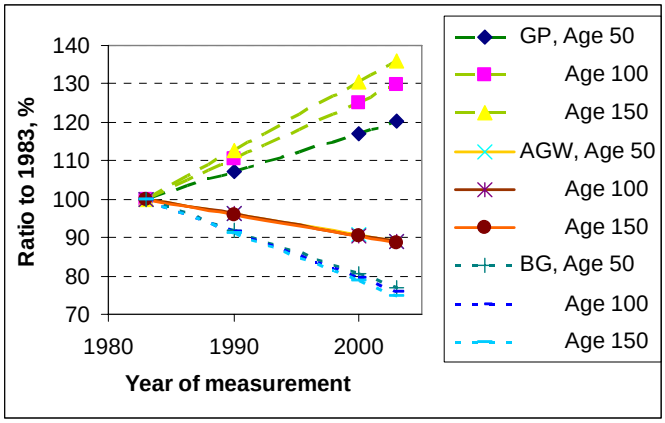

Fig. 1. Temporal trends of allometric ratios of LB fractions.

RESULTS AND DISCUSSION

Use of the LB models, which do not take into account the temporal trends of allometric ratios, did not change the average density of LB and its structure in 1993–2003 (Table 1): about 70% of LB carbon is stored in AGW, 6% in GP and 24% in BG (here and below all components of ecosystems are included, not only LB of trees). Including the temporal trends changes the estimates. If the regional models are used (see *acclimation 1* in Table 1; part of these models was not statistically significant due to lack of data for some regions), the average density of LB for 2003 was less at ~6% (Table 1, 4.45 and 4.20 kg C m^{-2}, respectively). The general model (*acclimation 2*) decreased average density to 3.86 kg C m^{-2} or at ~15%. The most probable estimate is between the latter two values. Both approaches substantially increased the share of green parts (the corresponding estimates are 5.9%, 6.8% and 8.2%) and decreased the share of two other fractions (AGW and BG). Disregarding these trends may generate a substantial bias in remotely sensed indicators which are based on measurements of leaf area index (LAI) in forests.

Table 1. Live biomass of Russian forests

Region	Live biomass by fractional components, % to total						Total, Tg C	Average density, kg C m^{-2}	
	trees				lower layers				
	stem	branches	foliage	roots	US	GFF		total	GP
Russia, 1993	56.8	10.1	3.52	22.9	2.04	4.62	33848	4.43	0.263
Russia, 2003	56.8	10.2	3.52	22.8	1.99	4.63	34499	4.45	0.263
Including European part	58.9	10.6	3.94	21.6	1.65	3.34	9374	5.50	0.316
Asian part	56.0	10.1	3.36	23.3	2.12	5.11	25125	4.15	0.249
Russia, 2003 (acclimation 1)	56.0	10.1	4.15	22.4	2.20	5.14	32615	4.20	0.286
Including European part	58.8	10.7	4.34	20.9	1.76	3.57	8853	5.20	0.325
Asian part	55.0	9.9	4.07	23.0	2.37	5.72	23762	3.92	0.275
Russia, 2003 (acclimation 2)	57.8	8.7	5.15	19.9	2.52	5.95	29952	3.86	0.318

The total NPP (2003) is estimated at 2382.2 Tg C yr^{-1}, which gives the average density at 307 g C m^{-2}. About one-fifth of the NPP is allocated in AGW (14.7% in stems and 5.5% in branches). NPP of foliage and roots of trees are similar (27.9% and 29.0%, respectively). A relatively large part of NPP is allocated in undergrowth (6.3%) and green forest floor (16.6%). Of the total amount, 27.4% of NPP relates to European Russia and 63.6% to Asian Russia. Forests of the European part are at about one-third more productive than forests in Asian Russia (the average NPP densities are 383 and 283 g C m^{-2}, respectively). Totally, green parts allocate a substantial part of NPP, 36.5%. The above NPP estimates do not account for the acclimation.

The paper analyzes possible reasons that contributed to the above structural specifics and recent trends in LB and NPP: (1) completeness of the analysis (all components of ecosystems and recognized impacts are considered); (2) probable biases that have been generated by previously used destructive methods of measurements and other reasons; (3) regional climatic change in Russian territories during the last decades.

REFERENCES

Lapenis A., A. Shvidenko, D. Shepashenko, S. Nilsson (2005), Acclimation of Russian forests to recent changes in climate, *Global Change Biology* (accepted).

Shvidenko, A., S. Nilsson, D. Shepashenko, and Y. Bouloui (2005), Semi-empirical models for assessing biological productivity of Northern Eurasia forests, *Ecological Modeling* (accepted).