

## 12 Carbon budget of the Russian boreal forests: a systems analysis approach to uncertainty

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### INTRODUCTION

The total land area of the Russian boreal zone is 1527.6 Mha, including 1143.0 Mha of Forest Fund areas and 735.8 Mha of forested areas. These estimates are based on Forest State Account data (Goscomles SSSR 1990, 1991). Forest Fund areas include forest land and non-forest land. Forest land is in turn divided into forested areas, covered by closed forests, and unforested areas, designated for forests but temporarily without a forest (sparse forests, burnt areas and dead stands, grassy glades). Non-forest land is represented by unproductive land, such as bogs, rocks, sand, and glaciers, and by land with special uses (forest roads, water reservoirs, and relatively small areas of arable lands, pastures farms, etc., situated on Forest Fund areas). For a more detailed description see, e.g., Nilsson et al. (1992). Nearly 95% of all Russian closed forests are considered boreal. Thus, the Russian boreal forests play an important role in the global carbon (C) cycle.

Estimates of the C budget for the boreal zone, as well as for the Russian forests and landscapes, vary greatly (some estimates are listed in Table 12.1). Estimates of the total C flux for the Russian forests and the forests of the former Soviet Union during the last 20 years have varied, from showing them to be a slight net source to being a significant sink of about 1 Pg C yr<sup>-1</sup>.

The disagreement in estimates concerning the role of the boreal forests as a whole (and the Russian forests as a part of the whole) in the C budget has not yet been resolved (Kauppi et al. 1992; Houghton 1993; Shvidenko et al. 1994a). Basic reasons for the disagreement in the estimates include the following:

- Differences in the approaches and models used, differences in the structuring of the C cycles, and differences in the measurement of the basic indicators of the C cycle.
- The lack of knowledge of some basic processes.
- The complicated structure of the problem.
- The scale of Russian territory, which encompasses extremely diverse climatic, orographic, and anthropogenic conditions.
- The incompleteness, uncertainties, and shortcomings of data needed for robust analyses.
- The disagreements between the classification schemes used.

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**Table 12.1.** Estimates of the role of boreal and temperate biota in the carbon (C) budget.

ZONE, REGION	PERIOD	Pg C yr <sup>-1</sup>	SOURCE
TBZ <sup>a</sup> , forests	1953–1975	+1.0 to +1.2	Armentana and Ralston (1980)
FSU <sup>a</sup> , forests	1953–1975	+0.5	Armentana and Ralston (1980)
FSU, forests	1982	-0.199	Shaver et al. (1982)
TBZ, forests	–	+1.6 to +1.9	Johnson and Sharpe (1983)
TBZ, forests	–	-0.5	Houghton et al. (1983)
TBZ, forests	1980	+0.973	Melillo et al. (1988) <sup>c</sup>
TBZ, land	1980	-0.025	Melillo et al. (1988)
FSU, land	1980	-0.037	Melillo et al. (1988) <sup>d</sup>
FSU, forests	1980	+0.048	Melillo et al. (1988)
Russia, forests	1990	+1.02	Makarov et al. (1990)
Russia, forests	1990	+0.4	Zavarzin (1992)
Russia, forests	1988	+0.184 to +0.212	Isaev et al. (1993) <sup>e</sup>
BZ <sup>a</sup> , forests	1966–1988	+0.76	Sedjo (1992)
Canada forests	1986	+0.0768	Kurz et al. (1992)
Europe, forests	1970–1980	+0.08 to 0.12	Kauppi et al. (1992)
FSU, forests	1978–1988	+0.416	Sedjo (1992)
FSU, forest biomes	mid-1980s	+0.475, +0.517	Kolchugina and Vinson (1993a, 1993b)
Russia, forests	1990s	+0.1 to +0.4	Kokorin et al. (1993)
FSU, forests	1966–1988	+0.46	Shvidenko et al. (1994a)
Russia, forests	1987–1990	+ 0.3 to +0.5	Dixon et al. (1994)

a TBZ = temperate and boreal zones; FSU = former Soviet Union; BZ = boreal zone.

b + (-) indicates a sink (source) of atmospheric C in the terrestrial biota;

c Regrowth and reforestation.

d Includes boreal forests, deciduous forests, and temperate grasslands.

e Sequestration in wood on forested areas (771 Mha).

The estimation of the C budget is complex, involving different types of variables, such as deterministic, stochastic, quantitative, and qualitative variables and expert estimates. Currently some important internal system interactions (e.g., many aspects of the post-disturbance processes in soil) can only be represented in the form of “black-box” models. There are rather restricted possibilities for a consecutive formalisation and structuring of the C cycle due to a lack of required information from previous decades or centuries. The problem as a whole and its components have a typical fuzzy character. Consequently, any investigations of the total forest C budget or of the Russian forest C budget must be greatly simplified.

In our analyses, we used simple, pragmatic principles of system (holistic) analysis (goals, objects, structure, integrity, partition, connection, etc.) to estimate the sources of basic uncertainties in the C budget of the Russian boreal forests and landscapes. The following features of the problem were given special attention:

- Stability and improvement of the C budget are essential parts of the sustainable development paradigm and forests are the frame of the boreal landscape’s ecological sustainability.
- The forest C problem is dynamic, and forest succession is one of the most important processes of the system; also, the dynamics of the forests are, in turn, part of temporal and spatial changes in land use, land cover change, and land management change.
- Methods and models used should yield quantitative estimates of basic indicators and related uncertainties using available information.