LONG TERM TEMPORAL AND SPATIAL VARIABILITY OF CARBON IN PERMAFROST–DOMINATED FOREST ECOSYSTEMS

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ABSTRACT

The forests of Siberia represent one of the last natural frontiers in the world. Nearly 65% of Siberia's forests grow in areas with permafrost and Larch forests are dominated here. According to our estimates, carbon stocks in the soils of permafrost forest and tundra ecosystems of Yakutia amount to 17 Gt (altogether 126 Mha of forest area and 37 Mha of tundra). It is about 25% of total carbon stock in forest soils of the Russian Federation. This carbon has been accumulated during centuries, and rapid climate change may release its huge amount for relatively short period, thus enhancing rather source than sink role of Russia. The total stock of terrestrial phytomass carbon of forests, tundra and meadows of Yakutia is 2.2-4.5 Gt C, including 0.053 Gt C of tundra and meadows.

Long term (1993-2003) tower network studies were conducted at experimental forest station "Spasskaya Pad" of the Institute for Biological Problems of Cryolithozone SD RAS (62º 15' N, 129º 37' E, 30 km north of Yakutsk).). The study site is a typical mature 180-year-old larch forest with red-bilberry cover (*Laricetum limnasozo-vacciniosum*), growing in relatively moist loamy soil with sandy loam pieces. Average and maximal wood stand height is 17 and 27.7 m respectively. Mean diameter of trees is 18.5 cm, canopy area index – 2.6, and density – 876 trees per ha.

For common analysis of net carbon dioxide ecosystem gas-exchange (NEE) we used both closed and open eddy-correlation systems at 34 m height. The eddy-correlation system consists of infrared gas analyzer Licor (USA), ultrasound anemometer Gill (USA), control and data record unit from Campbell (USA). Soil respiration was measured using two systems also – automatic one with 4 dark chambers, every 15 min (PP system, GB) and manual EGM-4 (PP system, GB). Transect measurements of soil respiration intensity were done depending on wind rose (north-west and south-east) every 50 m at a distance of 500 m from the tower.

Under taiga zone conditions of Central Yakutia woody plants have rather small biomass of photosynthesizing organs. So, larch needle mass in Yakutia (1.68 t per ha) is twice as less as in countries with humid climate. Small needle biomass at low leaf assimilating index (up to 2,0) and shortened period of photosynthetic activity stipulated low primary productivity of the larch – main forest-forming species of Yakutia (NPP = 3.1±0.3 t ha^{-1} $year^{-1}$).

Our long term (1996-2004) observations show that during about 100-day growing reason (late May to early September) the permafrost forest ecosystems are sink of carbon dioxide with maximum assimilation capacity of 22 kg CO_2 ha^{-1} day^{-1} or 6.1 kg C ha^{-1} day^{-1}. Daily productivity of larch photosynthesis in humid years is a factor of 2.5 of dry years, and makes on average 332.6±45 mM CO_2 m^{-2} day^{-1} against 139.5 in very dry years. This corresponds also to values for other taiga larch forests (*Laricetum vacciniosum*) – from 170 to 220 mM CO_2 m^{-2} day^{-1} [*Benecke et al*., 1981; *Vygodskaya et al*.,1997].

Seasonal maximum of the photosynthetic activity of forest canopy plants in droughty years is observed in June, and in moist years – in July or August. During growing season the woody plants of Yakutia consume 1.5 to 4.0 t C $season^{-1}$. Dark respiration costs of larch for the growing season make 22% to 57% of maximum photosynthesis.

Average soil respiration intensity during plant growing season comes to 2.2-6.9 kg C ha^{-1} day^{-1}. Maximum of permafrost forest soil respiration in Central Yakutia is observed in late August to early September. Annual soil CO_2 emission makes on average 4.5±0.6 t C ha^{-1} $year^{-1}$.

Inter-annual variation of net ecosystem exchange (NEE) in the permafrost zone amounts to 1.7-2.4 tC ha^{-1} $year^{-1}$, which results in the upper limit of annual sequestering capacity of 450-617 Mt C year^{-}. The Far East larch forests of Siberia accumulate annually 0.4-1.0 Gt C that is comparable with the values for European and tropical forests. Net biome productivity (NBP) of Siberian larch forests may be assessed approximately within 0.26-0.86 Gt of carbon.

The Proposal of the Russian Federation to UNO Convention on Climate Change of 1995 estimates the total annual forest carbon sink of Russia to be 0.16 G t [*Interagency commission*...,1995], which is much lower than the values obtained by us and other foreign researches. The contribution of Siberian forests (eastward from Ural) into this sink we assume to be 55-62%. Annual sequestration of permafrost Siberian larch forests comes almost to half of the overall sink of Russian forests (55%), and soil emission makes about 27% (Table).

Table 1. Annual carbon budget of Russia and Siberia, G t C $year^{-1}$

Assimilation		
	Siberia	1.3 (Shimel et al.,2001;Goodale et al.,2002)
	Larch forests of Siberia	0.4-1.0
	Larch forests of Yakutia	0.2-0.4
Soil emission		
	Russian	2.6-3.0 (Kudeyarov et al., 1995)
	Larch forests of Siberia	0.6-0.9
	Larch forests of Yakutia	0.3-0.4
NEE		
	Russia	0.82 (Goodale et al.,2002)
	Larch forests of Siberia	0.45
	Larch forests of Yakutia	0.18

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