Acclimation of Russian forests to recent changes in climate

ANDREI LAPENIS, ANATOLY SHVIDENKO, DMITRY SHEPASCHENKO, STEN NILSSON and ANANTHA AIYYER

UNIVERSITY AT ALBANY State University of New York

IIASA

Abstract

Assessments made over the past few decades have suggested that boreal forests may act as a sink for atmospheric carbon dioxide. However, the fate of the newly accumulated carbon in the living forest biomass is not well understood, and the estimates of carbon sinks vary greatly from one assessment to another. Analysis of remote sensing data has indicated that the carbon sinks in the Russian forests are larger than what has been estimated from forest inventories. In this study, we show that over the past four decades, the allometric relationships among various plant parts have changed in the Russian forests. To this end, we employ two approaches: (1) analysis of the database, which contains 3196 sample plots; and (2) application of developed models to forest inventory data. Within the forests as a whole, when assessed at the continental scale, we detect a pronounced increase in the share of green parts (leaves and needles). However, there is a large geographical variation. The shift has been largest within the European Russia, where summer temperatures and precipitation have increased. In the Northern Taiga of Siberia, where the climate has become warmer but drier, the fraction of the green parts has decreased while the fractions of aboveground wood and roots have increased. These changes are consistent with experiments and mathematical models that predict a shift of carbon allocation to transpiring foliage with increasing temperature and lower allocation with increasing soil drought. In light of this, our results are a possible demonstration of the acclimation of trees to ongoing warming and changes in the surface water balance. Independent of the nature of the observed changes in allometric ratios, the increase in the share of green parts may have caused a misinterpretation of the satellite data and a systematic overestimation by remote sensing methods of the carbon sink for living biomass of the Russian forest.

Tree ring – NDVI paradox?

- Overall, for the entire northern forest, tree rings demonstrate systematic decline in radial growth since ~1960
- At the end of 20th century tree rings demonstrate a lower sensitivity (response) to climate change
- Inventory-based estimate of carbon sink to living biomass of Russian forests: **0.058** Gt/yr

- Normalized Difference Vegetation Index demonstrates persistent “Greening” at northern latitudes
- NDVI correlates well with changes in surface temperature
- NDVI-based estimate of carbon sink to living biomass of Russian forests: **0.29** Gt/yr

Please, see references in our publication list

Trends in various age groups of trees

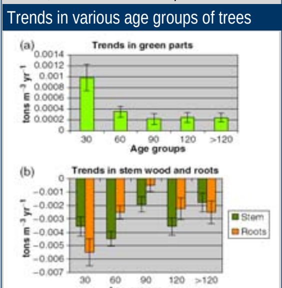

Figure 5

Zooming on a pixel: St. Petersburg region, Russia

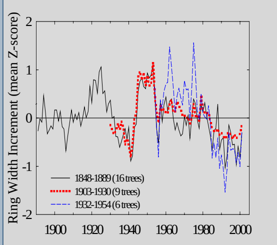

Figure 1

Our studies demonstrate decline in growth of Norway Spruce from St. Petersburg region (Lisino)

Climate change can’t explain decline in tree growth

The decline in growth of Norway spruce from St. Petersburg region can not be explain by climatic factors. Multiple regression with 24 climatic variables (see details in our publications) predict a fast growth for the last 40-30 years. The real growth, however, is much lower, while the seasonally accumulated NDVI demonstrate a faster, consistent with climatic conditions increase in the greening of the same region (see below).

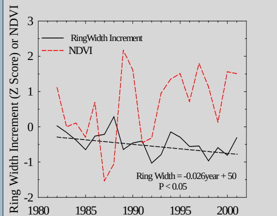

Figure 2

Trends in trees fractions over 28 ecoregions

Figure 3

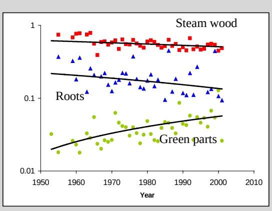

Figure 4

Average trends in trees parts.

During the last 40 years, the share of green parts (leaves, and needles) did increase (Fig. 4), while the share of stem wood and the share of roots (including fine roots) did decrease. These changes were stronger among younger trees (Figure 5).

The increase in the green parts shows a good correlation with warmer and wetter conditions in European Russia (increase of Palmer Drought Severity Index (PDSI))

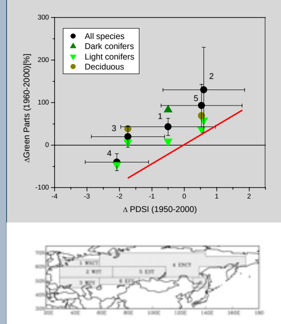

Figure 6

If the water regime was the ONLY factor influencing changes in the allocation of carbon to green parts, the relationship shown in Figure 6 should cross the center of the coordinates and we would see a decline in the average fraction of green parts in the Russian forests. Numbers on the Figure 6 represent 5 of 6 major ecoregions (see above).

Trends in trees parts and changes in the carbon density of living biomass in Russian forest

Carbon density of aboveground wood, roots, and green parts increased from 1961 to 1998 by 4%, 21%, and 33%, respectively.

Independent of the nature of the observed increase in the share of photosynthetic tissue of trees, this phenomenon may have caused misinterpretations of satellite data on the changes in leaf indices.

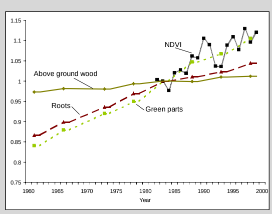

Figure 7

Trends in green parts are consistent (Figure 7) with increase in seasonally accumulated NDVI. Green parts, however, account only for a small fraction of carbon in living biomass.

Trends in trees parts and carbon sequestration in living biomass

One can use trends in the carbon density of carbon density of different tree parts (Figure 7) to correct existing 1961-1998 inventory-based estimates of carbon sink to living biomass of Russian forests. This calculations demonstrate carbon sink of ~0. 022-0.122 Gt/yr or ~3 times smaller than NDVI-based estimates.

Published papers

Lapenis, A.G., Shvidenko A.A., Nilsson N., Aiyyer, A.R. ***2005*** Acclimation of Russian forests to Recent Changes in Climate. ***Global Change Biology.*** Volume 11 Page 2266 - December 2005

Lawrence, G.B., Lapenis, A.G., Berggren, D., Aparin, B.F., Smith, K.T., Shortle,W.C., Bailey, S.B. Varlyguin, D.V., and Babikov, B. ***2005*** Climate Dependency of Tree Growth Suppressed by Acid Deposition Effects on Soils in Northwest Russia. ***Environmental Science and Technology.*** 39 (7): 2004-2010

Questions for future study

What are the relationships between tree ring increments and NDVI in various types of Russian forest ecoregions?

Could changes in the status of soil nutrients (N, Ca, P etc.) alter the relationship between annual tree ring increments and seasonally accumulated NDVI?

Could the increase in the atmospheric CO_2 concentration and Nitrogen deposits contribute to the cause of increase in the share of green parts?

How common is increase in the share of green parts in other boreal forests?

Could the increase in the share of green parts and decline in the share of roots and woody parts limit the sink of atmospheric carbon to the living biomass of Russian and other forests?