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Climate warming shifts carbon allocation from stemwood to roots in calcium-depleted spruce forests

Andrei Lapenis, Gregory Lawrence, and Alexander Buyantuev
United States (andreil@albany.edu)

Increased greening of northern forests, measured by the Normalized Difference Vegetation Index (NDVI), has been presented as evidence that a warmer climate has increased both net primary productivity (NPP) and the carbon sink in boreal forests. However, higher production and greener canopies may accompany changes in carbon allocation that favor foliage or fine roots over less decomposable woody biomass. Furthermore, tree core data throughout mid- and northern latitudes have revealed a divergence problem (DP), a weakening in tree ring responses to warming over the past half century that is receiving increasing attention, but remains poorly understood. Often, the same sites exhibit trend inconsistency phenomenon (TIP), namely positive, or no trends in growing season NDVI where negative trends in tree ring indexes are observed. Here we studied growth of two Norway spruce (Picea abies) stands in western Russia that exhibited both the DP and TIP but were subject to soil acidification and calcium depletion of differing timing and severity. Our results link the decline in radial growth starting in 1980 to a shift in carbon allocation from wood to roots driven by a combination of two factors: (a) soil acidification that depleted calcium and impaired root function and (b) earlier onset of the growing season that further taxed the root system. The latter change in phenology appears to act as a trigger at both sites to push trees into nutrient limitation as the demand for Ca increased with the longer growing season, thereby causing the shift in carbon allocation.