Spatial variability of the net ecosystem production and its component fluxes across a managed boreal forest landscape in Sweden: A biometric and chamber data-based analysis

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A managed boreal forest landscape is a diverse successional mosaic of clear-cuts to old-growth stands of different species growing on a variety of soil types. Consequently, this high spatial heterogeneity strongly impacts the forest net ecosystem production (NEP) across the managed landscape. However, the quantification of the variability of NEP and its component fluxes across forested landscapes is currently highly uncertain due to the complex interactions between forest structure and physiological processes and their changes over time.

Here, we assessed the spatial variability of NEP and its component fluxes during a 3-year period (2016-2018) over a boreal forest landscape (ca. 68 km²) located within the Krycklan catchment (64°14′N, 19°46′E) in northern Sweden. For this purpose, we selected 50 representative forest plots (10 m radius) across the catchment spanning various tree species (pine- and spruce-dominated stands) and forest age classes (from clear-cuts to old-growth forests). In each plot, forest floor CO₂ fluxes were manually measured with custom-made closed chambers in monthly intervals during the growing seasons 2016-2018. Measurements were carried out across natural (both light/dark measurements) and trenching/vegetation removal plots (0.45 × 0.45 m) to partition the net forest-floor exchange (NEFF) into its contributing components, i.e., gross primary production (GPPFF) and respiration (ERFF). ERFF was further separated into plant autotrophic and soil heterotrophic respiration (RaFF and RhFF). Plot-level biometric measurements were conducted to determine the net primary production of trees and forest floor vegetation (NPPF and NPPFF) as well as heterotrophic dead wood respiration (decomposition, RhDW). Finally, NEP was calculated as NEP = NPPF + NPPFF - RhFF - RhDW.

Our results showed that NPPF consistently increased with forest ageing, while an opposite pattern was observed for NPPFF. In general, spruce stands showed lower NPPF compared to spruce stands at each given age class. In contrast, pine stands showed consistently higher NEFF, GPPFF, ERFF, RhFF, RaFF, and NPPFF compared to spruce stands. The forest floor was a net CO₂ source, which increased with stand age due to the progressive decrease in GPPFF, while the ERFF remained similar among all the age classes. In addition, an analogous age-related pattern was observed in RhFF. Our findings also depicted an increasing NEP with forest age from about ≈ 54±67 g C m⁻² yr⁻¹ during the
initial stages of development (i.e., 5-30 years-old) to a maximum of 170±68 g C m\(^{-2}\) yr\(^{-1}\) in middle-aged stands (i.e., 60-100 years-old). Higher NEP was generally observed for pine compared to spruce stands. Interestingly, we found that the old-growth forests steadily continue to accumulate C, which is contrary to the common view that they become C neutral or sources.

Overall, this comprehensive study improves our understanding of the spatial variability of the C balance over the heterogeneous regional forest landscape in northern Sweden, identifying tree species, forest floor vegetation and forest ageing as key drivers.