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Acclimating tree C-N resource balance suggests diverse above-ground growth and carbon stock changes in boreal forests under climate change

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Ongoing environmental change calls for methods for modelling possible consequences of acclimation of plants to climate change. Forest models often assume that growth and forest biomass is determined by growth equations and set of other rules. Growth equations may be further sensitive to availability of limiting attributes. The dynamical balance between limiting resources, namely the nutrient availability from soil and the carbon gain from atmosphere, then determines the biomass accumulation of a forest.

However, empirical data has evidenced that there are many features in trees that are plastic, and may shift the balance to unexpected direction. For example, FACE studies report a dilution of leaf nitrogen with elevating CO_2 concentration and decreasing nutrient gradients evidence the increasing root-allocation of biomass. Mechanistic understanding for these phenomena is limited, but they can be understood as evolutionary purposeful phenomena where plastic change of traits maximizes the plant performance. Few studies have attempted to quantify the potential significance of plastic mechanisms for the forest growth in the changing climate.

To overcome that shortcoming, we constructed a model system, in which the tree structure acclimates to new climate by optimally co-allocating two key ingredients, nitrogen and carbon, to organs by maximizing the whole-plant NPP. The approach assumes that whole-plant NPP is appropriate proxy for fitness of trees. To do this, we applied OptiPipe - a model building on the functional balance hypothesis and solving the optimal allocation of resources, and PRELES - a simplified model of canopy C and water exchange. The focal area was boreal forests of Finland, where recent climate change scenarios (RCP) predict lengthening and warmer seasons, and no clear change in water availability.

We found out that climate change exerts diverse response for tree and ecosystem carbon gain, which varies by site quality. Richest (fertile) sites provided enough nitrogen to support above ground growth increases, with small changes in root allocation. The NPP of poor sites benefitted less from climate change, and less stem wood was produced on the account of increased allocation of C to roots (for nutrient acquisition). Our results demonstrate the potential for the optimality concepts in finding the potential limits for growth in DGVM. They also emphasize the information needs required for studies of growth acclimation, i.e. reliable estimates of release of nitrogen from soils and estimates of constraints of acclimation.