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INSTITUTIONEN FÖR BIOLOGI OCH MILJÖVETENSKAP

Acclimation of boreal Norway spruce to climate change

Empirical and modelling approaches

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Abstract

Climate change impacts forests and forests in turn affect climate change. The long-term responses and climate feedbacks of forests depend on the acclimation of trees to altered conditions. Numerous experiments have been carried out to understand the impact of rising CO_2 concentration ([CO_2]) and warming on trees. However, most of them have been on young individuals of temperate locations and limited information is available for mature trees and non-temperate regions. This thesis aims to improve the understanding and predictability of physiological acclimation responses to climate change in Norway spruce (*Picea abies*), a key species of the European part of the boreal biome. Acclimation responses of photosynthesis, respiration and stomatal conductance were determined using continuous measurements of CO_2 and water vapour fluxes of shoots and trees exposed to elevated [CO_2] and/or warming inside whole tree chambers at Flakaliden field site, northern Sweden (Paper I). Furthermore, climate and river runoff data from central and northern Swedish catchments during the last 50 years were used to analyze drivers of temporal trends in evapotranspiration of boreal forests (Paper II). The thesis further explores the relative importance of different types of acclimation (of photosynthesis, respiration, stomatal conductance and phenology, alone or in combinations) for shoot and crown level fluxes of CO_2 and water vapour using the process-based MAESTRA model (Paper III).

Results demonstrated that elevated [CO_2] increased net photosynthesis although it decreased maximum photosynthetic carboxylation capacity. Warming had no significant effect on net photosynthesis or maximum carboxylation capacity. Shoot respiration increased in elevated [CO_2] but was not significantly affected by warming. Shoot respiration was also found to exhibit pronounced seasonal acclimation. Stomatal conductance at light saturation and reference air vapour pressure deficit was not affected by elevated [CO_2] but was significantly decreased by warming. Warming treatment had no effect on transpiration as decreased stomatal conductance compensated for the increase in evaporative demand. Forest evapotranspiration in central Swedish boreal forested landscapes increased over the past 50 years without any significant change in runoff. The positive evapotranspiration trend was related to increasing precipitation and forest standing biomass together with lack of stomatal water savings under rising [CO_2].

Simulations showed that tree physiological acclimation generally acted to dampen the responses of tree net photosynthesis and transpiration. Under a no-acclimation scenario, elevated [CO_2] greatly increased shoot and crown net photosynthesis and decreased transpiration while warming increased transpiration but had little effect on photosynthesis. However, photosynthetic and respiratory acclimation greatly reduce the positive effect of elevated [CO_2] on tree CO_2 assimilation, while stomatal acclimation counteracted the positive effect of warming on tree water consumption.

The findings of this thesis have important implications for the projections of future carbon and water fluxes for the boreal region. The observed boreal long-term acclimation responses of respiration and stomatal regulation differ from those of most temperate regions. Furthermore, the findings guide modellers by quantifying the relative importance of different types of acclimation responses. Physiological acclimation generally dampened instantaneous responses and it is critical to incorporate these responses into vegetation models to improve projections of atmosphere-biosphere interactions of boreal regions in a changing climate.

Keywords: acclimation, dark respiration, evapotranspiration, MAESTRA, phenology, photosynthesis, *Picea abies*, stomatal conductance, V_{cmax}, warming