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Peatland simulator connecting drainage, nutrient cycling, forest growth, economy and GHG efflux in boreal and tropical peatlands

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Forest growth in peatlands is nutrient limited; principal source of nutrients is the decomposition of organic matter. Excess water decreases O_2 diffusion and slows down the nutrient release. Drainage increases organic matter decomposition, CO_2 efflux, and nutrient supply, and enhances the growth of forest. Profitability depends on costs, gained extra yield and its allocation into timber assortments, and the rate of interest. We built peatland simulator Susi to define and parameterize these interrelations.

We applied Susi-simulator to compute water and nutrient processes, forest growth, and CO_2 efflux of forested drained peatland. The simulator computes daily water fluxes and storages in two dimensions for a peatland forest strip located between drainage ditches. The CO_2 efflux is made proportional to peat bulk density, soil temperature and O_2 availability. Nutrient (N, P, K) release depends on decomposition and peat nutrient content. Growth limiting nutrient is detected by comparing the need and supply of nutrients. Increased supply of growth limiting nutrient is used to quantify the forest growth response to improved drainage. The extra yield is allocated into pulpwood and sawlogs based on volume of growing stock. The net present values of ditch cleaning operation and the gained extra yield are computed under different rates of interest to assess the profitability of the ditch cleaning.

The hydrological sub-models of Susi-simulator were first parameterized using daily water flux data from Hyytiälä SMEAR II-site, after which the predictions were tested against independent hydrologic data from two drained peatland forests in Southern Finland. After verification of the hydrologic model, the CO_2 efflux, nutrient release and forest growth proportionality hypothesis was tested and model performance validated against long-term forest growth and groundwater level data from 69 forested peatland sample plots in Central Finland. The results showed a clear relation between the stand growth, nutrient availability, and CO_2 efflux. Potassium was the main limiting factor for the forest growth. This indicates that management aiming at decreasing heterotrophic CO_2 efflux by raising the ground water table will decrease the forest growth. From the C balance perspective the growth rate of the tree stand becomes essential. Modelling approach enables a search for an optimal management schedule for producing timber in situation when there is a price given for release of C. Ditch network maintenance by ditch cleaning becomes profitable if: i) the initial drainage is very poor, ii) the availability of the critical nutrient is sufficient, iii) during prolonged rainy conditions, and iv) the tree stand is Scots pine (Pinus sylvestris) dominated and v) in a phase where most of the extra yield is allocated into sawlogs.

The simulator and its holistic approach has been successfully implemented in both tropical pulpwood plantations in Sumatra, Indonesia and in Finnish boreal forests.