Sensitivity of Simulated Forest Growth to Changes in Climate and Atmospheric CO_2

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Introduction

In the scope of the study GERMAN FOREST SECTOR UNDER GLOBAL CHANGE the process based forest model 4C is used to investigate changes in forest productivity under the current climate and future climate scenarios. Sensitivity analyses and a regional application under different climate change scenarios are presented.

Model 4C ('FORESEE' - Forest Ecosystems in a Changing Environment)

4C is characterized by

- Explicit modelling of establishment, growth, and mortality of tree cohorts
- Three discrete time steps: *a) daily* for soil dynamics and phenology, *b) one to two weeks* for net primary productivity (NPP), and *c) annual* for tree growth (allocation), population dynamics
- Soil water balance, C/N turnover and soil temperature calculated for a layered soil
- Net photosynthetic production by the canopy and allocation of assimilates onto tree organs simulated explicitly
- Mortality based on carbon balance and an age-dependent mortality is included
- Initialization with a given stand structure and simulation of silviculture interventions

4C thus comprises closed carbon, nitrogen and water balances and can be applied to unmanaged and managed forests (see also poster: „*Application of the process based forest model 4C for analysis of hydrological fluxes at Level II sites in Brandenburg*").

Sensitivity of growth increment to climate change

A set of growth simulation runs was performed for a pine forest in Brandenburg. Simulations run for 40 years (weather data 1951-1990 from a nearby weather station). Several climate change scenario runs were carried out for which increases in temperature and defined percentage changes in precipitation were applied to all daily input data.

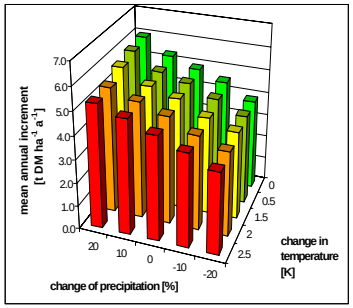


Figure 1: Mean annual stem wood increment of a pine stand (initialized with data from a forest inventory) at the Kienhorst site (90 years old, 13.59°O 53.01°N) under different climate change conditions

Distinct decreases in growth occur with decreases in precipitation. Higher temperatures have less impact on growth. Increased temperatures are expected to lead to increased transpiration and thereby to an earlier occurrence of water deficits in summer.

Sensitivity to changes in atmospheric CO_2

For a pine forest stand in Southern Finland (61° 51' N 24°18' E, 170m) the modeled effects of increasing atmospheric CO_2 partial pressures is demonstrated in Figure 2. The curves show percent changes in net primary production relative to a simulation run for which the atmospheric CO_2 content was held constant at the level of 1924.

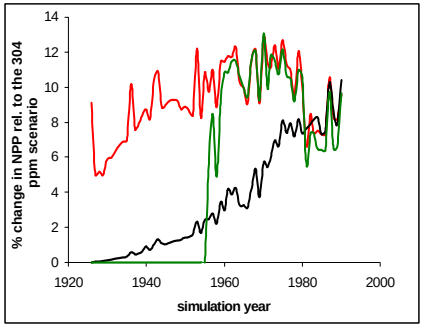
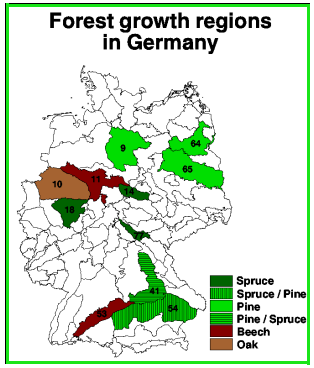


Figure 2: Percent change in net primary production (NPP) of a constant CO_2 scenario (354 ppm, red line), the continuous historic increase (from 304 to 354 ppm, black line), and a step change from 304 to 354 ppm at simulation year 1956 (green line) relative to a non-change scenario (304 ppm).

All three CO_2 regimes result in higher NPP compared to the reference scenario. Increase in NPP is due to increase in assimilation and increase in leaf area. The transient component of increases in NPP because of higher leaf masses is reduced in the course of stand development, when mortality is accelerated because of competition for light.

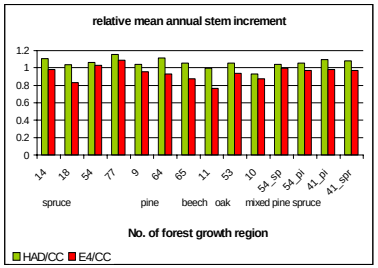
Regional analysis of growth increment



Simulation experiment:

- 24 forest stands were simulated for 12 selected forest growth regions (FGR), see figure left
- Forest stands represent dominating tree species (pine, spruce, beech, or oak) and age classes
- Simulated averaged annual stem increments of three 30 year scenario runs were compared
- Productivity changes were scaled to the national level

Climate scenarios: Current climate (**CC**): 1961-1990; climate change: 2041-2070 with 3K temperature increase and mostly precipitation decrease from ECHAM4 (**E4**) and 3K temperature increase with precipitation increase from HadCM2 (**HAD**).



rel. Productivity (%)	species	HAD	E4
	spruce	+7.7	-4.4
	pine	+7.4	-7.2
	beech	+2.3	-15.9
	oak	-7.1	-12.2

Aggregated productivity response of the four major tree species in Germany to two different climate change scenarios

The regional differences of impacts across Germany are due to the regional differences in climate scenarios and site conditions. Compared to other FGRs for FGR 54 and 77 (spruce) the E4 scenario predicted increased precipitation which leads to growth gain. The differences in the projected changes in precipitation between the two climate change scenarios E4 and HAD result in opposed growth responses (see Table and Figure above).

Simulation experiments with **4C** demonstrate the impact of changing environmental conditions on forest productivity. The results of the analysis at representative sites are usable in timber market models to investigate impacts of climate change on the forest sector. The results stress the importance to analyse different climate change scenarios in forest ecosystem impact assessments.

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