Forest Biodiversity and C-Sequestration As a Function of Past and Future Climate Changes

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Transient climatic changes may impact on forests in a multitude of ways, e.g. by altering net ecosystem productivity or interspecies competition, which may modify species assemblages. In this study we use a forest model to quantitatively assess the impacts of past and future climatic variability and change on two key forest functions biodiversity maintenance and carbon (C) sequestration.

Simulations were performed for 12 sites representative of the main climatic zones and forest types of Switzerland. To investigate the role of historic climate variability and change we used the long-term, high-quality monthly temperature and precipitation data set from Begert & al. [1] that covers the period from 1864-2003. Five successive time windows, each covering 28 years were used to define five baseline climates for the forest simulations. To assess possible effects of future climatic changes we used two most recent CO_2 stabilization scenarios (450, 1'000 ppm) for global mean near-surface temperature (Tglob) [2], plus the Tglob from an extended IPCC SRES A2 scenario [3] (E-SRES A2, assuming Tglob to stabilize in year 3000 at 7°C above 1990 mean). Three site-specific, transient climate change scenarios were then constructed by applying the three Tglob scenarios to local temperature and precipitation sensitivities [4] that were estimated by means of statistical downscaling [5] from a SRES A2 simulation with the CSIRO GCM. Forest impacts were assessed using the forest gap model FORCLIM in its most recent, fully transient mode. This analysis focuses on differences in the simulated equilibrium states, which resulted by assuming a fixed climate for each past time window or a no more changing climate in a far distant future (beyond 3000). The dissimilarity of species compositions was quantified with an index that is based on evaluating for each species the relative changes in the proportions of the biomass.

The simulated number of species and the total C stock at equilibrium were found to be insensitive to the choice of the past climate window. However, for the most recent window (1976-2003) significant changes in species composition (ca.15%) were obtained. Under the future climate change scenarios, the 450 ppm stabilization scenario shows no impact on carbon sequestration. For the "medium" (1'000 ppm) and "high" (E-SRES A2) climate change scenarios, the site Saentis gets forested, while the site Sion suffers a total forest dieback. Site Geneva shows a partial dieback under the E-SRES A2 scenario (Fig. 1). Except at Sion, equilibrium species numbers were always found to increase under all climate change scenarios. The most severe changes were obtained in the composition of tree species, which was found to change between 16% and 74% for the "medium" climate change scenario and by between 43% and 95% for the A2 scenario (Fig. 2). Similar to Fischlin & Gyalistras [6] we divided the responses at the 12 sites into 5 classes: 1) decreasing biomass, but increasing number of species (low-elevation sites: Basel, Lugano, Geneva), 2) no significant climate change impacts (other sites in Swiss Plateau: Berne, Zurich), increasing biomass and species number 3) with forests currently present (sub-alpine sites: (Chaumont, Davos, Engelberg, Sils-Maria), and 4) with new forests where none existed before (alpine site Saentis), and reduced biomass and species numbers (central alpine site Sion).

Our results suggest that due to the observed late 20th century climate trends some Swiss forests are already out of equilibrium with present climate, and that this disequilibrium is likely to increase in the future. Tree species composition appears to be impacted strongest, followed by tree species number and total C stocks. Transient mid-term (next 50-100 years), effects show considerably different impacts, but were not yet analyzed in the study presented here.

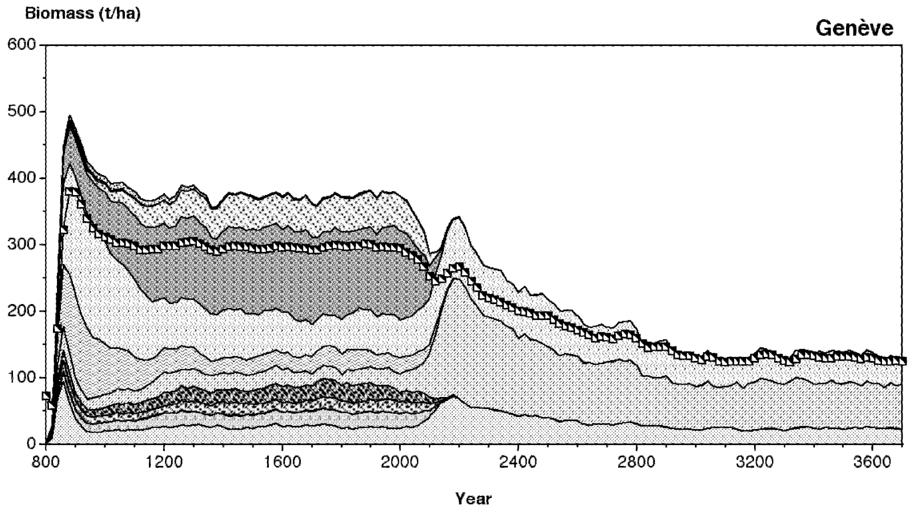

Fig. 1: Forest succession as simulated by FORCLIM at site Geneva under the scenario of strongest climate change (E-SRES A2). Grey tones represent tree species – black line total of above- and below-ground carbon stocks. Total biomass suffers a temporary dieback in the 21st century. After a short recovery period with a new species composition, the forest biomass declines gradually over the course of centuries to considerably low levels.

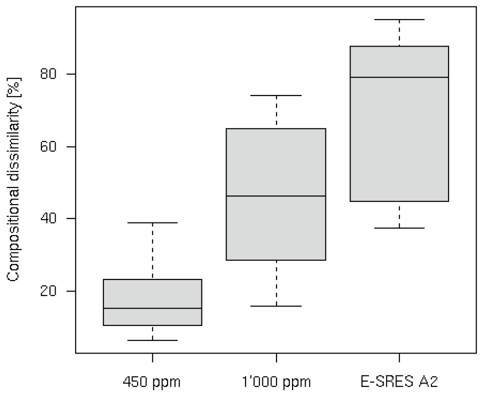

Fig. 2: Dissimilarity of forest compositions (in %) as simulated by FORCLIM. The box plots show the dissimilarities between the equilibrium forests under three climatic change scenarios and the base-line climate as given by the first time window (1864-1891) according to [1] at 12 Swiss sites (dissimilarity index represents the fraction of the biomass with a complete change in species abundance). "450 ppm" and "1'000 ppm" are CO_2 stabilization scenarios [2], "E-SRES A2" refers to an extended SRES A2 scenario assuming a stable, global temperature beyond 3000 (see also text).

Cited literature

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