Feedback of forest distribution on the simulated climate of the metropolitan region of Hamburg

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Introduction

In the project KLIMZUG-NORD the chamber of Agriculture of Lower Saxony suggests forest conversion as one possible adaptation strategy to cope with projected drier and warmer summers. Conversion of coniferous to deciduous forest ensures an increased groundwater recharge because of less canopy interception and reduced transpiration outside the growing season (e.g. Chmielewski 2007)

Definition of forest conversion: *conversion of mostly coniferous forest monocultures to deciduous and mixed forests.*

Observed processes induced by forest conversion

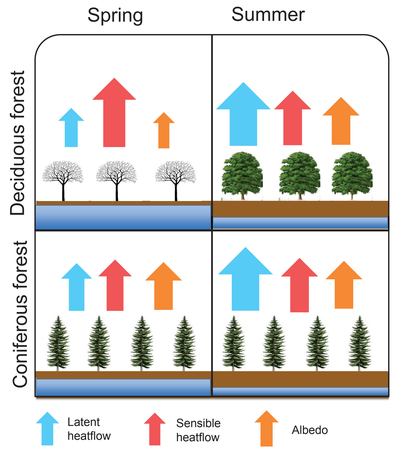

Figure 1: Impacts of forest conversion on the water- and energy cycle in temperate regions with soils darker than vegetation

Deciduous in comparison to coniferous forests

Spring

- Higher sensible heat flow; lower latent heat flow: less evapotranspiration
- Higher albedo: soil is darker than the vegetation.
- Higher temperature in winter and spring

Summer:.

- Assumption: Leaf area index and albedo are the same for coniferous and deciduous forests
- No differences in fluxes
- Higher soil water content: less consumption outside the growing season

Methods

Implementation of forest conversion into REMO

Landsurface: Data of the German Digital Landscape Model (Basis-DLM2009) of the Federal Agency for Cartography and Geodesy (GeoBasis- DE/BKG, 2010)

REMO is calculating with a match of parameters which are allocated to the ecosystem classes (Hagemann, et al. 1999, 2002).

Constants: Forest ratio, surface roughness length, maximum soil water holding capacity
Cycles: Surface albedo without snow, fractional vegetation cover, leaf area index (LAI)

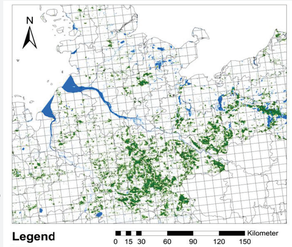

Figure 3: Area of forest conversion in the metropolitan region of Hamburg

The parameter in each grid box are aggregated for the different classes

Changes in the land surface parameter by forest conversion

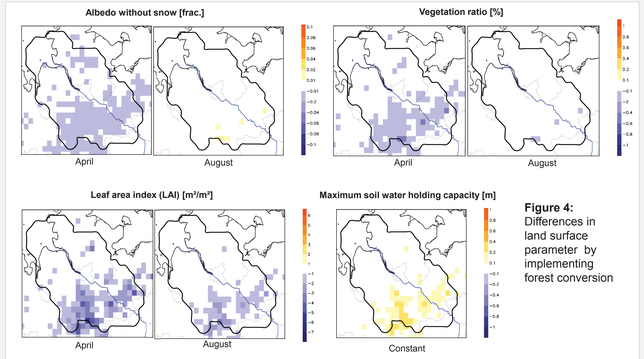

Figure 4: Differences in land surface parameter by implementing forest conversion

Results: Feedback of forest conversion in a dry summer 2003:

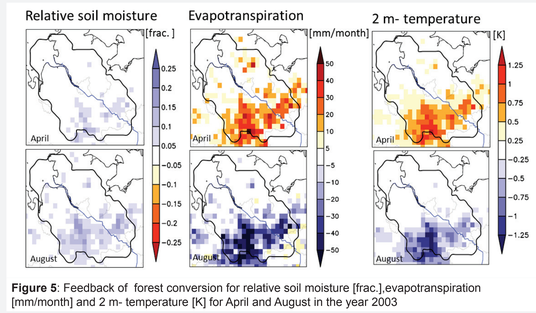

Figure 5: Feedback of forest conversion for relative soil moisture [frac.],evapotranspiration [mm/month] and 2 m- temperature [K] for April and August in the year 2003

- Increase in soil moisture
- Less evapotranspiration in winter/spring and
- Lower albedo in winter/spring

➡Warming in winter/spring

- Evaporative cooling in summer

➡Lower 2 m- temperature in summer

Results: Sensitivity of forest distribution under different climate conditions

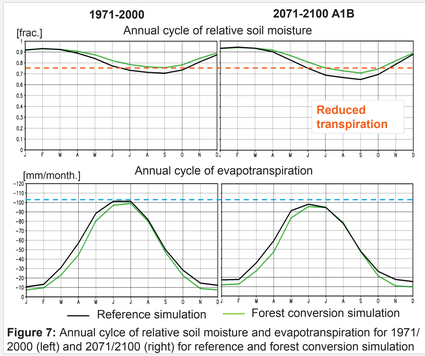

Figure 7: Annual cylce of relative soil moisture and evapotranspiration for 1971/2000 (left) and 2071/2100 (right) for reference and forest conversion simulation

Climate change signal for the metropolitan region of Hamburg under A1B emission scenario:

- 2 m- temperature is projected to increase more in winter than in summer
- Precipitation is projected to increase in winter and decrease in summer
- Less evapotranspiration in summer because of limited soil water availability

Under the A1B emission scenario warm and dry summer occur more often. Due to the improved water storage in the soil by forest conversion the effect of evaporative cooling in summer occurs more often.

Research questions:

How does forest distribution feedback on the simulated climate of the metropolitan region of Hamburg? And does the regional model REMO reproduce the observed processes?

How could the feedback change under different climate conditions?

Methods

Simulations with the regional climate model REMO

Grid: 49x41x27
Resolution: 0.088 ~10x10km²
Version: REMO2011

Periods:
1990-2009 (ERA-Interim)
1970-2000 (ECHAM5-MPIOM)
2070-2100 (ECHAM5-MPIOM)
under A1B emission scenario

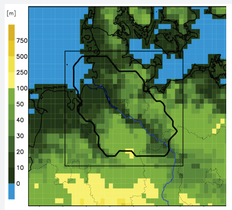

Figure 2: Orography [m] of model domain

Results: Feedback of forest conversion in a wet summer 2002:

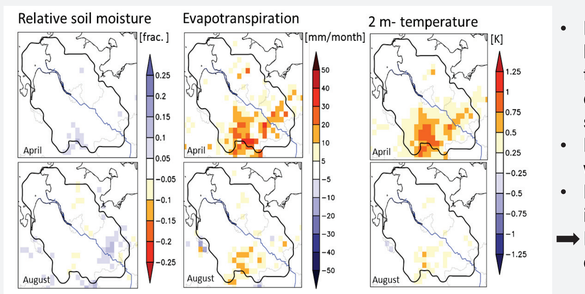

Figure 5: Feedback of forest conversion for relative soil moisture [frac.],evapotranspiration [mm/month] and 2 m- temperature [K] for April and August in the year 2002

- More or less the same high soil moisture, therefore almost no differences of relative soil moisture
- Lower albedo in winter/spring and
- Less evapotranspiration in spring/summer

➡Higher 2 m- temperature during the whole year

Conclusion

With forest conversion, REMO simulates an increase of soil moisture in spring/summer/fall in all years except for wet years like 2002. In winter/spring less evapotranspiration and lower albedo leads to higher temperatures. REMO represents observed processes.
Under A1B emission scenario there are different water conditions in soil and atmosphere. The climate change signal of the 2 m- temperature is intensified in winter/spring with forest conversion. Warm and dry summer with particularly low soil moisture are projected more often at the end of the 21st century. With forest conversion, the water storage is improved and therefore the effect of evaporative cooling occurs more often.

References:

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