Regional model simulations of vegetation, land-use changes and their effect on climate in Europe at 6k and 0.2k years BP

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Background

Humans have potentially affected climate long before we started to burn fossil fuel, e.g. by changing vegetation. Forests are cut down to make room for graze land or agricultural land.

Indirect effects: changed amounts of CO₂

Direct effects: changed surface properties
Previous results

- GCM simulations of last millennium: colder climate when vegetation is reduced. (e.g. Jahn et al, 2005; Brovkin et al., 2006; Pitman et al., 2009; Pongratz et al., 2009a; Goosse et al., 2012)

- Theoretical studies with homogeneously changed global vegetation show the same effect. (e.g. Kleidon et al., 2000)

- There are regional differences, but they are described as ambiguous or hard to evaluate. (e.g. Pitman et al., 2009; Goosse et al., 2012)
Questions

i) Did historical land-use have any influence on regional climate?

ii) Which processes are important for vegetation climate interaction?

iii) How much will the RCM-simulated climate differ depending on the description of past anthropogenic land cover used?

iv) Can we use climate proxy data to evaluate the model simulations?
Properties of different land cover

**Forest**: Low albedo, High evaporation

**Open land**: High albedo, Low evaporation

- Higher albedo → Lower temperature
- Lower evaporation → Higher temperature
- Deforestation
Time periods and vegetation

- Two time periods:
  - 6k (~ Mid-Holocene Warm Period) Relatively warm, low human impact on vegetation/land cover.
  - 0.2k (~ Little Ice Age) Cool, land-use much more extensive than at 6k.

- Three vegetation estimates:
  - Potential vegetation. Vegetation is allowed to grow freely.
  - HYDE3.1. Moderate land-use. (Klein Goldewijk et al., 2010)
  - Kaplan, KK10. Extensive land-use. (Kaplan et al., 2009)
Model approach

GCM (General Circulation Model): ECHO-G
RCM (Regional Climate Model): RCA3
DVM (Dynamic Vegetation Model): LPJ-GUESS
ALC (Anthropogenic Land Cover): HYDE3.1 and Kaplan (KK10)
Evaluation of ALC vegetation

KK10 is closest to REVEALS vegetation in northern Europe
Vegetation from LPJ-GUESS

% of Forest Cover | % of RCA3 PFT | % of Forest Cover | % of RCA3 PFT

6kV | 6kV | 0.2kV | 0.2kV

6kV+H3.1 | 6kV+H3.1 | 0.2kV+H3.1 | 0.2kV+H3.1

6kV+KK10 | 6kV+KK10 | 0.2kV+KK10 | 0.2kV+KK10

Forest Cover %: 100, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, 5, 0

Breakdown: 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, 5, 0

Open land %: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 100
Model vegetation

Two time periods: 6k and 0.2k

Three vegetation descriptions:
- potential veg.(V)
- + HYDE3.1(V+H)
- + Kaplan KK10 (V+K).

Fraction forest (%)
Temperature 0.2k (°C)
Precipitation 0.2k (mm/mon)
A closer look at three regions at 0.2k
Annual cycles 0.2k
Latent heat flux

Western Europe
Eastern Europe
Iberian Peninsula
Properties of different land cover

**Forest:** Low albedo, High evaporation

**Open land:** High albedo, Low evaporation

Deforestation

- Higher albedo  →  Lower temperature
- Lower evaporation  →  Higher temperature
Model proxy comparison (6k-0.2k)

ΔT

V

V+H3.1

V+KK10

Proxy

ΔT(°C) DJF

ΔT(°C) JJA
Model - proxy comparison (6k-0.2k)

$\Delta P$

- $V$
- $V+H3.1$
- $V+KK10$
- Proxy

$\Delta P$ (mm/month) DJF

$\Delta P$ (mm/month) JJA
Conclusions

- Past land-use changes are big enough to impact climate. Temperature response of up to ±1°C in summer. Depends on anthropogenic land cover change.

- The differences in simulated climate depend mainly on changes in albedo and heat fluxes. The dominant effect will depend on local/regional climate and vegetation characteristics.

- The importance of vegetation motivates more detailed vegetation reconstructions and land-use estimates, and more high resolution model simulations.

- Proxy data cannot be used to evaluate model results. The uncertainties in the proxies are at least as large as the differences between simulations.
Temperature 6k (°C)
Precipitation 6k (mm/mon)
Albedo 0.2k

Latent heat flux 0.2k (W/m²)

0.2k_V+K - 0.2k_V

0.2k_V

0.2k_V+K - 0.2k_V