Assessment of Climate Change for the Baltic Sea Basin BACC II

Causes of Regional Change—Land Cover

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Baltic Earth Earth System Science for the Baltic Sea Region

Chapter 25: Attributing causes of regional climate change

Land cover change

This subchapter discusses land-cover change as an external forcing of regional climate change. The influence of land-cover change on global and regional climate change is poorly know at this time. Natural, climate-induced land-cover change (e.g. replacement of tundra vegetation by forest, or the inverse) is part of the climate system and may produce either positive or negative **feedbacks** on climate, i.e. may either amplify or mitigate the initial change; anthropogenic land-cover change (e.g. deforestation or reforestation) may have similar effects and is, in that case, a **climate forcing**. A clear attribution of climate change to anthropogenic land-cover change is thus very difficult.

1. Interactions between vegetation and climate

→ **Biogeophysical effects** are related to the exchange of energy and moisture between the atmosphere and the land surface. There are two possible contrasting biogeophysical effects of a vegetation/land-cover change (climate or human-induced) from grass- to forest-dominated land surface:

- → a warming effect due to the lower albedo of forests compared to that of low herb vegetation (high albedo), and
- → a cooling effect due to higher evapotranspiration associated with forest expansion.

→ **Biogeochemical effects** are mainly photosynthesis-mediated and result in terrestrial carbon sinks and sources. For example, in cold regions, warming leads to vegetation growth, increasing photosynthesis and carbon uptake, which then leads to a cooling.

All these factors and processes are often operating in parallel and may have opposite effects. Anthropogenic deforestation, for instance, leads to a decrease in carbon uptake, and to a release of carbon via decomposition of dead wood or burning, i.e. has a warming effect. On the other hand, deforestration may also produce a cooling effect due to increased albedo. t is important to understand which of these effects is dominant and whether the net result is a warming or a cooling. The feedback loops shown in Figure 1 may be modified or eliminated by taking anthropogenic land cover change into account.

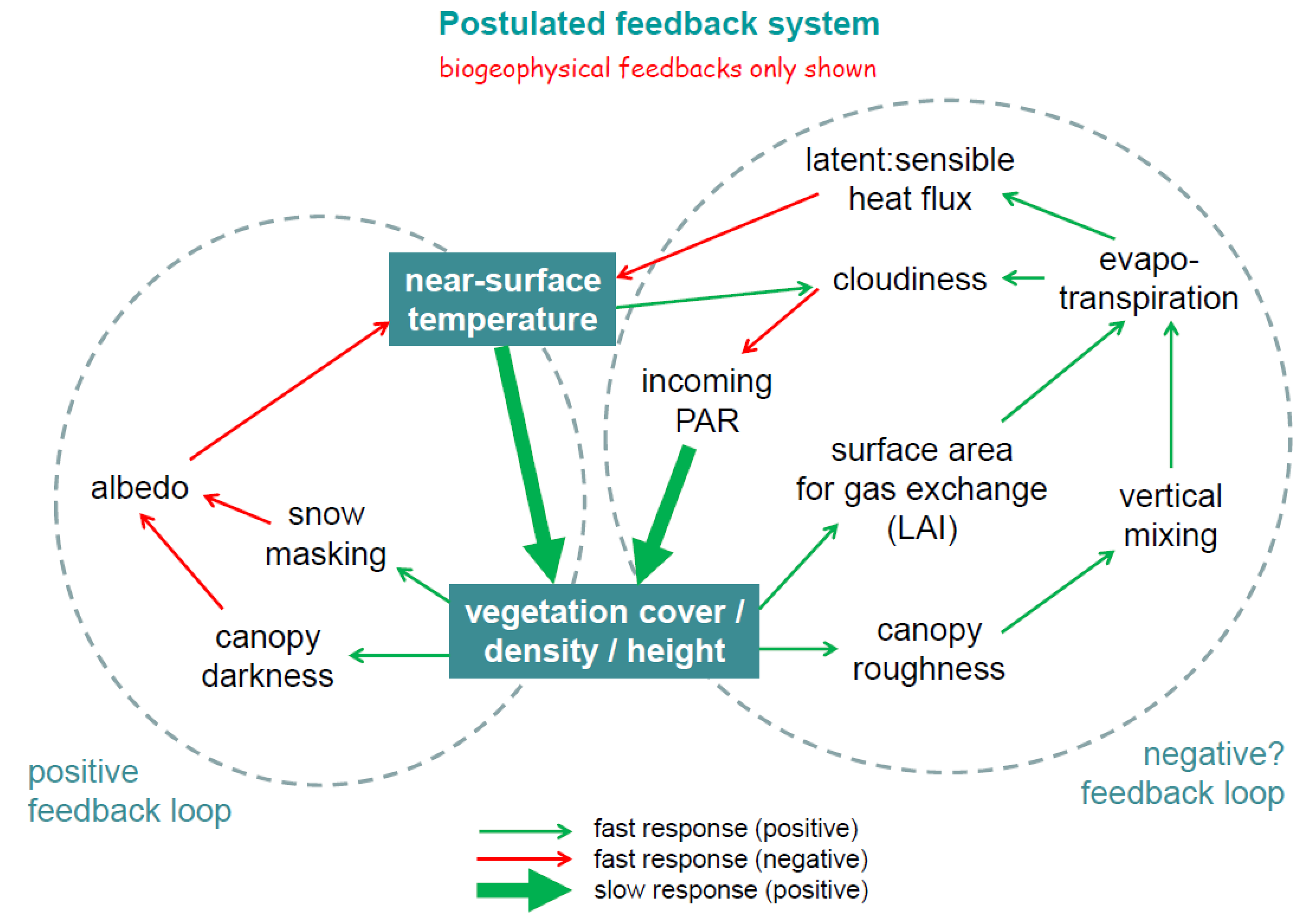

Figure 1: Land cover-climate interactions: A simplified scheme of the biogeophysical feedback system (after Ben Smith, unpublished). LAI: Leaf Area Index; PAR: Photosynthetically Active Radiation.

2. Past anthropogenic land-cover changes and their effects on climate

Scenarios of past anthropogenic land cover change (ALCC; e.g. Kaplan et al. 2009, Pongratz et al. 2010) show very inconsistent results. Pollen records from lake sediments and peat deposits may resolve some of these inconsistencies (Figure 2). Pollen records for NW Europe reveal i) deforestation from ca. 4,000 BC (Neolithic time), with particularly large deforested areas from ca. 1,000 BC (Bronze Age) up to the 19th century, and ii) reforestation from the mid-19th century. In Europe (and the Baltic Sea region), deforestation was at its maximum around AD 1850-1900 (60-80%, Figure 2).

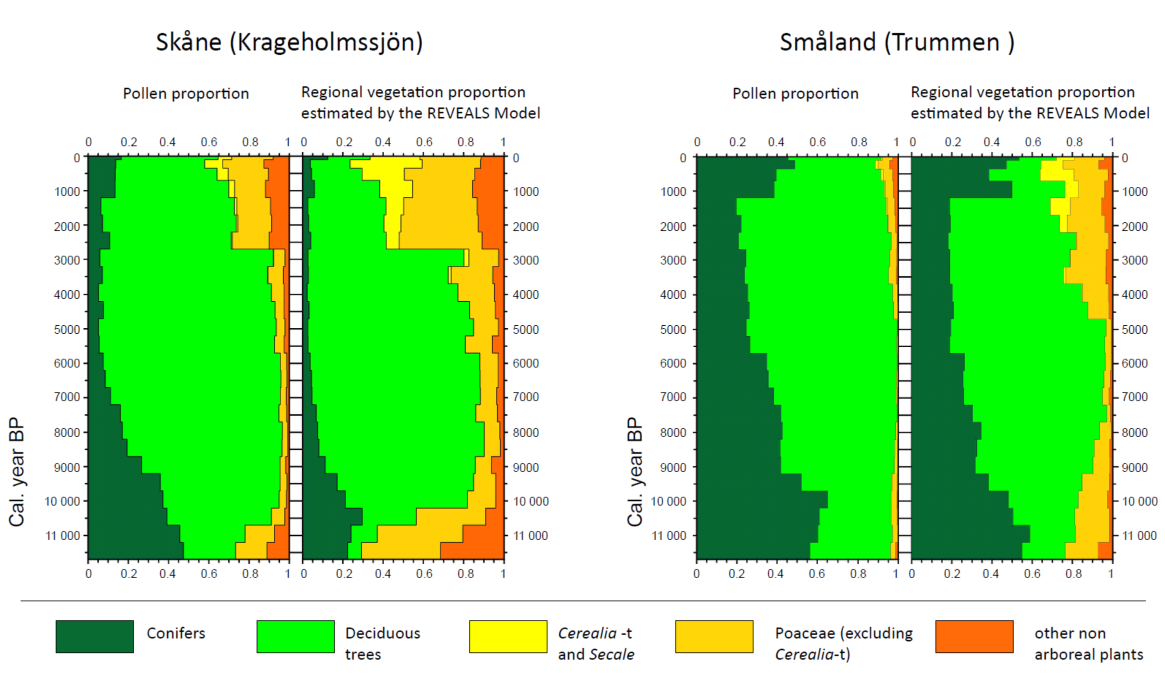

Figure 2. Results from the LANDCLIM project (from Gaillard et al. 2010 in Climate of the Past 6). Reconstructions using the REVEALS model to simulate the last 10,000 years of vegetation change (right in each panel) in southern Sweden based on the pollen records (left in each panel) from two lakes. REVEALS was run with 24 pollen taxa (corresponding to plant types), grouped into "conifers", "deciduous trees","Cereals" (Cerealia-t. (cereals other than rye) and Secale (rye)) and"other non-arboreal plants" (herbs and shrubs). Poaceae = grasses.

3. Global and Regional effects

On the regional scale, biogeophysical feedbacks are of particular interest since these exert a direct measurable effect on regional climate. Biogeochemical feedbacks are more relevant in the context of global climate change. However, the Baltic Sea region has extensive forests and wetland areas, therefore the carbon storage in vegetation and soils in the region is significant, although specific regional estimates are lacking.

Results from global climate models: Globally, biogeophysical effects from ALCC during the last millennium apparently had a slight cooling influence on mean temperature (−0.03 K in the 20th century), while biogeochemical effects led to a strong warming (0.16–0.18 K) (Pongratz et al. 2010). The climate response to historical ALCC, both globally and in most regions, is dominated by a warming due to the release of CO_2.

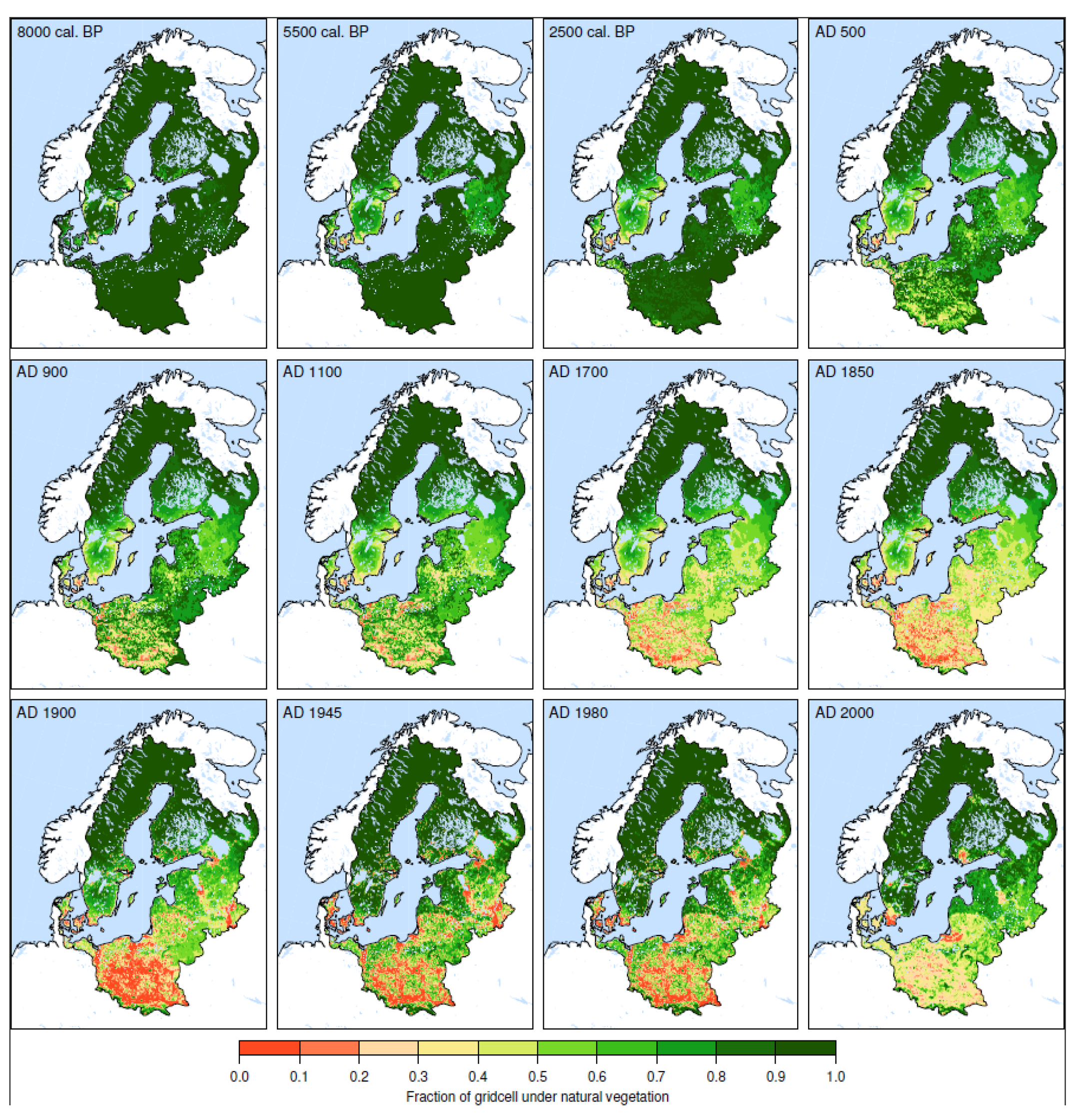

Figure 3: Past anthropogenic land–cover change in the Baltic Sea basin over the Holocene, simulated using models of population growth and soil suitability for agriculture and grazing . The time trend of increasing population and agricultural land use can be seen in this series of maps covering the last 8,000 years (KK10 scenarios extracted for the Baltic Sea area, from Kaplan et al. 2009 and 2012)

4. Regional effects, continue

Regionally, the biogeophysical effect is larger. The cooling in northern high and mid latitudes was found to be largely albedo driven, leading to a winter cooling of up to 0.9 K in northeast Europe (Pongratz et al., 2010), in accordance with previous and later studies (Betts 2001; de Noblet- Ducoudré et al., 2012). Therefore, strong local biogeophysical effects can substantially influence the spatial pattern of the net temperature response, particularly over agricultural areas. New climate simulations using a regional climate model published after 2013 (Strandberg et al., 2014) show that the biogeophysical forcing of anthropogenic deforestation in Europe at AD 1750 is between +1°C and - 1°C, its sign and magnitude depending on the season and geographical location.

5. Conclusions

Land cover changes should be accounted for when exploring the impact of human forcings on the regional climate, especially in regions which have undergone intensive anthropogenic land cover change (such as e.g. Europe). The magnitude of land cover forcing under past, current and projected future climate warming is still poorly known and much debated. It is not clear what the net effect is and will be at global and regional scales, but from the available information it is clear that it will differ between regions. More research and further modelling studies are needed to improve future land use management in the light of a changing climate.

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