Land-use and land cover change: an energy balance perspective

Key messages:

- The Earth's surface energy balance is altered by changes in land use and land cover (LULCC), which impacts seasonal and annual surface temperature and precipitation at the local to regional level.
- Mitigation and adaptation strategies at the local level should take into account the overall effect of LULCC on climate, including the effects due to alterations of the surface energy balance ("biophysical effects"), beyond the effects on greenhouse gas balances ("biochemical effects").
- A synthesis of existing knowledge highlights the need to provide effective tools for measuring and monitoring biophysical effects of LULCC at local to global level so as to provide to policy makers instruments for an overall evaluation of LULCC-climate impacts.

Context and importance of the problem

Land-use and land-cover changes (LULCC) have a recognized effect on climate, both in terms of changes in the carbon cycle due to changes in vegetation and soil carbon (biogeochemical effects), but also through variations in the surface energy budget mediated by reflected sunlight, evapotranspiration, canopy structure, etc. (known collectively as biophysical effects). Biophysical effects result in changes in seasonal and/or annual surface temperatures and precipitation with prevalently local to regional effects, which depend - in sign and in magnitude - on the latitude and ecosystems where they occur. Although biophysical impacts on climate can be relevant at the regional scale, the international UNFCCC process focuses on the biogeochemical effects. Nonetheless, since LULCC is a regional phenomenon, two emerging questions are: How to provide a simple climate metric that summarizes the changes in temperature and precipitation due to biophysical impacts following large scale LULCC? How to both account for the global LULCC climate impacts from biochemical processes and local/regional impacts from biophysical processes, especially in view of land-based mitigation and adaptation strategies?

Recent advances

We have produced a synthesis of the existing knowledge on temperature and precipitation changes due to biophysical effects of LULCC in order to provide an evidence base to policy makers on which to judge the need for an assessment of biophysical changes caused by land-based mitigation/adaptation policies. One objective of LUC4C is to provide a tool for policy makers that supports quantification and monitoring of LULCC biophysical effects of land use change; this tool is under development, the review presented here serves as a first step towards it.

Effect of deforestation on temperature

Existing literature suggests that vast regional deforestation has a predominantly warming effect in the tropics of about +0.60±0.7°C due to reduced evapotranspiration, but a cooling effect in the boreal regions, due to increased reflection of sunlight especially in winter (-2.2 ±1.1°C) (Figure 1). Temperate ecosystems are influenced by both evapotranspiration and light-reflection; the warming/cooling effect of LULCC is therefore highly uncertain and may be affected strongly by local conditions. The modeled regional LULCC effects on global annual average temperatures (Figure 2) suggest that the effects on regional temperature propagate globally in terms of a similar sign of signal of change in temperature, but the magnitude of global temperature change is smaller, showing alterations of the global annual average temperature from 0.5°C (Boreal and Temperate regions) to +0.16±0.26°C (Tropical region).

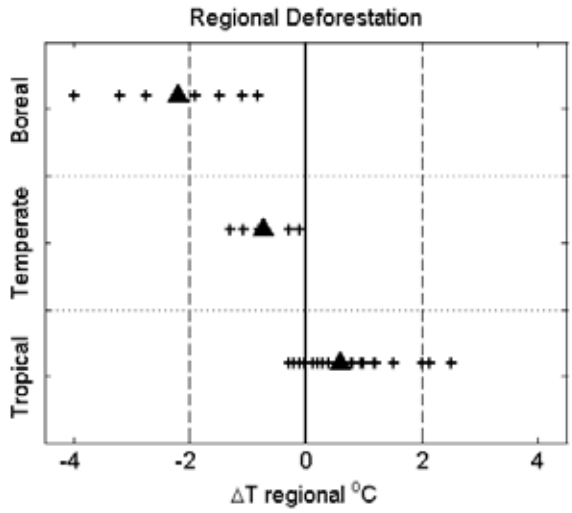


Figure 1: Biophysical effects of complete regional LULCC deforestation on regional average temperatures (°C, expressed as difference to a case with non-LULCC, ΔT). Black crosses represent results from individual model simulations, filled triangles are the mean of each region.

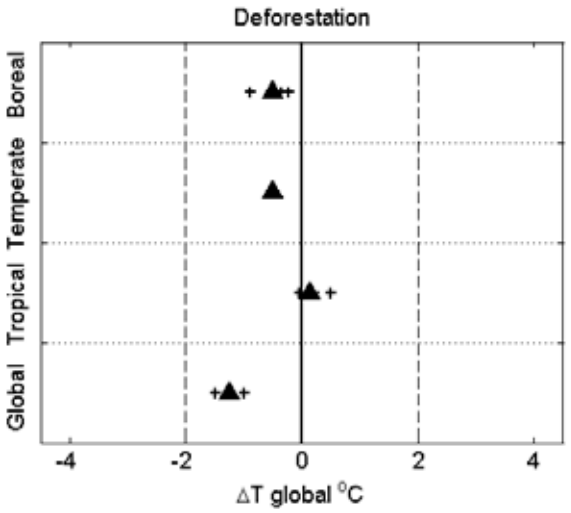


Figure 2: The global ΔT that was simulated to be associated with regional (or global) deforestation. Black crosses represent results from individual model simulations, filled triangles are the mean.

Effect of deforestation on Precipitation

Regardless of the ecological zone, complete deforestation at the regional level often leads to a reduction in annual precipitation in simulation experiments, although the number of studies is extremely scarce and very uncertain (Figure 3). The strongest deforestation-precipitation effects are likely to occur in tropical zones, followed by the temperate zone, and the boreal regions. Similar to the effects of LULCC on temperature (see above) values in the Figure below are taken from model simulation studies in which a complete removal of tree vegetation is assumed for a vast study area.

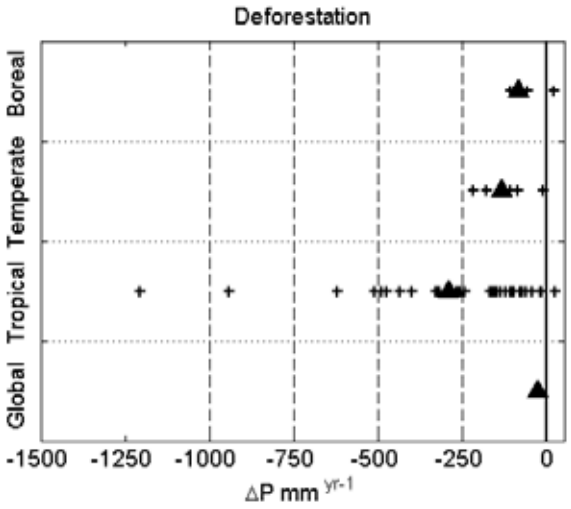


Figure 3: Biophysical effects of regional (or global deforestation) on regional/global changes of average annual precipitation. Black crosses represent individual model simulations, filled triangles the mean.

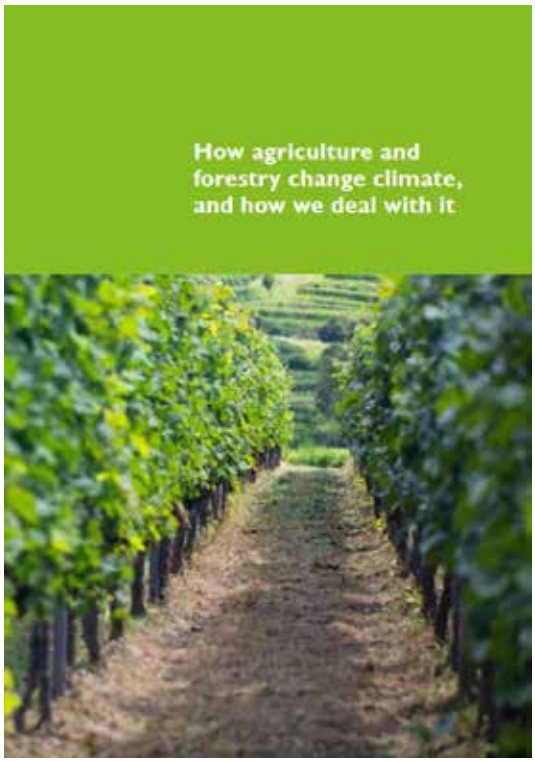
Policy recommendations

So far, the evidence drawn from published scientific literature is derived from simulations that apply idealized global/regional-scale deforestation or reforestation experiments using global climate or earth system models. However, this presents difficulties in assessing the dependency of biophysical climate effects on the size of the LULCC. Nevertheless, our analysis shows clearly that for a comprehensive assessment of LULCC impacts on local to regional climate, the LULCC biophysical effects have to be taken into account. The biophysical effects following LULCC are important for ecosystems, their biodiversity and the water cycle. Thus a clear understanding of these is important for assessing local impacts and adaptation needs. Policies at the local to regional level that aim to address both mitigation and adaptation objectives will thus be more effective if they account for biophysical climate effects of the LULCC.

The project LUC4C, *Land-use change: assessing the net climate forcing, and options for climate change mitigation and adaptation*, is funded by the EU.

The aim of LUC4C is to bring forward our knowledge about the interactions of climate change and land-use change. The scientists in LUC4C work on the development of complex earth system models, tools for providing an integrative assessment of the land-use change - climate change interplay, and guidelines for policy and other societal stakeholders. LUC4C seeks to identify and understand the societal and environmental drivers of land-use and land-cover change, as well as why they are relevant to climate change. The project evaluates different mitigation and adaptation policies in view of how they affect important ecosystem processes, and whether (unintended) conflict with other eco-system services related to land-use and land-cover changes arise from the implementation of such policies.

More information can be found on the project website www.luc4c.eu.



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