Paying more attention to land-use will benefit climate change assessments

Estimates of the historical and future impacts of land-use change on climate (e.g., carbon loss following deforestation for food production; carbon uptake in reforested areas) are mostly based on modeling studies. Model-based assessments are uncertain due to lack of observational data, insufficient understanding of natural processes, and strong simplifications in the modeling process. This can lead to over- or underestimation of land-based climate change mitigation (e.g., through afforestation) and adaptation (e.g., crop and soil management) potentials.

Current global climate and vegetation models, whose results support the development of climate change mitigation and adaptation policies, typically incorporate only a single land-use dataset to estimate impacts for historical times. Furthermore, the implementation of managed land often lacks important details about diversity of crop types and the processes that drive the transition from natural to managed vegetation. To reduce uncertainty in estimates of climate impact through land-use change and enhance the quantification of net land-based mitigation and adaptation potentials, the design of large-scale modeling studies needs to better account for variation in land-use representations, as long as empirical data cannot provide sufficient accuracy. **Constraints and limitations of current approaches need to be openly communicated and recommendations should be tested for robustness under alternative model-representations.**

Assessments of land-based climate mitigation options need to account for the competing claims on land resources. Land that is designated as 'available' for climate mitigation purposes is frequently used by traditional, low-intensity land-use, provides a range of ecosystem services, and can sustain high levels of biodiversity. Simplistic assumptions can largely overestimate land-based mitigation potential or lead to trade-offs and conflicts with existing functions of the land.

Context and importance of the problem

Land-use change is estimated to contribute substantially to greenhouse gas emissions (e.g., around one third of total anthropogenic CO_2 emissions since preindustrial times) and also changes the surface energy and water balance. Historically, climate models did not account for human impact on the land surface, e.g., through agricultural activity. Instead, the vegetated land surface was represented by natural vegetation only. Although now increasingly included, the representation of land-use in climate models still suffers from several problems. Observational data to verify the output of land-use change models are scarce (especially for historical times) or come with insufficient resolution and accuracy. For example, maps of the current global distribution of croplands deviate substantially (Figure). These deviations increase for historical times, since for these periods, maps need to be derived from models that are based on uncertain relationships between population density estimates and land requirements to feed people.

Context and importance of the problem

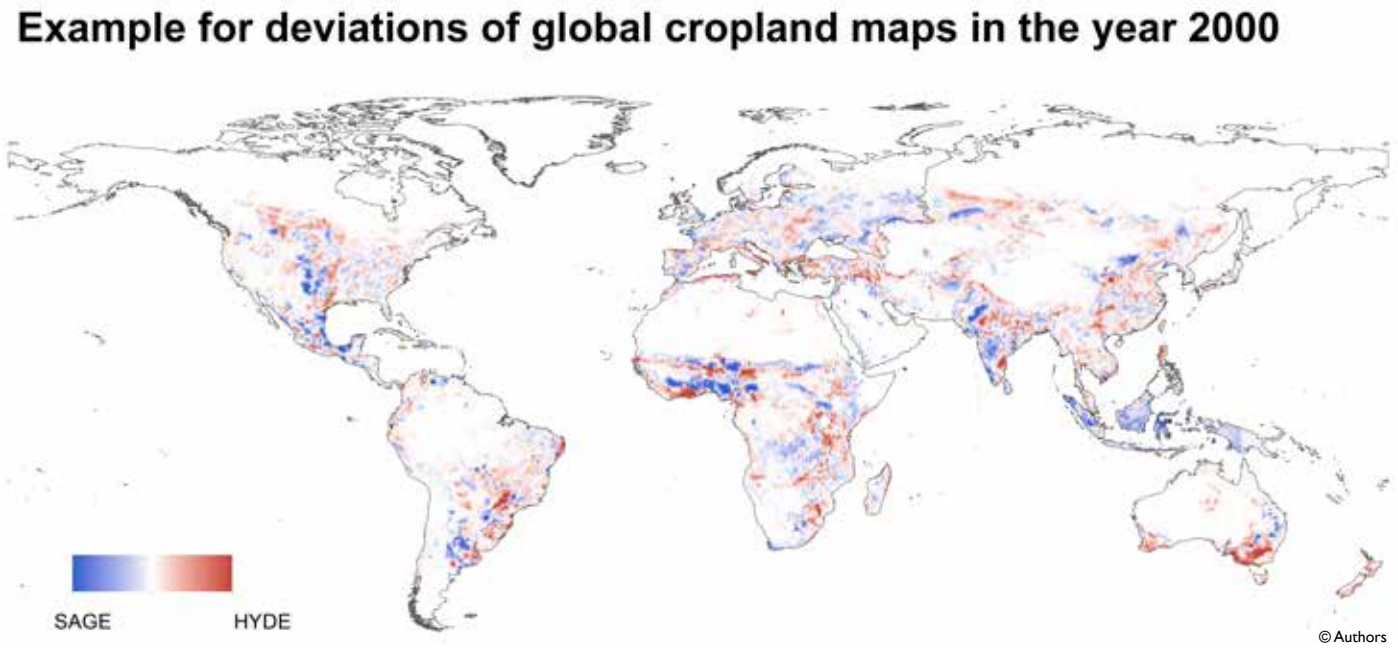

Figure: Differences in global distribution of cropland in the year 2000 between two commonly used data products (SAGE, Ramankutty et al. (2008); HYDE 3.1, Klein Goldewijk et al. (2010)). Blue colors indicate greater area of cropland in the SAGE product, while red colors indicate a greater area of cropland in the HYDE 3.1 product.

Moreover, in global climate and vegetation models, expansion of managed land is often implemented following simple rules that do not account for regional socio-economic conditions and human decision-making. However, even simple decisions like if a forest rather than a natural grassland is converted to agricultural land may have large impacts, e.g. on the amount of CO_2 emitted.

These uncertainties propagate to the final impact assessments (e.g., what is the contribution of human land-use activity to greenhouse gas emissions and climate change) and can affect decisions on which land-based mitigation and adaptation options are most promising to prevent people from future adverse effects of a changing climate.

Recent advances

Currently, efforts within the modeling communities contributing to the IPCC reports relate to the standardization of land-use data products, selection of a single historical-to-future harmonization approach, and the development of a common land-use implementation strategy in climate and vegetation models. These efforts enhance consistency within the modeling frameworks and allow to evaluate land-use change models in comparison studies. However, this approach also assumes a high certainty about human land-use change history and potential futures and ignores uncertainties related to data inconsistencies and modeling approaches. Harmonization averages out variations in data and model results that have arisen through different definitions of land-use, different observations and different assumptions in models.

Policy recommendations

More attention to land-use data and modeling is required to improve the reliability of climate projections. In order to provide scientific underpinning for land-based mitigation, advances can be made by promoting good practice such as:

1) Fostering initiatives that improve land-use change (and related) observational data on a global scale, including ensuring sufficient spatial and temporal resolution, to aid improvements in model development and evaluation;
2) Facilitating open access to high resolution satellite imagery, including appropriate frameworks for storage, management and quality assurance of data products for end users would support the development of high quality land-use change data products;
3) Considering, beyond the current widely used integrated assessment approaches, advances in novel land-use modeling approaches in order to better account for the human decision-making aspect of land-use change;
4) Promoting (nested) regional scale assessments within global analyses, since with such an approach local realities and trade-offs can be addressed more realistically;
5) Accounting for uncertainty in the modeling process (i.e., including different plausible estimates of historical and future land-use change in the climate modeling process).

To do so, facilitation of knowledge exchange between the climate modeling community and stakeholders (e.g., policy makers) is needed to ensure both that stakeholders are up-to-date with the latest relevant scientific findings, but also that their needs are heard and taken into account in the scientific process.

Klein Goldewijk K, Beusen A, Janssen P (2010) Long-term dynamic modeling of global population and built-up area in a spatially explicit way: HYDE 3.1. The Holocene, 20, 565-573.

Ramankutty N, Evan AT, Monfreda C, Foley JA (2008) Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000. Global Biogeochemical Cycles, 22.

Prestele, R., Arneth, A., Bondeau, A., de Noblet-Ducoudré, N., Pugh, T. A. M., Sitch, S., Stehfest, E., and Verburg, P. H. (2016): Current challenges of implementing land-use and land-cover change in climate assessments, Earth System Dynamics Discuss., 2016, 1-28.

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 ecosystem 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.

How agriculture and forestry change climate, and how we deal with it

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