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The effect of the replacement of forests by agricutural land on mean and extreme temperature in temperate regions from 1850 to present

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During the industrial period, the extent of forest was reduced in favour of the expansion of agriculture in most temperate regions. This has impacted local climate conditions by modifying the physical properties of the land surface such as albedo and evapotranspiration rate. Previous modelling studies suggest that these historical land-use and land-cover changes (LULCC) have had a cooling effect annually, in some regions of a similar magnitude as the temperature changes driven by increasing greenhouse gas (GHG) concentrations, but with large differences in the magnitude and the seasonal pattern of the temperature response among models [1,2]. These studies were however limited to seven GCMs, and the considered simulations were run with global non-coupled models using fixed Sea Surface Temperatures (SSTs).
Here, our goal is to reassess these findings using a larger number of fully coupled historical simulations from the Coupled Model Intercomparison Project phase 5 (CMIP5). We include only CMIP5 models providing at least three ensemble members, in order to take interannual variability into account. These historical simulations were driven by both natural (volcanoes) and anthropogenic forcings (GHG, land-use, aerosols). In order to disentangle the effect of LULCC from that of other forcings, we compared climate changes in neighbouring grid cells in which surface temperature is assumed to respond similarly to GHG and other large-scale forcings, but which differ in terms of land-use forcing.
Our analysis confirms that the expansion of agriculture at the expense of forests lead to a local cooling in winter, with nine models out of 11 indicating such a behaviour, and it also suggests that this response was primarily driven by albedo changes. However, the results reveal a higher model disagreement than what was previously found regarding the impact on summer temperature changes, with five models out of 11 showing a warming effect of LULCC, against only one out of seven in a previous inter-model comparison [1,2]. Furthermore, we show that this lack of agreement is even higher for the hottest extremes. This is largely related to the inter-model spread in evapotranspiration changes following the conversion from primary vegetation to cropland. We find that the uncertainty about the impact of LULCC on summer temperature is dominated by the inter-model spread, while the effect of interannual variability remains limited. The opposite is true for the winter season. On average, we calculate that the magnitude of the impact of LULCC on near-surface temperature from 1850 to present was about 30% as big as that of the cumulated effect of other forcings in North America, although this value highly depends on the considered model.

References:
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