Geophysical Research Letters

Supporting Information for

Why does the locally induced temperature response to land cover change differ across scenarios?

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Introduction

The figures are numbered according to the order of their reference in the main text:

- Figures S1, S2 and S6 show the changes in forest fraction and the resulting locally induced changes in surface temperature for land-use-induced land cover change, climate-induced land cover change and changing background climate. These results are described in sections 3.1 and 3.2 of the main text.

- Figure S3 shows that the synergies between land-use-induced and climate-induced land cover change are small. Thus, our choice of fist applying LULCC and then CILCC for the results in the main text does not influence our conclusions.

- In Text S1, and Figure S4, we assess the influence of changes in the vegetated fraction within a grid box.

- Figure S5 displays the changes in surface temperature for complete deforestation in two different background climates, and the difference of the two effects. This difference is used for calculating the influence of a changing background climate on the locally induced changes in surface temperature in the LCC scenarios as described in section 2.3 of the main text.

- In Text S2 and Figure S7, an idealized scenario is added to our assessment.

- Figure S8 shows results separately for areas where LCC leads to cooling and warming, respectively.

Text S1 - Influence of changes in the vegetated fraction.

In addition to changing forest cover fractions (*c)* within the vegetated part of each grid box, the vegetated fraction (veg_{max}) is changing in a warmer climate due to natural vegetation dynamics, altering the total forest fraction within a grid box. For the results in the main text, we fixed veg_{max} to the grid values of the year 2005, and only considered changes in *c*. Keeping this veg_{max} constant possibly leads to an underestimation of the role of climate-induced land cover change. In this supplement, we want to estimate how big the influence of changing veg_{max} can become. Note that when vegetated fraction increases, bare land is replaced by both grasslands and forests, while our method only allows calculating the effects of replacing forests by grasslands and vice versa, so the calculations here should be understood as a *rough* estimate for the influence of changing veg_{max}. Using the present-day look-up curve *s* for each grid box, we estimate the contributions of Δc, Δveg_{max}, and the synergy term $\Delta c\ \Delta veg_{max}$ as follows:

$$\Delta \mathrm{T}_{surf}\,(\Delta \mathrm{c}) = \mathrm{s}(c_{2100}) - \mathrm{s}(c_{2005}) \qquad (1)$$

$$\Delta \mathrm{T}_{surf}\,(\Delta veg_{max}) = \mathrm{s}(c_{2005} + c_{2005}(veg_{max2100} - veg_{max2005})) - \mathrm{s}(c_{2005}) \qquad (2)$$

$$\Delta \mathrm{T}_{surf}(\Delta c \Delta veg_{max}) = \mathrm{s}(c_{2005} + (c_{2100} - c_{2005})(veg_{max2100} - veg_{max2005})) - \mathrm{s}(c_{2005}) (3),$$

where equation 1 describes the response in locally induced surface temperature due to changes in *c* when veg_{max} is kept constant, equation 2 describes the response due to changes in veg_max when *c* is kept constant, and equation 3 describes the synergy between these two.

We assess the impact of the changing veg_{max} exemplarily for the RCP8.5 scenario as shown in Figure S4. The response due to a changing *c* (here land-use-induced plus climate-induced land cover change) clearly dominates the response to changing veg_{max} and the synergy term.

Text S2 – Influence of the pre-LCC forest fraction for an idealized scenario.

In section 3.3 of the main text, we examine the influence of pre-LCC forest fra**c**tions on the temperature response in realistic LCC scenarios. Here, we complement this assessment of realistic LULCC scenarios by an 'idealized' deforestation scenario similar to the experimental set-up proposed for the Land-Use Model Intercomparison Project (LUMIP) within CMIP6 [Lawrence et al., 2016]: We deforest the same areal extent as for historical deforestation, but we distribute the deforestation uniformly in highly forested areas (higher forest fraction than in 70% of all grid boxes) by deforesting proportionally to the 1850 forest fraction. Like this, we redistribute historical deforestation to areas with high forest cover (see Figure S1).

The deforestation-induced warming of historical and idealized deforestation is similar when using the linear look-up lines, so on average, LCC in both scenarios is located in areas which respond similarly to deforestation (see Figure S7). However, accounting for the nonlinearity reduces the effect of historical deforestation substantially less than 'idealized' deforestation. This difference has two reasons: First, the pre-deforestation forest fractions differ (on average 56% for historical, 70% for idealized deforestation in the year 1850). Since deforestation is generally more efficient (that means, deforestation causes more temperature change per unit forest fraction change) when starting from a low forest fraction (Figure 4 in the main text), historical deforestation is on average more efficient than deforestation in the idealized scenario. Second, historical deforestation is concentrated on comparably few grid boxes, and others remain largely untouched. In contrast, idealized deforestation is distributed over many grid boxes, so the deforestation of each grid box is small (Figure S1) and does not reach the low forest fractions, at which deforestation would be more efficient.

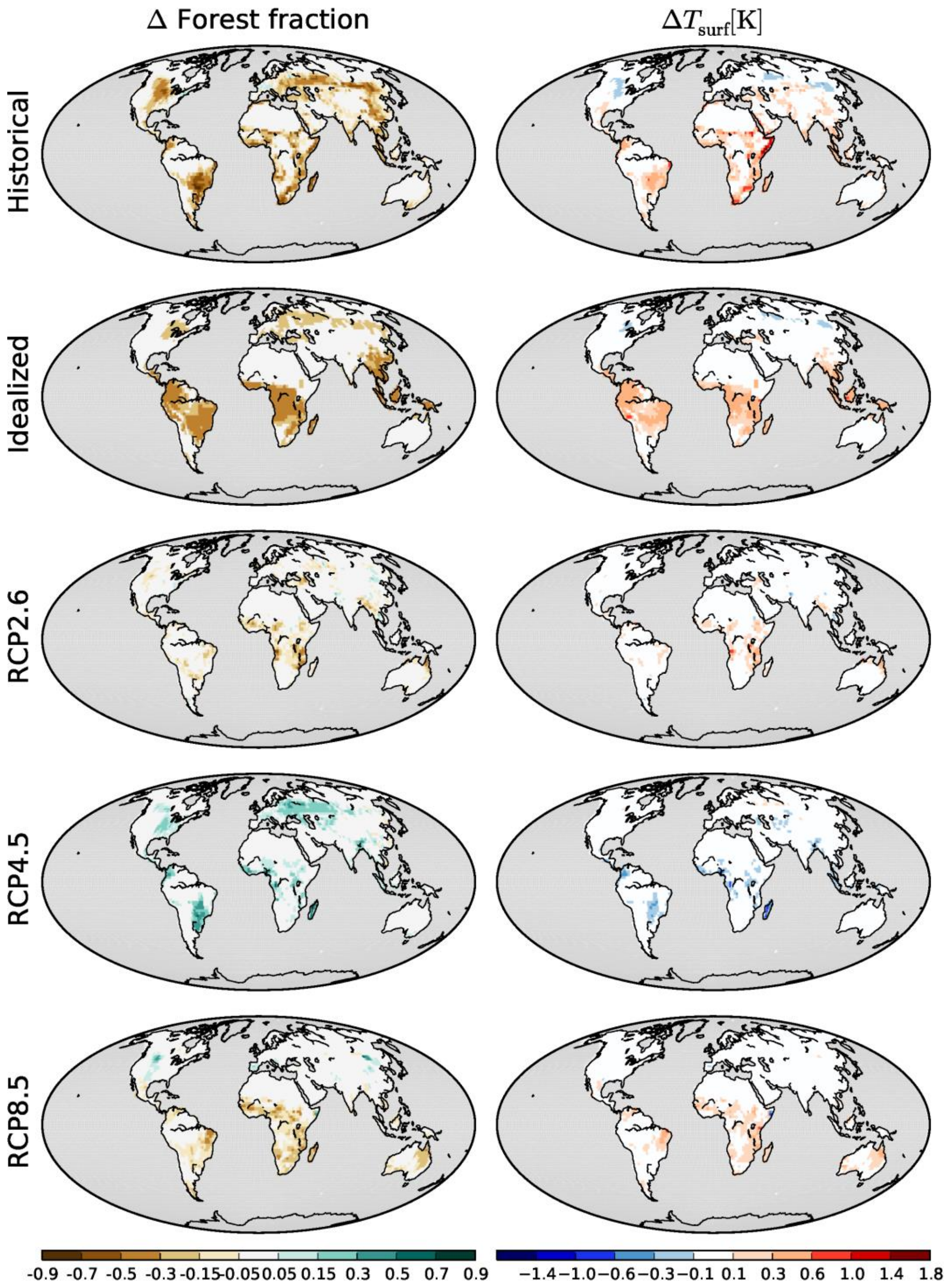

Figure S1. Land-use-induced land cover change (LULCC): changes in forest fraction and resulting changes in local surface temperature. The changes in surface temperature are obtained using the look-up map for present-day background climate and accounting for the nonlinearity. For a description of the 'idealized' scenario, see Text S2.

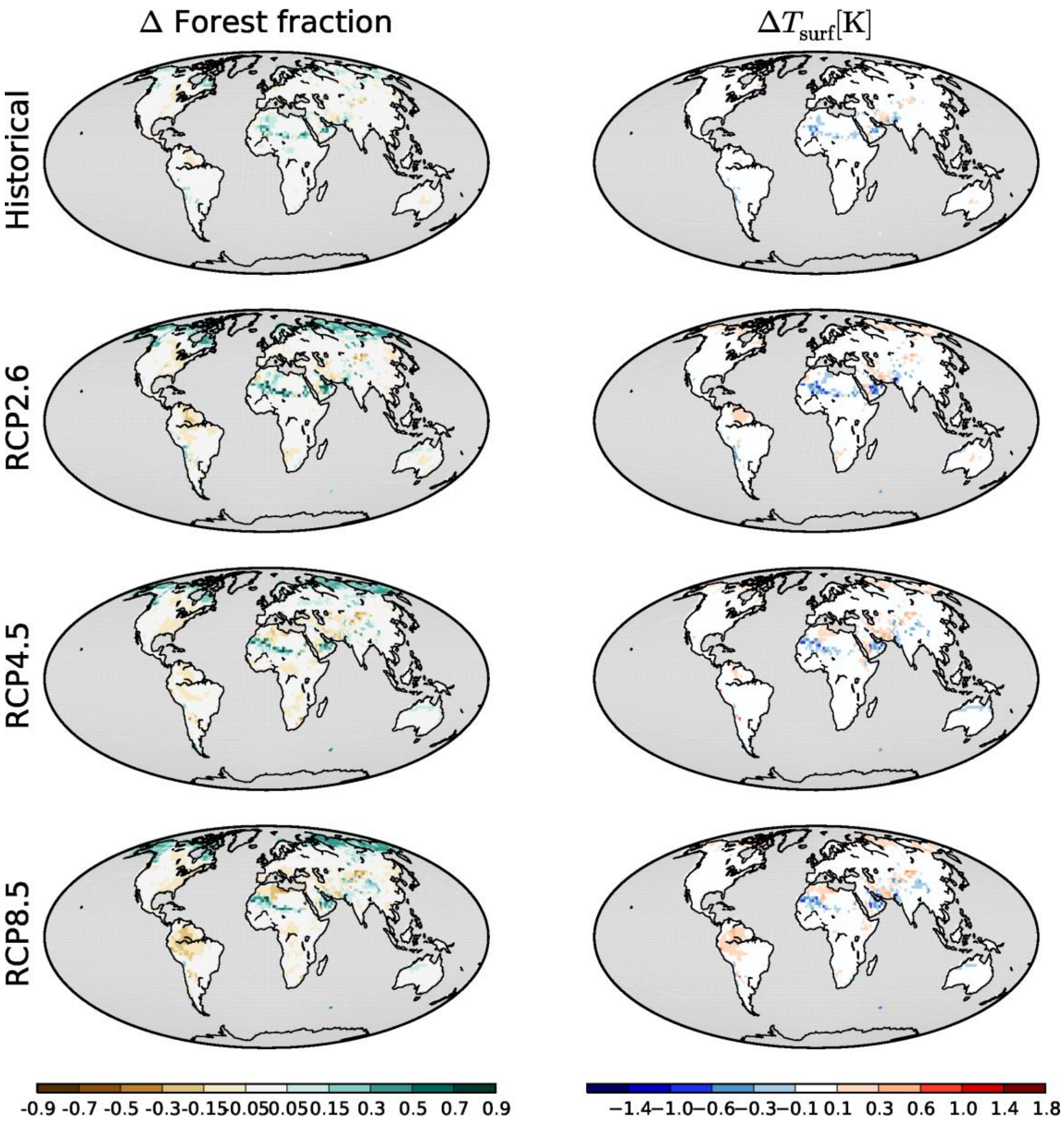

Figure S2. Climate-induced land cover change (CILCC): changes in forest fraction and resulting changes in local surface temperature. The changes in surface temperature are obtained using the look-up map for present-day background climate and accounting for the nonlinearity.

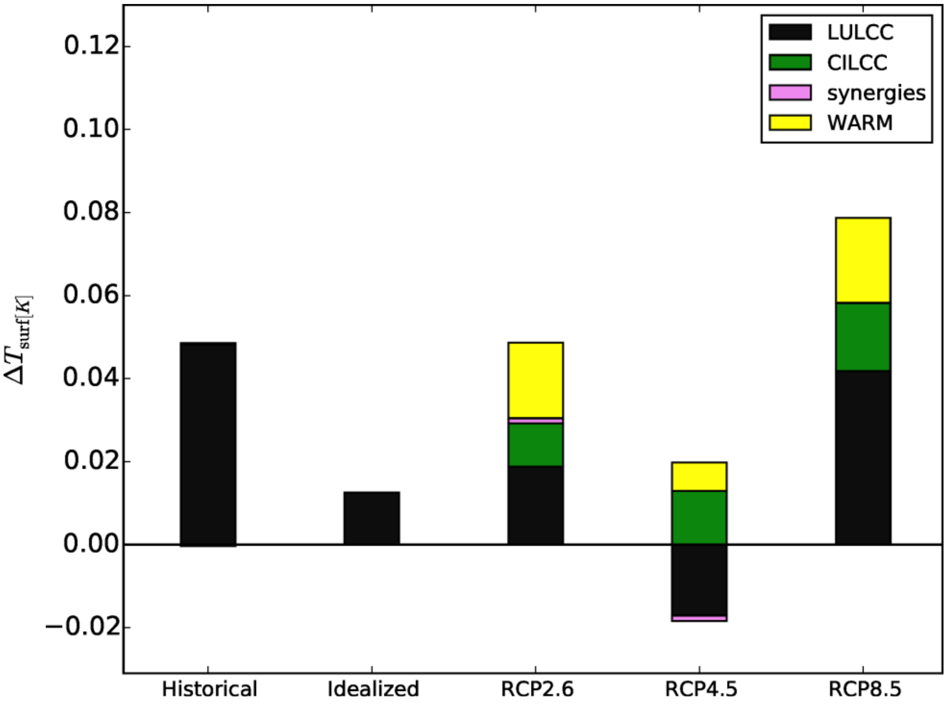

Figure S3. Despite the nonlinearity, it does not substantially matter whether we first calculate LULCC or CILCC. Due to the nonlinearity, applying both LULCC and CILCC might yield a different result from applying LULCC and CILCC separately; however, the synergies between them (pink bars) are small in all considered LCC scenarios, because LULCC and CILCC are mostly active in different regions (the affected regions in Figs S1 and S2 are mostly disjoint), as mentioned in section 2.2 of the main text.

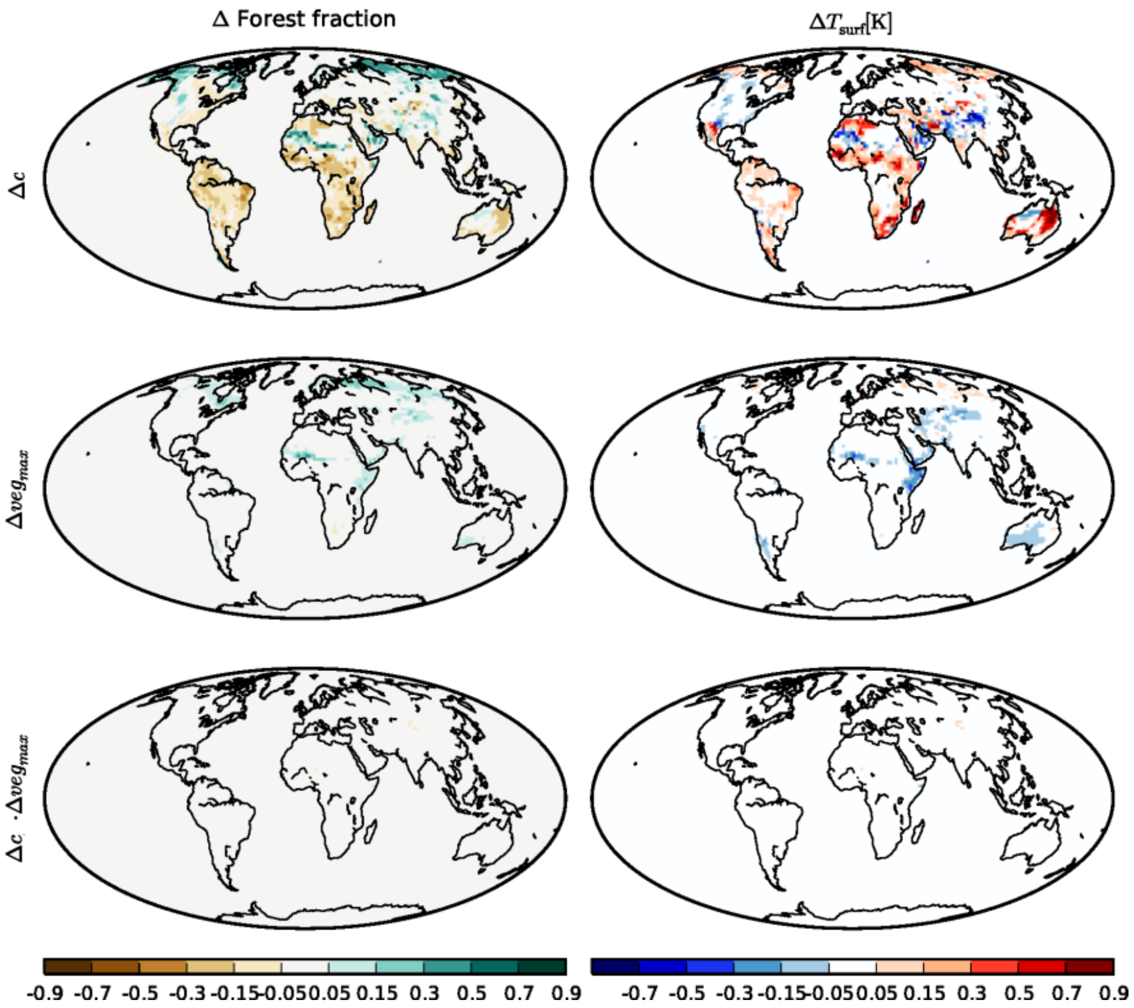

Figure S4. Influence of the changing veg_{max} in the RCP8.5 scenario. Changes in forest fraction (left) and corresponding locally induced changes in surface temperature (right). Top, middle and bottom figures correspond to equations 1, 2 and 3 in the supplementary Text S1.

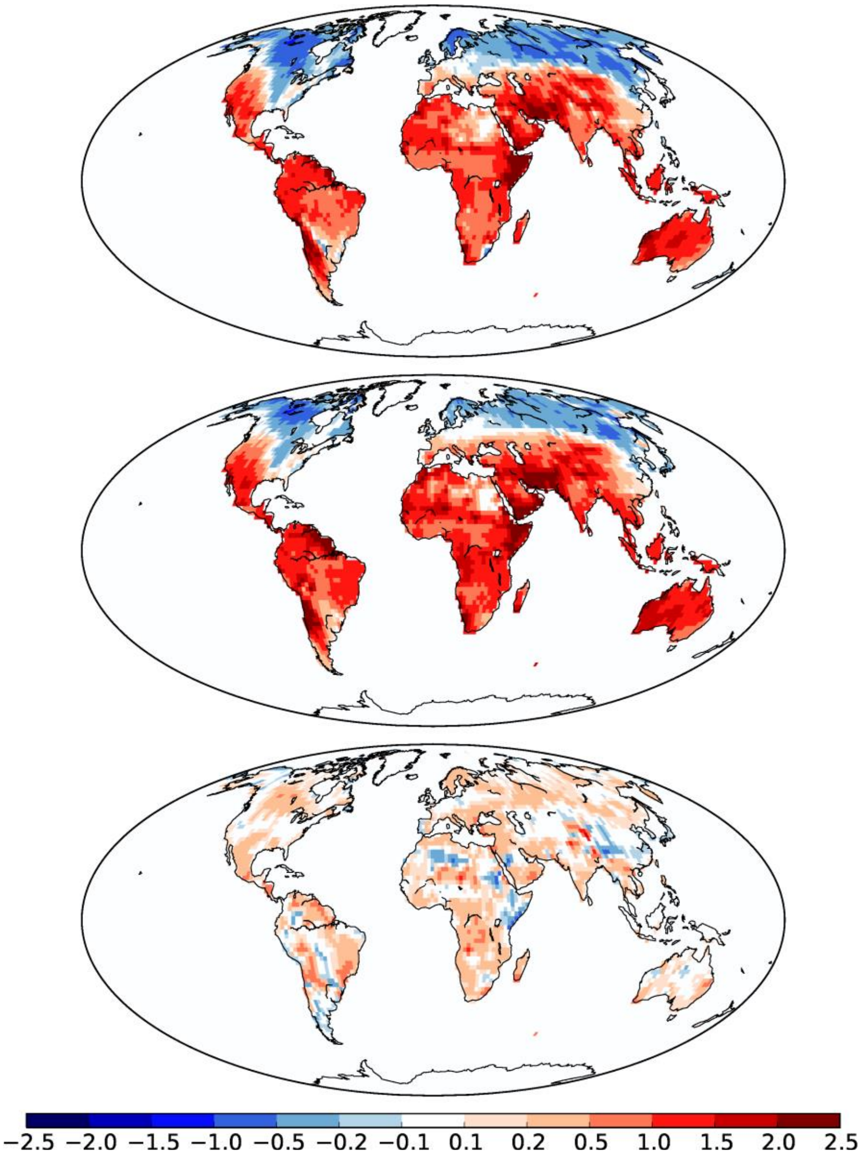

Figure S5. Locally induced changes in surface temperature [K] for a conversion from 100% to 0% forest cover in (top) present-day (1976-2005) background climate, and (middle) a warmer (RCP8.5 in 2070-2099) background climate. Bottom: Difference of these deforestation effects (in RCP8.5 minus in present-day background climate). Note that surface temperature responds strongly to deforestation also in semi-arid and arid regions, as in these regions the vegetated fraction of the grid boxes is overestimated by JSBACH.

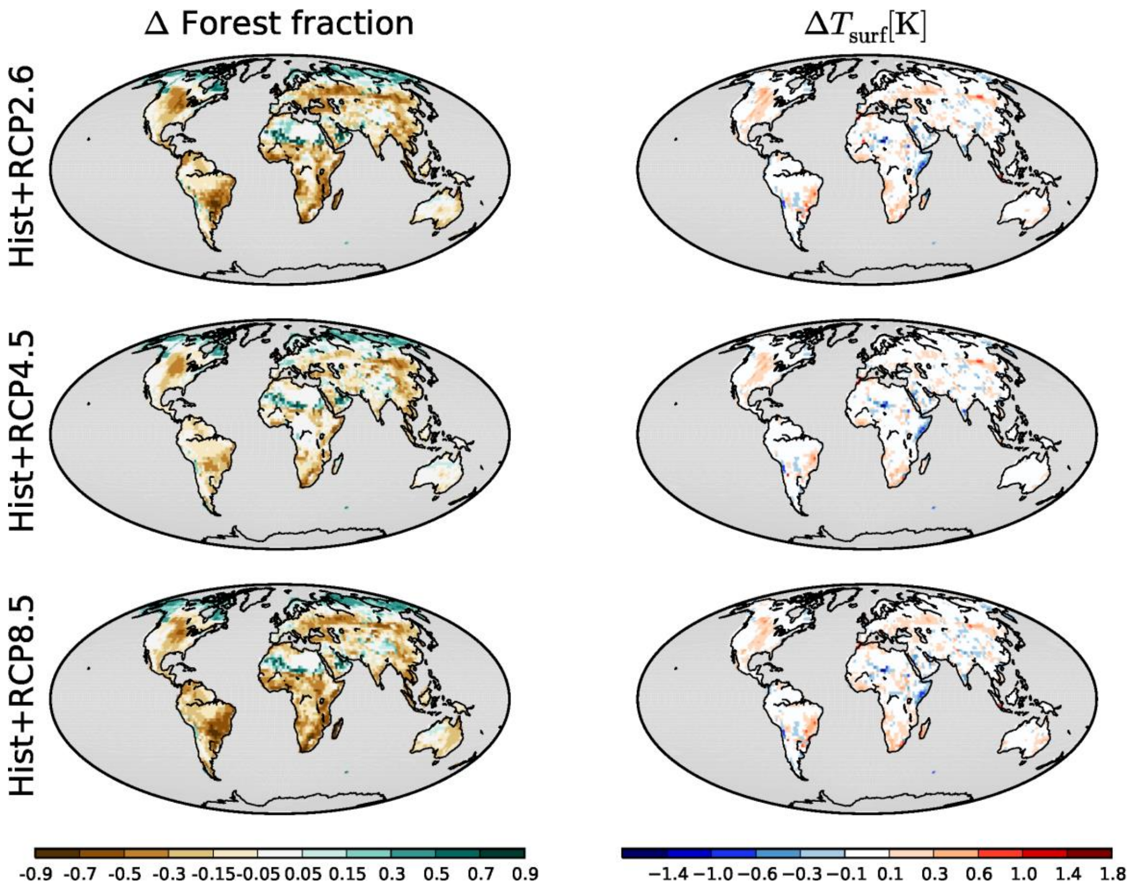

Figure S6. Influence of background climate warming (WARM): changes in local surface temperature, for the LCC scenarios Historical+RCP2.6, Historical+RCP4.5, and Historical+RCP8.5. These are the areas where LCC takes place cumulatively during the whole study period (years 1850-2100), and thus the areas that are affected by the changing background climate. The changes in surface temperature are obtained using the look-up maps for present-day and RCP8.5 background climate accounting for the nonlinearity (see Figure S5 for the effect of warming background climate on complete deforestation).

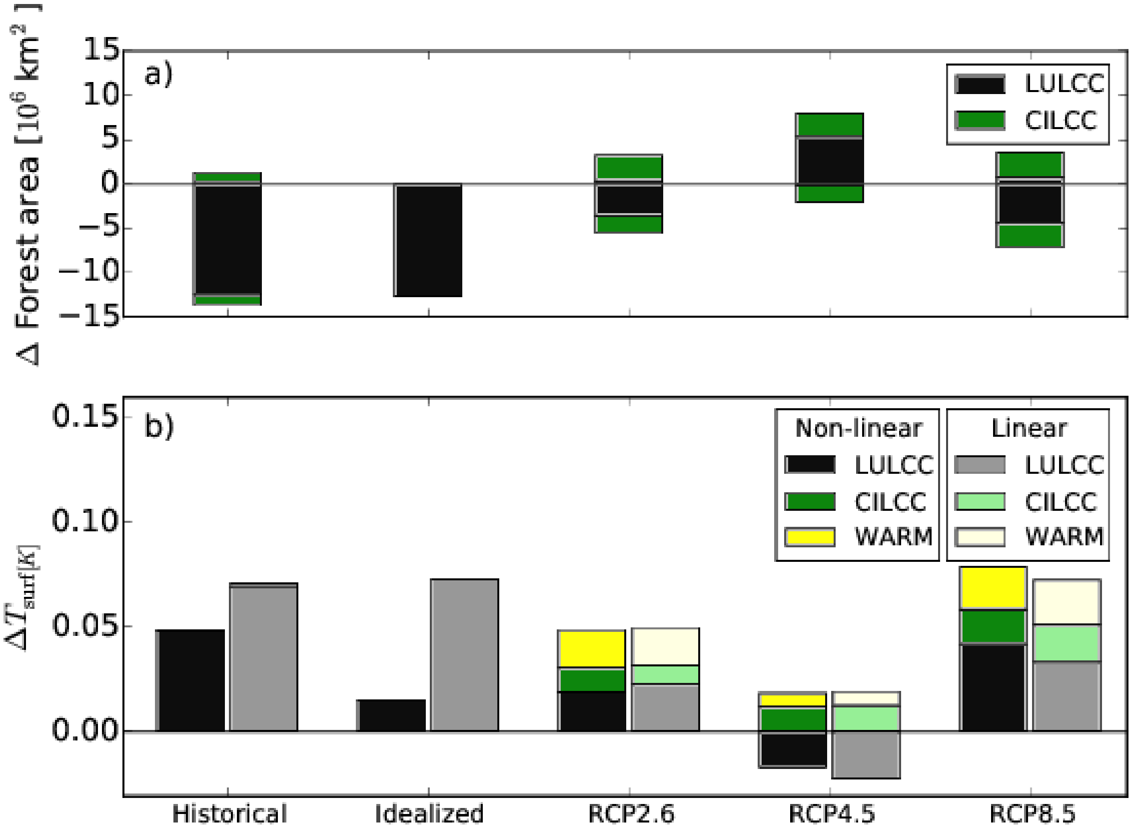

Figure S7. Comparison of LCC effects across scenarios. Same as Figure 3 (main text), but including the 'idealized' scenario. a) Changes in forest area. Within a scenario, there can be both, areas of forest gain (positive values) and forest loss (negative values). b) Contributions to local surface temperature changes from land-use-induced LCC, climate-induced LCC, and warming background climate. The vertical axis denotes surface temperature change averaged over land. For each scenario, the left bars account for the nonlinear surface temperature response, the right bars assume a linear response to deforestation.

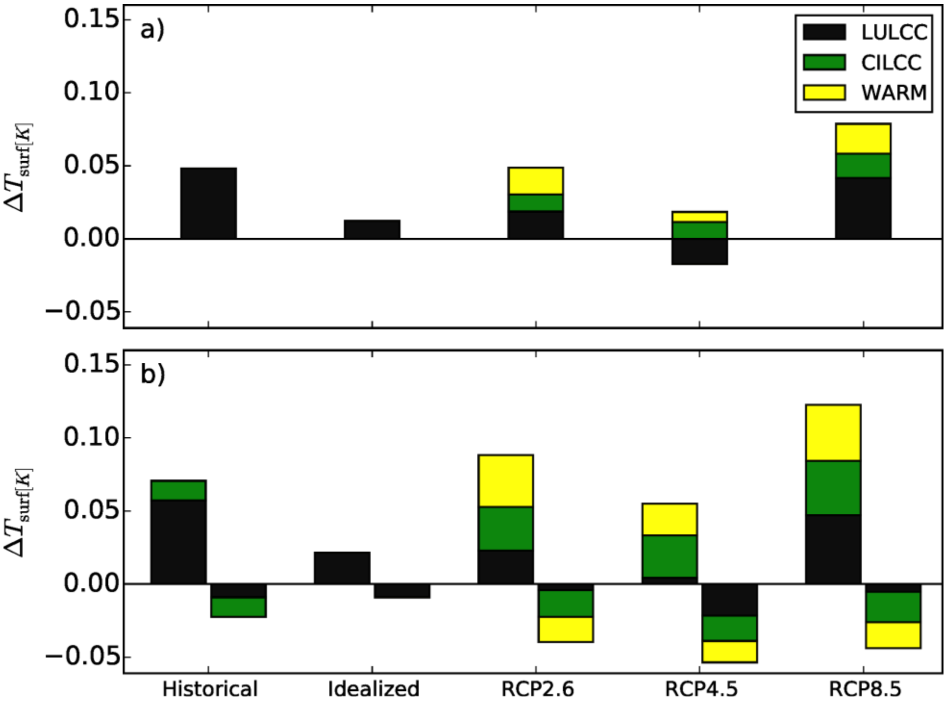

Figure S8. Taking spatial averages over land hides some of the signal, because positive and negative contributions cancel. *a)* Values from Figure 3*b)* in the main text. Influence of land-use-induced land cover change (LULCC), climate-induced land cover change (CILCC) and warming background climate (WARM) on the locally induced changes in surface temperature, averaged over land. *b)* These values are split into areas where the respective contribution was warming (left bars) or cooling (right bars), respectively. Especially for LULCC and WARM in the RCP scenarios, the net effect shown in *a)* are smaller than the gross effects shown in *b)*, as discussed in section 5 of the main text.