Supplementary information

How do afforestation and BECCS differ in their impacts on the land carbon cycle and surface climate?

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Supplementary information contains Figures S1 to S10 and Table S1.

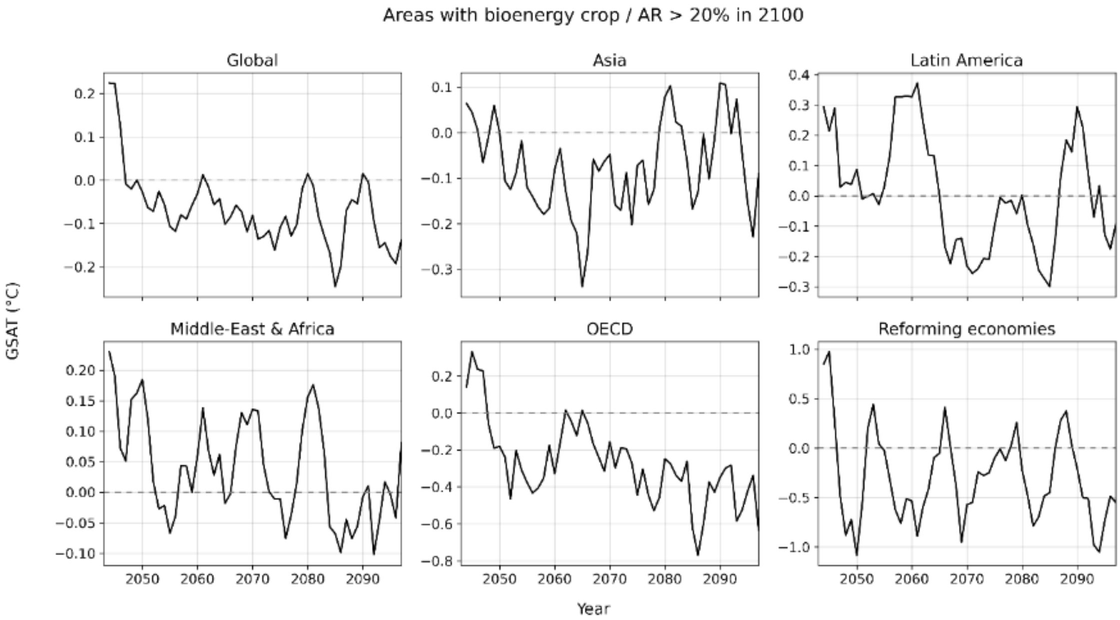

Figure S1. Global and subregional differences in land mean surface temperature (°C) between BECCS and AR experiments over gridboxes with over 20% of 2G bioenergy crops in 2100 by IPSL-CM6A-LR given as 5-year moving averages. Positive values indicate larger values in the BECCS than in the AR experiment.

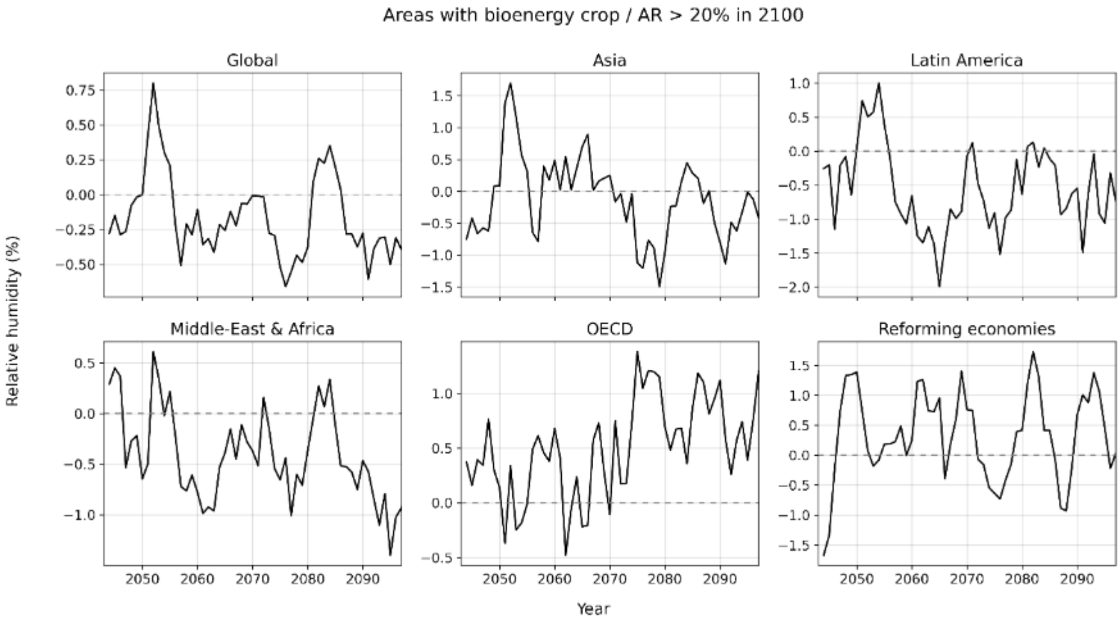

Figure S2. Global and subregional differences in land relative humidity (%) between BECCS and AR experiments over gridboxes with over 20% of 2G bioenergy crops in 2100 by simulated by IPSL-CM6A-LR given as 5-year moving averages. Positive values indicate larger values in the BECCS than in the AR experiment.

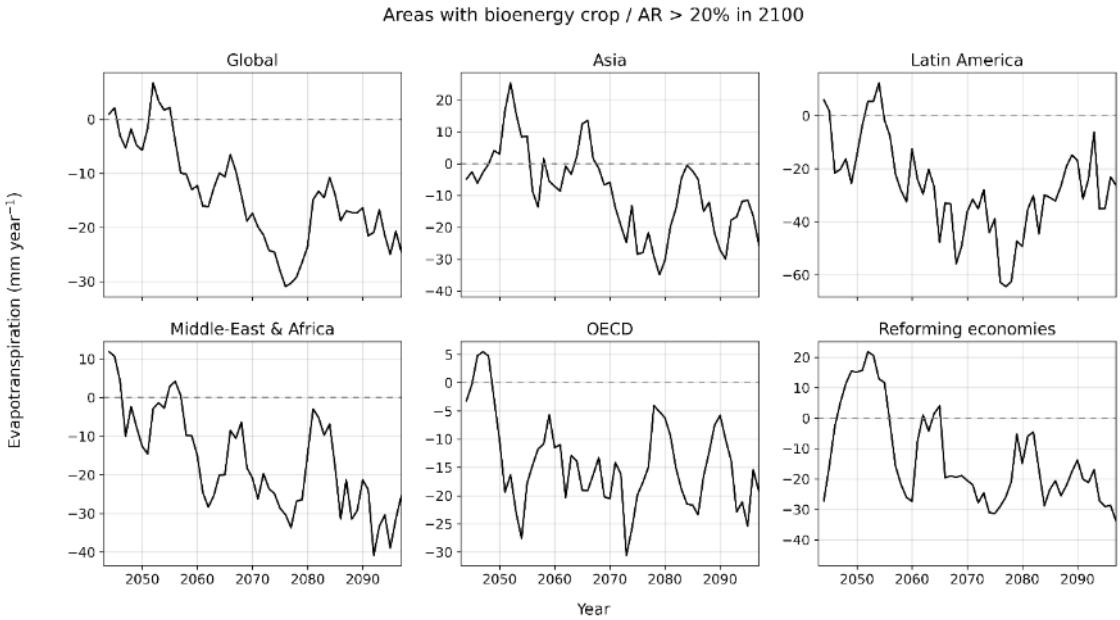

Figure S3. Global and subregional differences in land evapotranspiration (mm year^{-1}) between BECCS and AR experiments over gridboxes with over 20% of 2G bioenergy crops in 2100 by simulated by IPSL-CM6A-LR given as 5-year moving averages. Positive values indicate larger values in the BECCS than in the AR experiment.

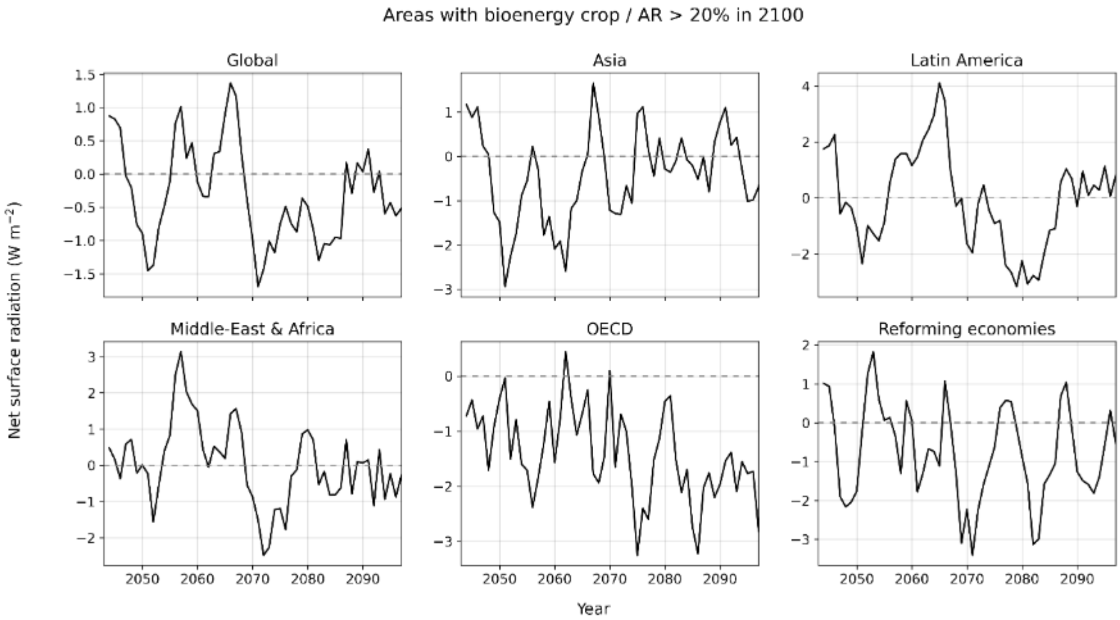

Figure S4. Global and subregional differences in land net surface solar radiation (W m^{-2}) between BECCS and AR experiments over gridboxes with over 20% of 2G bioenergy crops in 2100 by simulated by IPSL-CM6A-LR given as 5-year moving averages. Positive values indicate larger values in the BECCS than in the AR experiment.

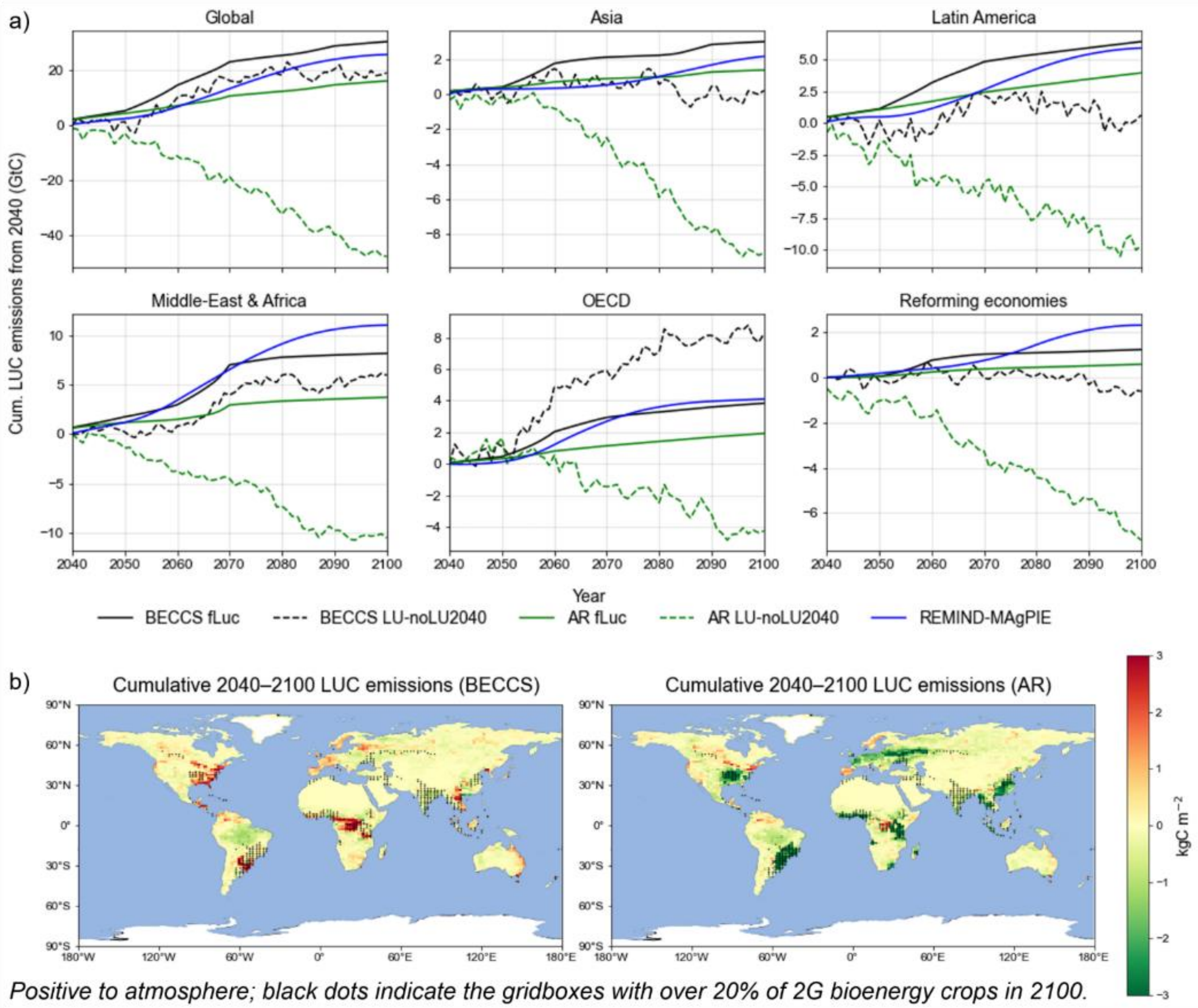

Figure S5. Time evolution of the cumulative LUC emissions (GtC, positive to atmosphere) over the 2040–2100 period (a) on a global scale estimated by REMIND-MAgPIE and IPSL-CM6A-LR using different approaches under the SSP5-3.4-OS. Spatial distributions of the cumulative LUC emissions over the 2040–2100 period in the BECCS and AR experiments. Black dots indicate the gridboxes with over 20% of 2G bioenergy crops in 2100.

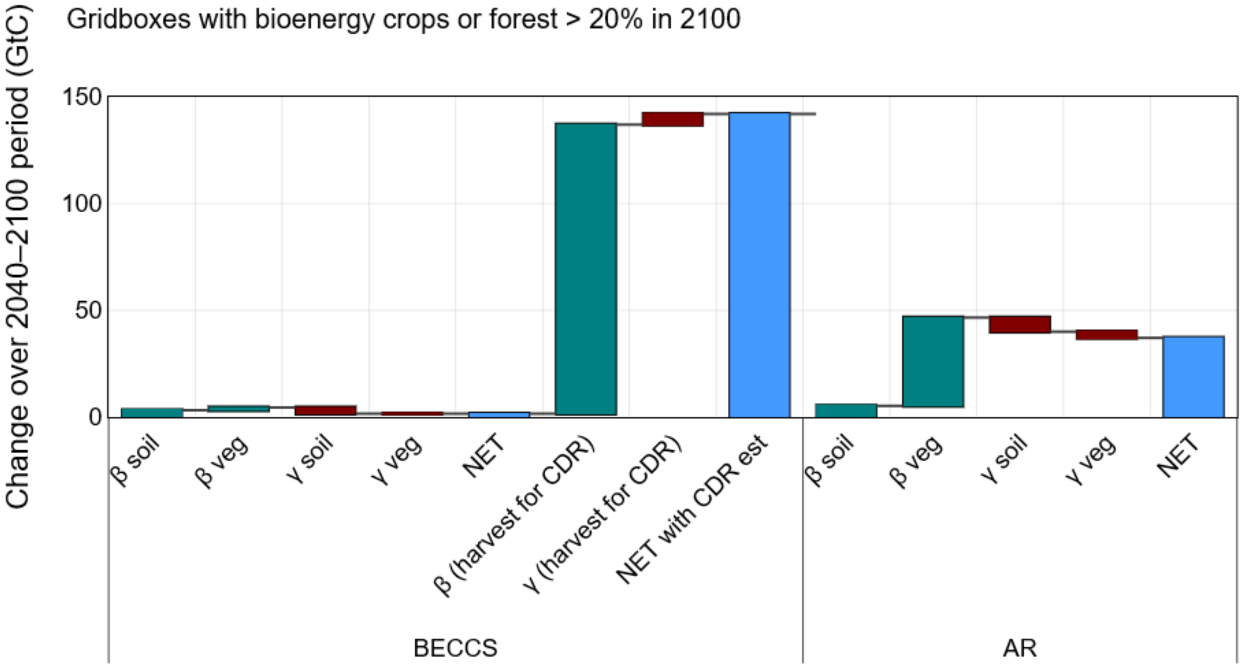

Figure S6. Changes in the β- and γ-driven contributions to the land carbon budget, including biomass harvest for BECCS CDR, in the BECCS and AR SSP5-3.4-OS experiments over the 2040–2100 period globally in the gridboxes with over 20% of 2G bioenergy crops in 2100. The β-driven contribution is estimated from BGC experiment and γ-driven contribution is estimated from the difference of COU and BGC experiments.

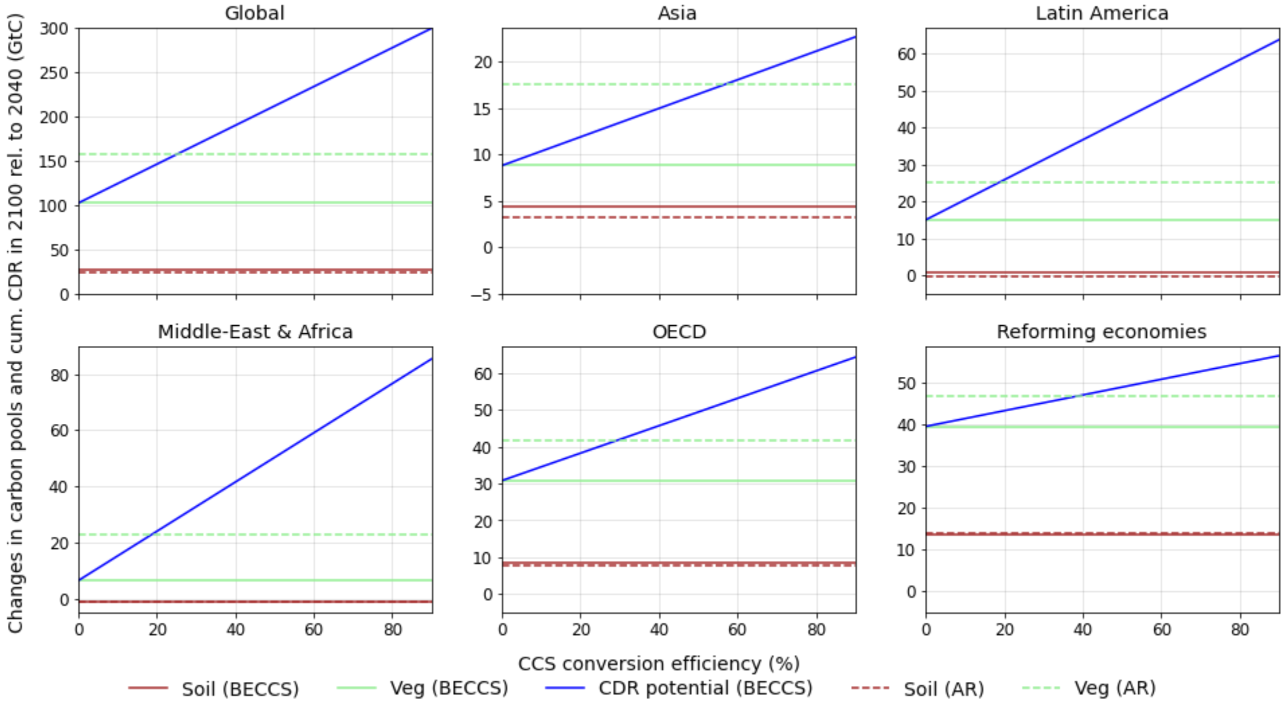

Figure S7. Variation of stacked changes in the contributors to land carbon budget, including BECCS CDR potentials (assuming CCS conversion efficiency factors from 50 to 90%) in 2100 in BECCS and AR SSP5-3.4-OS experiments from the COU and BGC simulations plotted against CCS conversion efficiency factor. Regional allocation of BECCS CDR potentials refers to the location of biomass extraction.

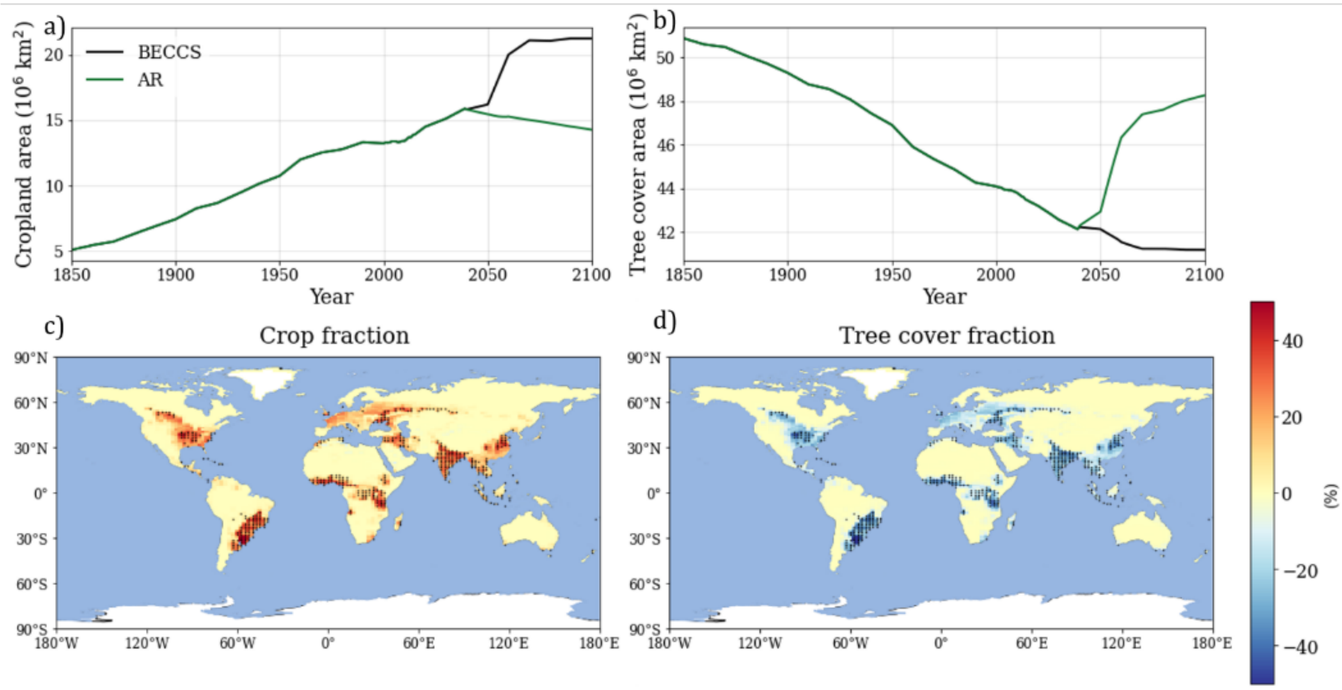

Figure S8. (a, b) Global cropland and tree cover areas (10^6 km^2) over the period 1850-2100. (c, d) Spatial distribution of the differences in the cropland and tree covers (%) in SSP5-3.4-OS with BECCS (standard) and AR experiments using IPSL-CM6A-LR in 2100. Positive values indicate a larger magnitude in BECCS than in the AR experiment. Black dots indicate the gridboxes with over 20% of 2G bioenergy crops in 2100.

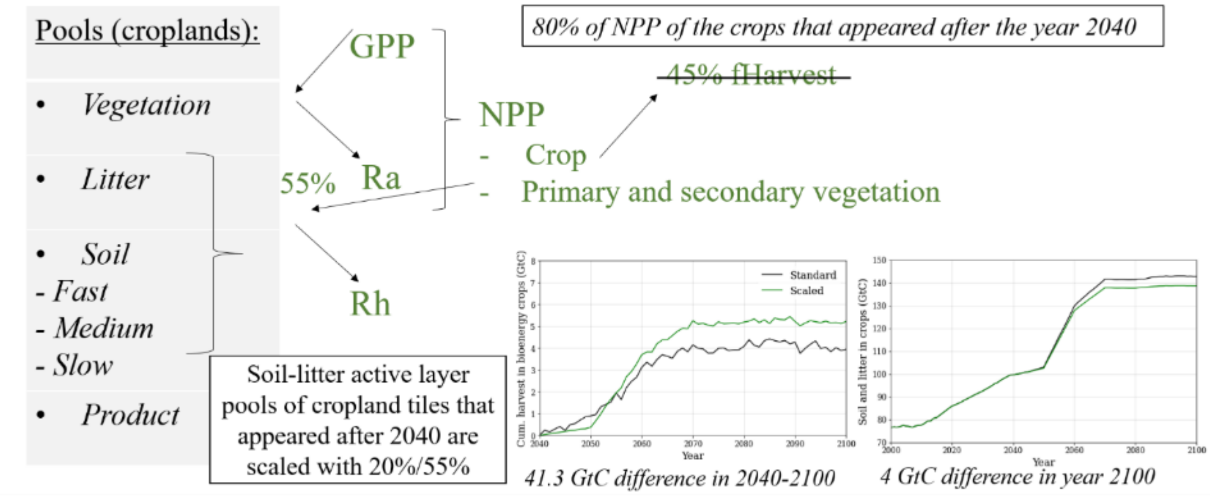

Figure S9. The schematic representation of the post-processing procedures that were applied to re-scale the harvest and soil carbon pool over the bioenergy croplands.

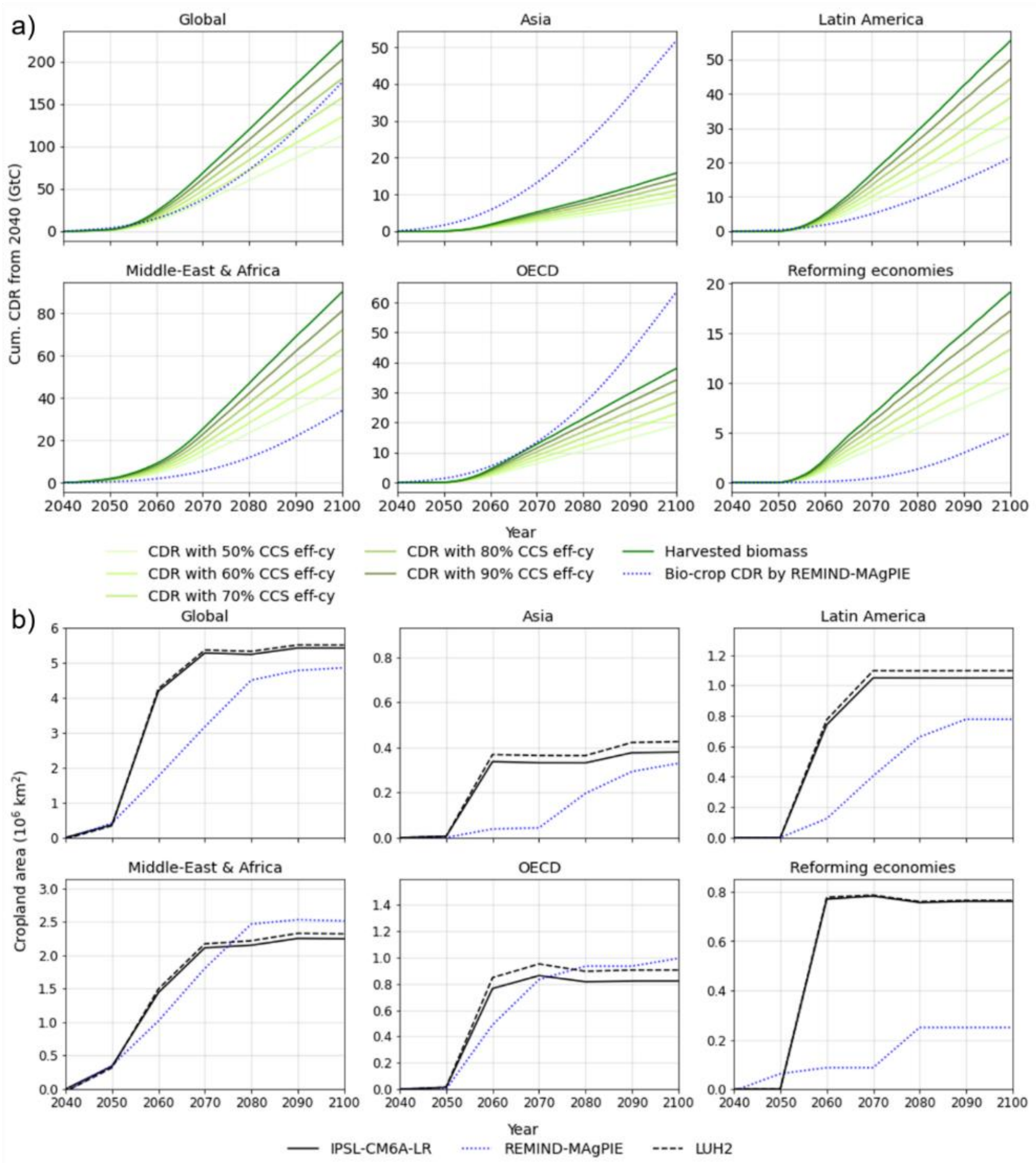

Figure S10. Global and regional (a) cumulative biomass harvest and CDR potential (GtC) in the bioenergy crops sequestered from 2040,estimated by REMIND-MAgPIE and IPSL-CM6A-LR with CCS conversion efficiency factors from 50 to 90%, (b) changes in the cropland area (10^6 km^2) relative to 2040 estimated by REMIND-MAgPIE, IPSL-CM6A-LR, and LUH2 under SSP5-3.4-OS.

Table S1. Comparison of global and regional CDR potentials and effects of biogeochemical and biogeophysical feedbacks of BECCS and AR under SSP5-3.4-OS pathway given at global and subregional (over the gridboxes with over 20% of 2G bioenergy crops in 2100) scales.

	Global	**Asia**	**Latin America**	**Middle-East & Africa**	**OECD**	**Reforming economies**
CDR potential	AR<< BECCS in the long-term, in the span of 20 to 30 years BECCS ≈ AR	BECCS < AR if CCS conversion efficiency < 60%	AR<< BECCS	AR<< BECCS	AR< BECCS	BECCS < AR if CCS conversion efficiency < 40%
Contributions of biogeochemical feedbacks	$\begin{cases} 0 < \beta_{BECCS} \ll \beta_{AR} \\ \gamma_{AR} < \gamma_{BECCS} < 0 \end{cases}$	$\begin{cases} 0 < \beta_{BECCS} \ll \beta_{AR} \\ \gamma_{AR} < \gamma_{BECCS} < 0 \end{cases}$	$\begin{cases} 0 < \beta_{BECCS} \ll \beta_{AR} \\ \gamma_{AR} <_{\epsilon} \gamma_{BECCS} < 0 \end{cases}$	$\begin{cases} 0 < \beta_{BECCS} \ll \beta_{AR} \\ \gamma_{AR} <_{\epsilon} \gamma_{BECCS} < 0 \end{cases}$	$\begin{cases} 0 < \beta_{BECCS} < \beta_{AR} \\ 0 < \gamma_{AR} \approx \gamma_{BECCS} \end{cases}$	$\begin{cases} 0 < \beta_{BECCS} < \beta_{AR} \\ 0 < \gamma_{AR} \approx \gamma_{BECCS} \end{cases}$
Biogeophysical effects	BECCS leads to cooling, AR to warming globally and in the northern latitudes, opposite in most of the subtropical regions	BECCS leads to higher max temperature and frequency of hot days in India	AR leads to non-radiative cooling, BECCS leads to higher max temperature and frequency of hot days	Spatially different temperature response, BECCS leads to lower surface humidity and a much higher frequency of hot days	BECCS leads to lower temperatures and surface humidity than AR	BECCS leads to lower temperatures and drier air, more frequent hot days than AR

$<_{\epsilon}$ is defined as “slightly less than”.