Earth System
Dynamics

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Supplement of

Biases in the albedo sensitivity to deforestation in CMIP5 models and their impacts on the associated historical radiative forcing

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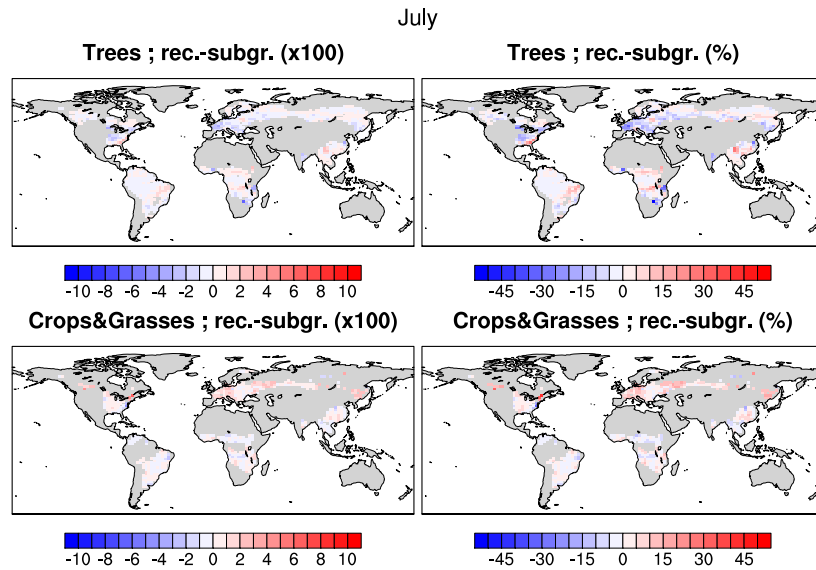
Trees	Crops/grasses
- Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m) - Closed (>40%) broadleaved deciduous forest (>5m) - Open (15-40%) broadleaved deciduous forest (>5m) - Closed (>40%) needleleaved evergreen forest (>5m) - Open (15-40%) needleleaved deciduous or evergreen forest (>5m) - Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	- Post-flooding or irrigated croplands - Rainfed croplands - Closed to open (>15%) grassland

Table S1: **List of the detailed land cover classes documented by the GlobCover dataset that are included in the two broad classes considered in this study (trees and crops/grasses).**
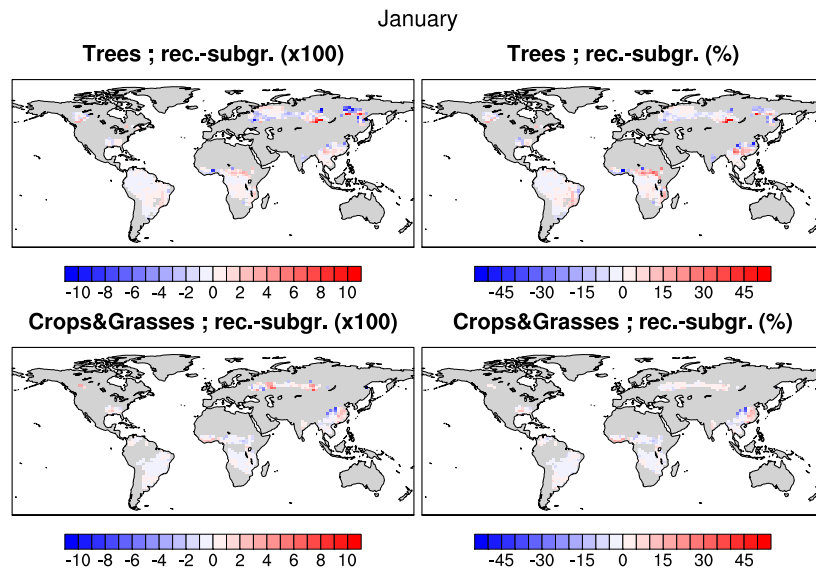
Climate model	Ensemble members included in the reconstruction of the present-day albedo of trees and crops/grasses	Ensemble members included in the reconstruction of the albedo changes associated with historical conversions between trees and crops/grasses	Ensemble from the factorial land-use-only or all-but-land-use experiments included in supplementary analyses
CanESM2	r1i1p1, r2i1p1, r3i1p1, r4i1p1, r5i1p1	r1i1p1, r2i1p1, r3i1p1, r4i1p1, r5i1p1	r1i1p2, r2i1p2, r3i1p2, r4i1p2, r5i1p2
CCSM4	r1i1p1, r2i1p1	r1i1p1, r2i1p1	r1i1p13, r6i1p13
CESM1-CAM5	r1i1p1, r2i1p1, r3i1p1	r1i1p1, r2i1p1, r3i1p1	
CESM1-FASTCHEM	r1i1p1, r2i1p1, r3i1p1	r1i1p1, r2i1p1, r3i1p1	
CESM1-WACCM	r1i1p1		
GFDL-CM3	r1i1p1, r2i1p1, r3i1p1, r4i1p1, r5i1p1	r1i1p1, r2i1p1, r3i1p1, r4i1p1, r5i1p1	
GFDL-ESM2G	r1i1p1	r1i1p1 (analysed together with GFDL-ESM2M)	r1i1p3, r1i1p4 (analysed together with GFDL-ESM2M)
GFDL-ESM2M	r1i1p1	r1i1p1 (analysed together with GFDL-ESM2G)	r1i1p3, r1i1p4 (analysed together with GFDL-ESM2G)
HadGEM2-ES	r1i1p1, r2i1p1, r3i1p1, r4i1p1	r1i1p1, r2i1p1, r3i1p1, r4i1p1	
IPSL-CM5A-LR		r1i1p1, r2i1p1, r3i1p1, r4i1p1, r5i1p1, r6i1p1	r1i1p1, r3i1p1
IPSL-CM5A-MR		r1i1p1, r2i1p1, r3i1p1	
MIROC5	r1i1p1, r2i1p1, r3i1p1, r4i1p1, r5i1p1	r1i1p1, r2i1p1, r3i1p1, r4i1p1, r5i1p1	
MIROC-ESM	r1i1p1, r2i1p1, r3i1p1	r1i1p1, r2i1p1, r3i1p1	
MIROC-ESM-CHEM	r1i1p1		
MPI-ESM-LR	r1i1p1, r2i1p1, r3i1p1	r1i1p1, r2i1p1, r3i1p1	
MPI-ESM-MR	r1i1p1, r2i1p1, r3i1p1	r1i1p1, r2i1p1, r3i1p1	
MPI-ESM-P	r1i1p1, r2i1p1	r1i1p1, r2i1p1	
NorESM1-M	r1i1p1, r2i1p1, r3i1p1	r1i1p1, r2i1p1, r3i1p1	
NorESM1-ME	r1i1p1		

Table S2: **List of the climate models analysed in this study and of their respective ensemble members of the all-forcing simulations included for the reconstruction of the monthly surface albedo climatology for trees and crops/grasses under present-day conditions (second column, see Section 2.3.1 for the description of the methodology), for the reconstruction of the surface albedo changes associated with historical transitions between trees and crops/grasses**
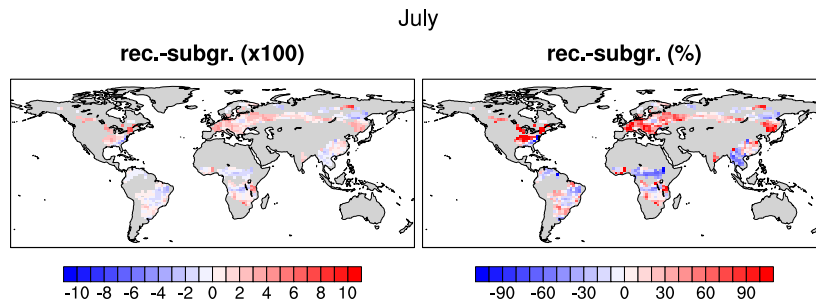
(third column, see Section 2.3.1 for the description of the methodology). The right column lists the ensemble members from the factorial land-use-only or all-but-land-use experiments that have been included in analyses presented in the Supplementary Material.

July

Trees ; rec.-subgr. (x100)   Trees ; rec.-subgr. (%)

Crops&Grasses ; rec.-subgr. (x100)   Crops&Grasses ; rec.-subgr. (%)

Figure S1: Absolute (left) and relative (right) difference between the reconstructed and subgrid estimates of the albedo of trees (upper row) and crops/grasses (lower row) in the CLM4.5 simulations, for the month of July. Note that absolute differences have been multiplied by 100 to facilitate reading.

January

Trees ; rec.-subgr. (x100)   Trees ; rec.-subgr. (%)

Crops&Grasses ; rec.-subgr. (x100)   Crops&Grasses ; rec.-subgr. (%)

Figure S2: Same as Figure S1, but for the month of January.

July

rec.-subgr. (x100)   **rec.-subgr. (%)**

-10 -8 -6 -4 -2 0 2 4 6 8 10   -90 -60 -30 0 30 60 90

Figure S3: Absolute (left) and relative (right) difference between the reconstructed and subgrid estimates of the albedo change associated to deforestation in the CLM4.5 simulations, for the month of January. Note that absolute differences have been multiplied by 100 to facilitate reading.

January

rec.-subgr. (x100)   **rec.-subgr. (%)**

-10 -8 -6 -4 -2 0 2 4 6 8 10   -90 -60 -30 0 30 60 90
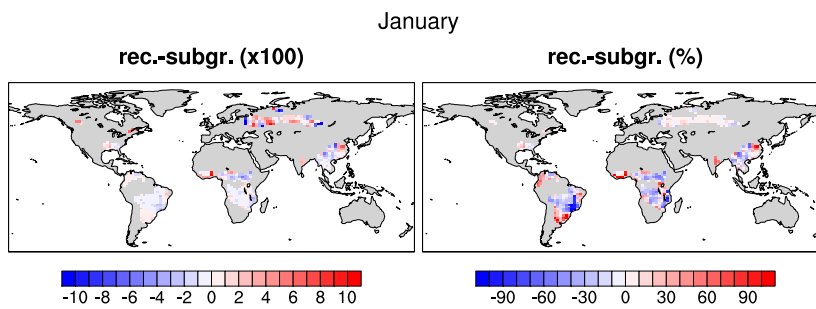
Figure S4: Same as Figure S3, but for the month of January.

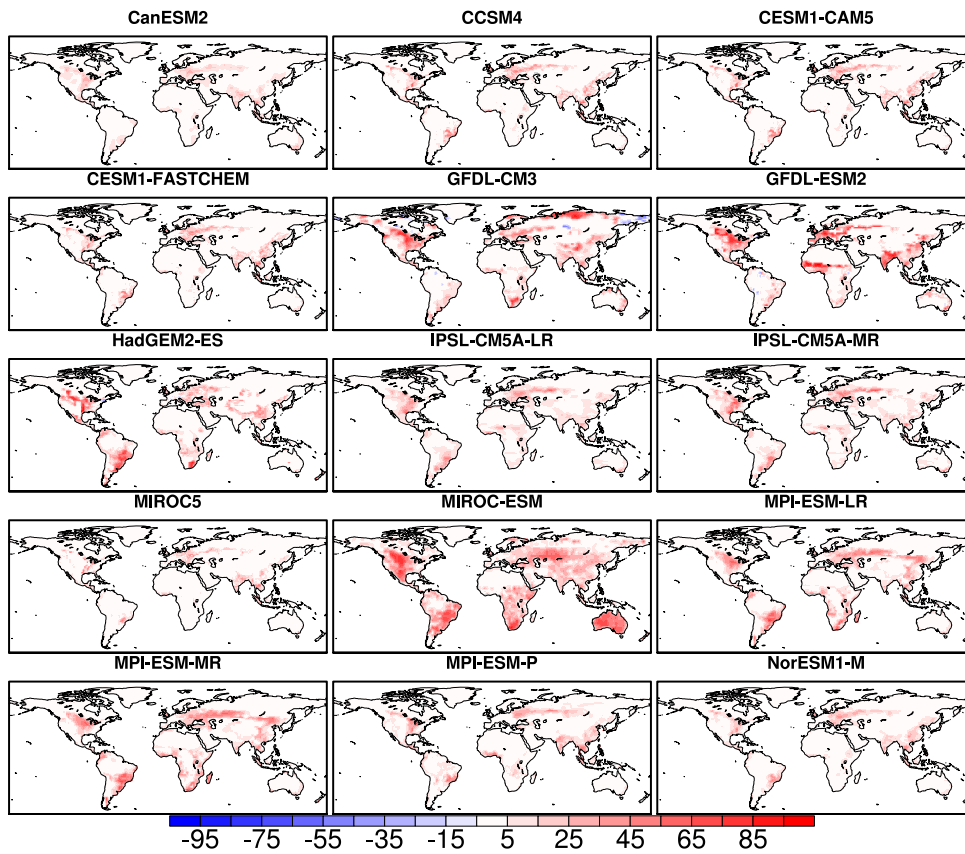# Historical conversion rate from trees to crops/grasses

Figure S5: Rates of conversion from trees to crop/grasses between pre-industrial times and the 1981-2000 period in CMIP5 models.

Albedo changes in CanESM2 (X100)

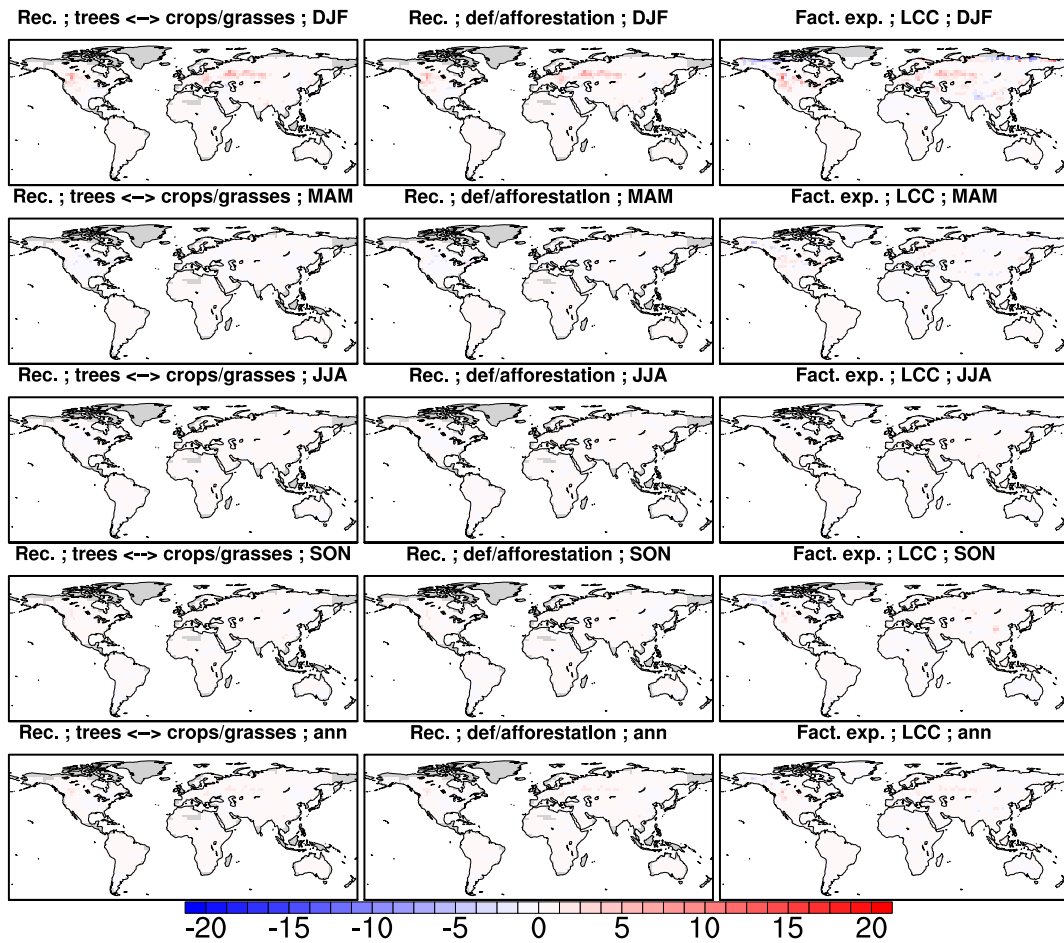| Rec. ; trees <–> crops/grasses ; DJF | Rec. ; def/afforestation ; DJF | Fact. exp. ; LCC ; DJF |
Rec. ; trees <–> crops/grasses ; MAM	Rec. ; def/afforestation ; MAM	Fact. exp. ; LCC ; MAM
Rec. ; trees <–> crops/grasses ; JJA	Rec. ; def/afforestation ; JJA	Fact. exp. ; LCC ; JJA
Rec. ; trees <–> crops/grasses ; SON	Rec. ; def/afforestation ; SON	Fact. exp. ; LCC ; SON
Rec. ; trees <–> crops/grasses ; ann	Rec. ; def/afforestation ; ann	Fact. exp. ; LCC ; ann

-20 -15 -10 -5 0 5 10 15 20

Figure S6: Reconstructed albedo changes associated to historical conversions between trees and crops/grasses (left column) or variations in tree cover (middle column), and albedo changes from all land-cover changes in factorial experiments (right column) in CanESM2. Results are shown for December-January-February (first row), March-April-May (second row), June-July-August (third row), September-October-November (fourth row), and the annual mean (last row). Note that albedo values have been multiplied by 100 to facilitate reading.
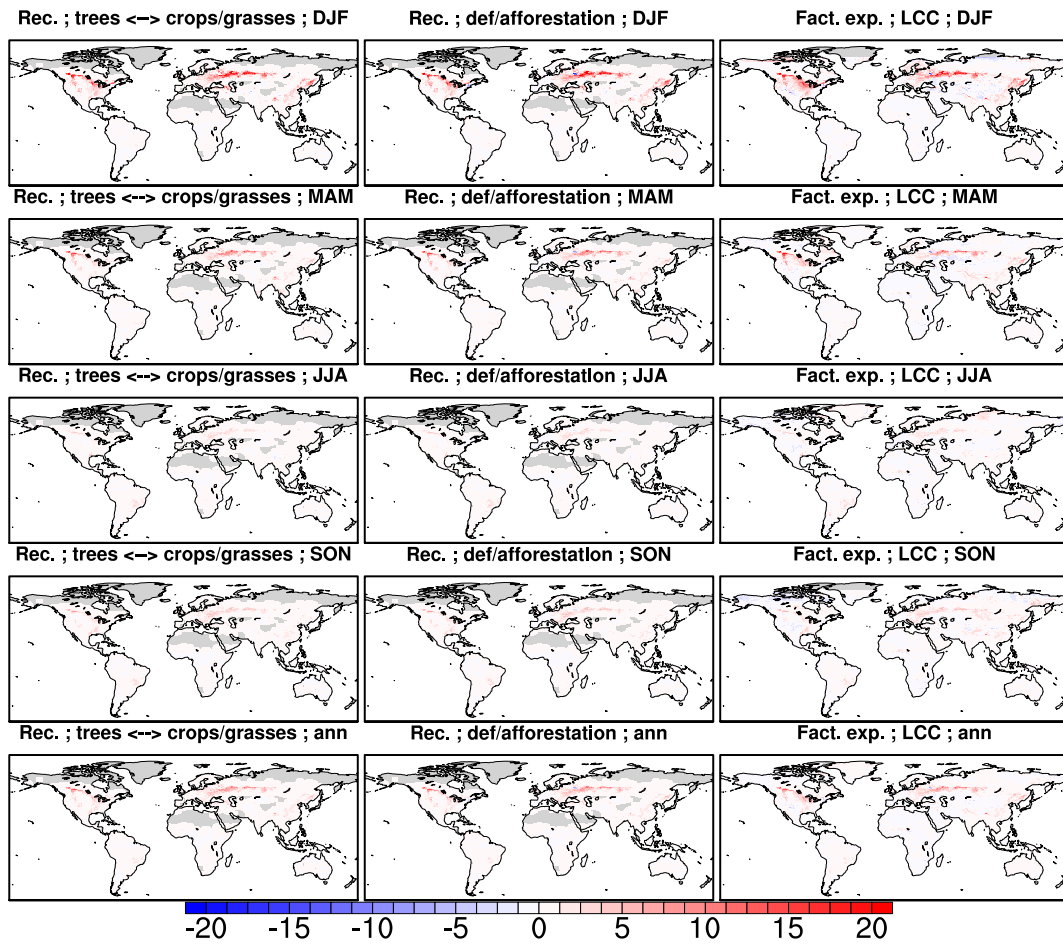
Albedo changes in CCSM4 (X100)

Figure S7: Same as Figure S6, but for CCSM4.
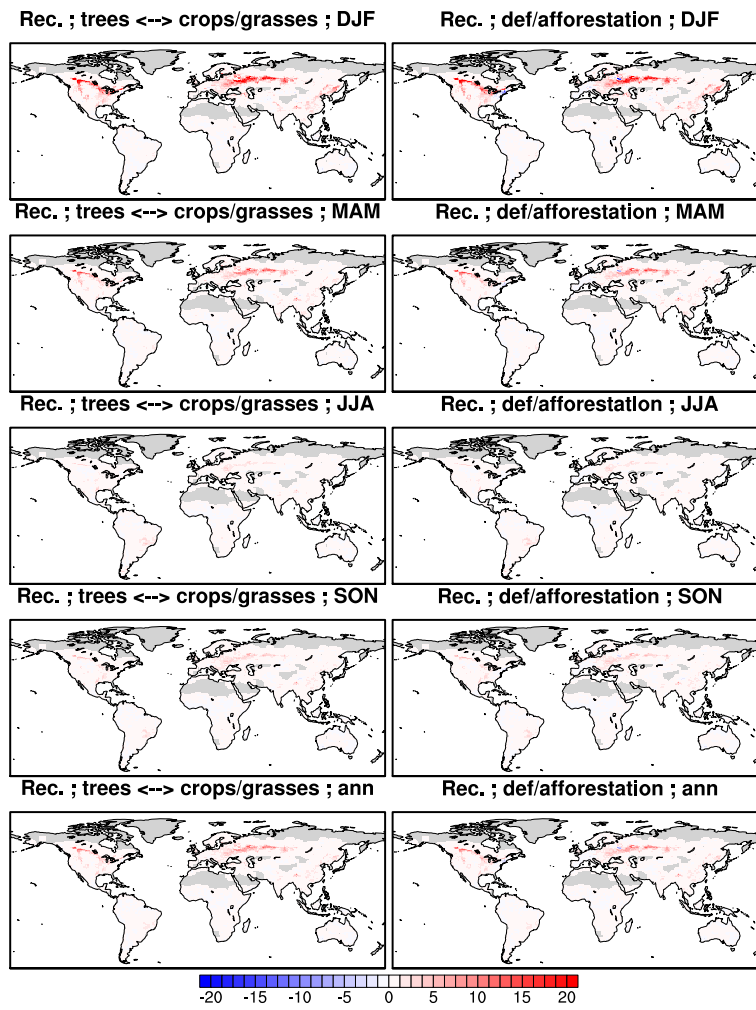
Albedo changes in CESM1-CAM5 (X100)

Figure S8: Reconstructed albedo changes associated to historical conversions between trees and crops/grasses (left column) or variations in tree cover (middle column) in CESM1-CAM5. Results are shown for December-January-February (first row), March-April-May (second row), June-July-August (third row), September-October-November (fourth row), and the annual mean (last row). Note that albedo values have been multiplied by 100 to facilitate reading.
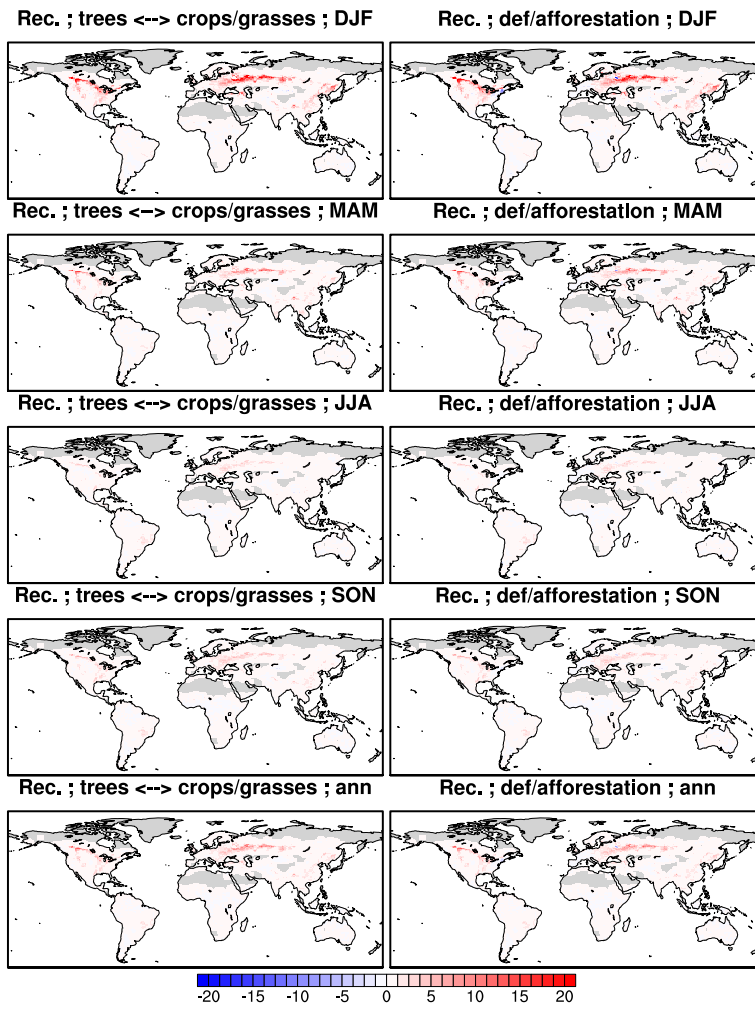
Albedo changes in CESM1-FASTCHEM (X100)

Figure S9: Same as Figure S8, but for CESM1-FASTCHEM.
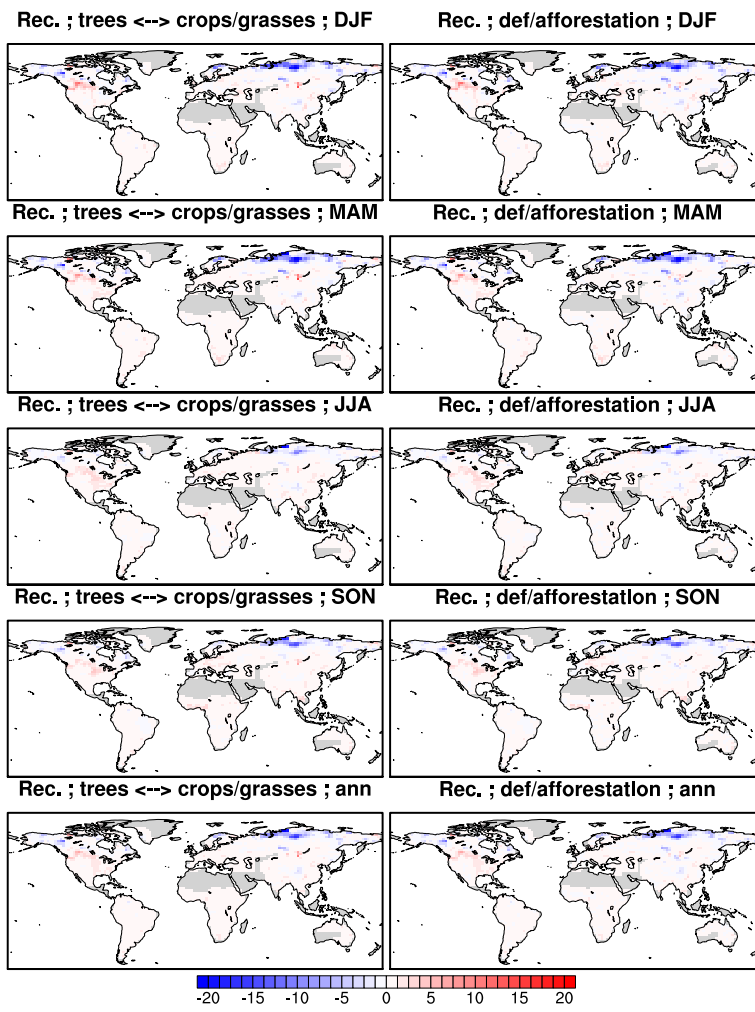
Albedo changes in GFDL-CM3 (X100)

Figure S10: Same as Figure S8, but for GFDL-CM3.
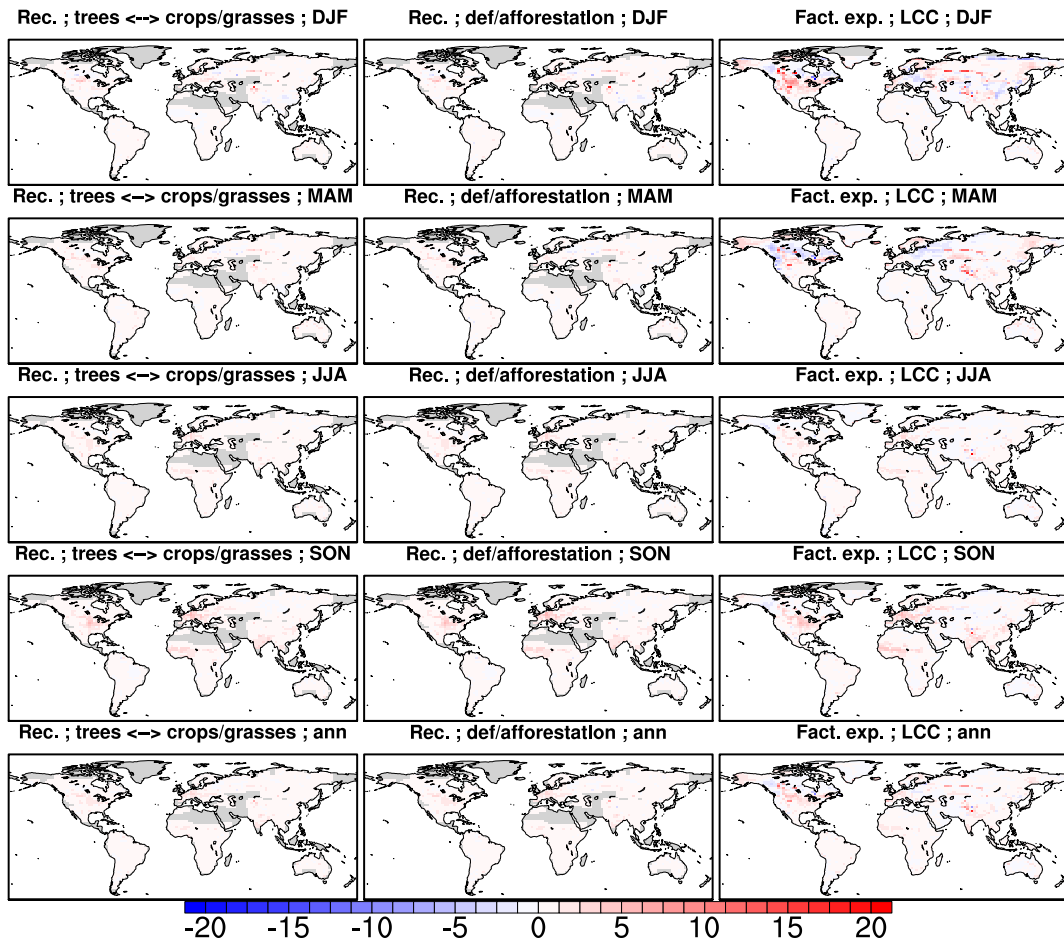
Albedo changes in GFDL-ESM2 (X100)

Rec. ; trees <--> crops/grasses ; DJF	Rec. ; def/afforestation ; DJF	Fact. exp. ; LCC ; DJF
Rec. ; trees <--> crops/grasses ; MAM	Rec. ; def/afforestation ; MAM	Fact. exp. ; LCC ; MAM
Rec. ; trees <--> crops/grasses ; JJA	Rec. ; def/afforestation ; JJA	Fact. exp. ; LCC ; JJA
Rec. ; trees <--> crops/grasses ; SON	Rec. ; def/afforestation ; SON	Fact. exp. ; LCC ; SON
Rec. ; trees <--> crops/grasses ; ann	Rec. ; def/afforestation ; ann	Fact. exp. ; LCC ; ann

-20   -15   -10   -5   0   5   10   15   20

Figure S11: Same as Figure S6, but for GFDL-ESM2.

Albedo changes in HadGEM2-ES (X100)

Rec. ; trees <--> crops/grasses ; DJF　　**Rec. ; def/afforestation ; DJF**

Rec. ; trees <--> crops/grasses ; MAM　　**Rec. ; def/afforestation ; MAM**

Rec. ; trees <--> crops/grasses ; JJA　　**Rec. ; def/afforestation ; JJA**

Rec. ; trees <--> crops/grasses ; SON　　**Rec. ; def/afforestation ; SON**

Rec. ; trees <--> crops/grasses ; ann　　**Rec. ; def/afforestation ; ann**
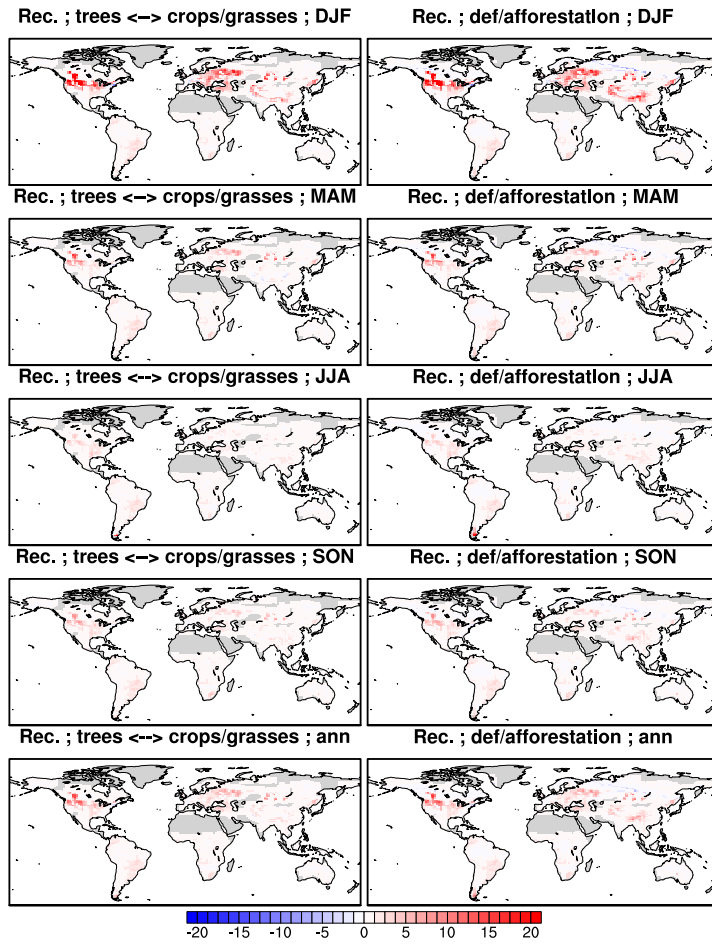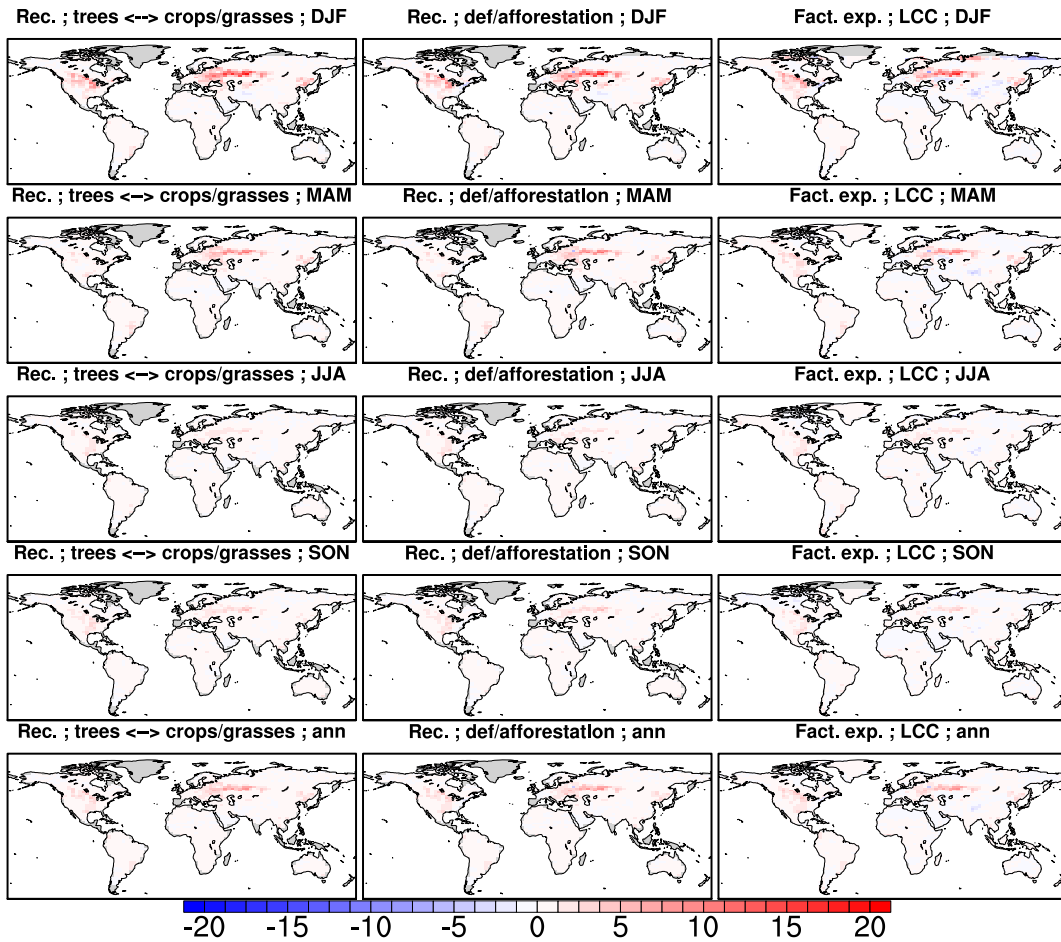

-20 -15 -10 -5   0   5   10 15 20

Figure S12: Same as Figure S8, but for HadGEM2-ES.

Albedo changes in IPSL-CM5A-LR (X100)

Figure S13: Same as Figure S6, but for IPSL-CM5A-LR.
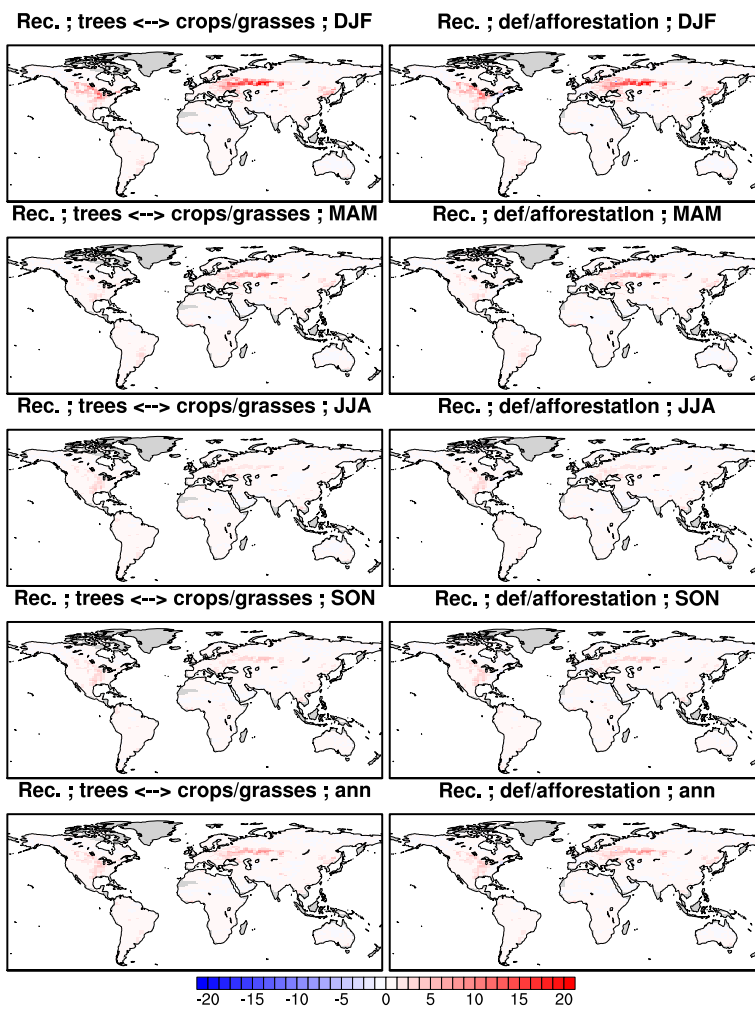
Albedo changes in IPSL-CM5A-MR (X100)

Rec. ; trees <--> crops/grasses ; DJF **Rec. ; def/afforestation ; DJF**

Rec. ; trees <--> crops/grasses ; MAM **Rec. ; def/afforestation ; MAM**

Rec. ; trees <--> crops/grasses ; JJA **Rec. ; def/afforestation ; JJA**

Rec. ; trees <--> crops/grasses ; SON **Rec. ; def/afforestation ; SON**

Rec. ; trees <--> crops/grasses ; ann **Rec. ; def/afforestation ; ann**

-20 -15 -10 -5 0 5 10 15 20

Figure S14: Same as Figure S8, but for IPSL-CM5A-MR.

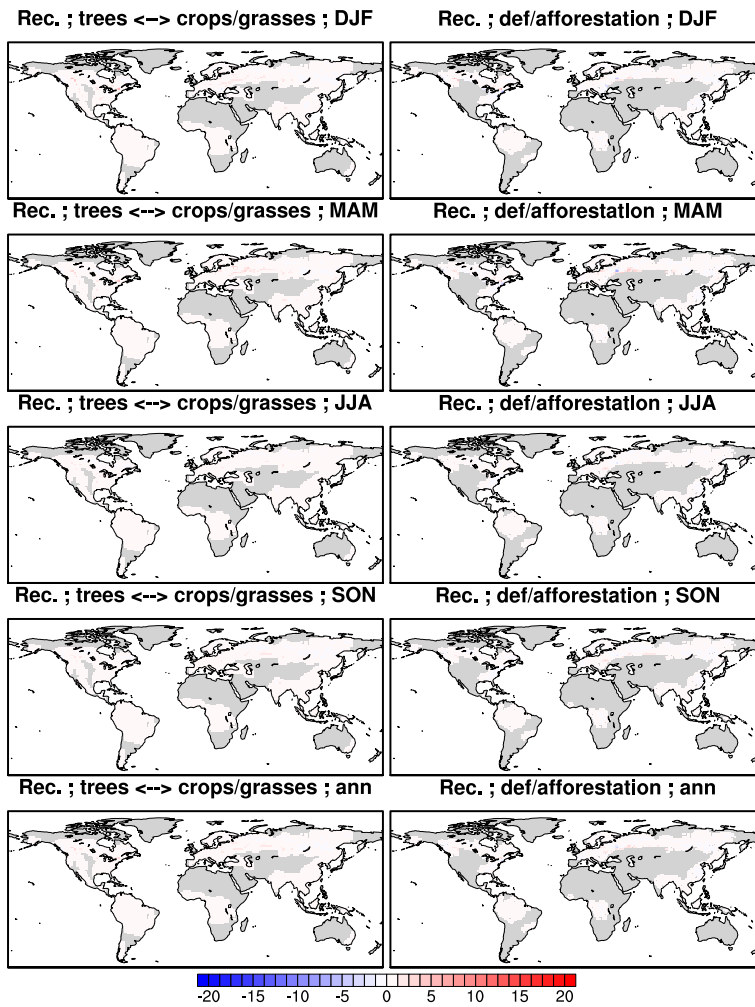## Albedo changes in MIROC5 (X100)

Figure S15: Same as Figure S8, but for MIROC5.
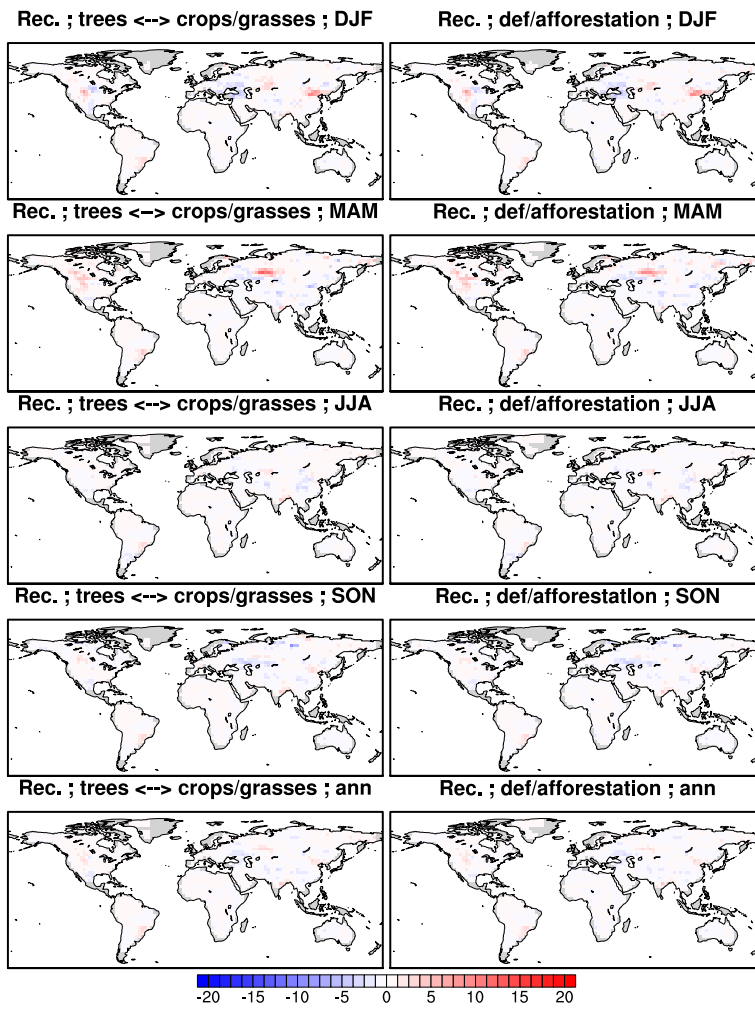
Albedo changes in MIROC-ESM (X100)

Figure S16: Same as Figure S8, but for MIROC-ESM.
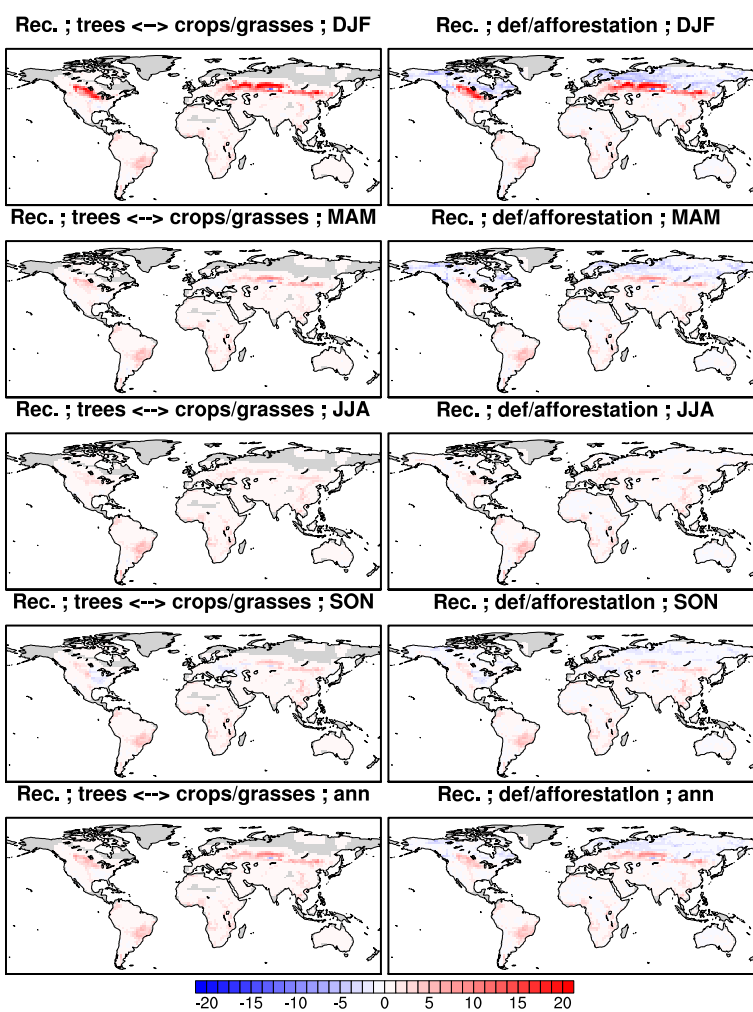
Albedo changes in MPI-ESM-LR (X100)

Figure S17: Same as Figure S8, but for MPI-ESM-LR.
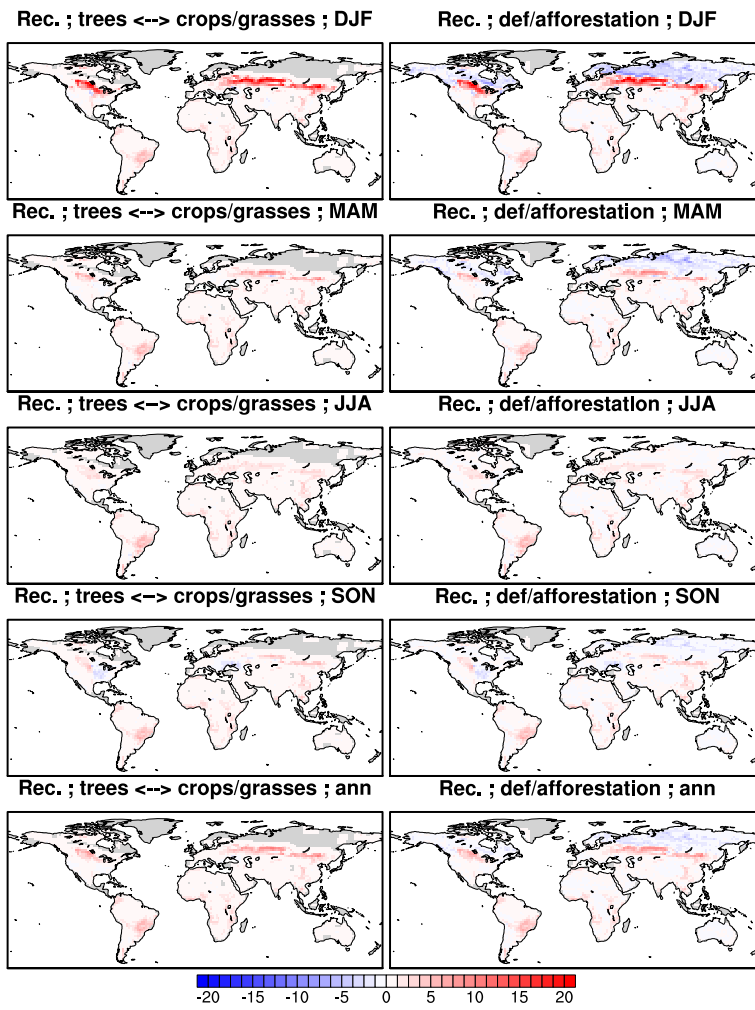
Albedo changes in MPI-ESM-MR (X100)

Rec. ; trees <--> crops/grasses ; DJF   **Rec. ; def/afforestation ; DJF**

Rec. ; trees <--> crops/grasses ; MAM   **Rec. ; def/afforestation ; MAM**

Rec. ; trees <--> crops/grasses ; JJA   **Rec. ; def/afforestation ; JJA**

Rec. ; trees <--> crops/grasses ; SON   **Rec. ; def/afforestation ; SON**

Rec. ; trees <--> crops/grasses ; ann   **Rec. ; def/afforestation ; ann**

-20 -15 -10 -5   0   5   10 15 20

Figure S18: Same as Figure S8, but for MPI-ESM-MR.

Albedo changes in MPI-ESM-P (X100)

Figure S19: Same as Figure S8, but for MPI-ESM-P.
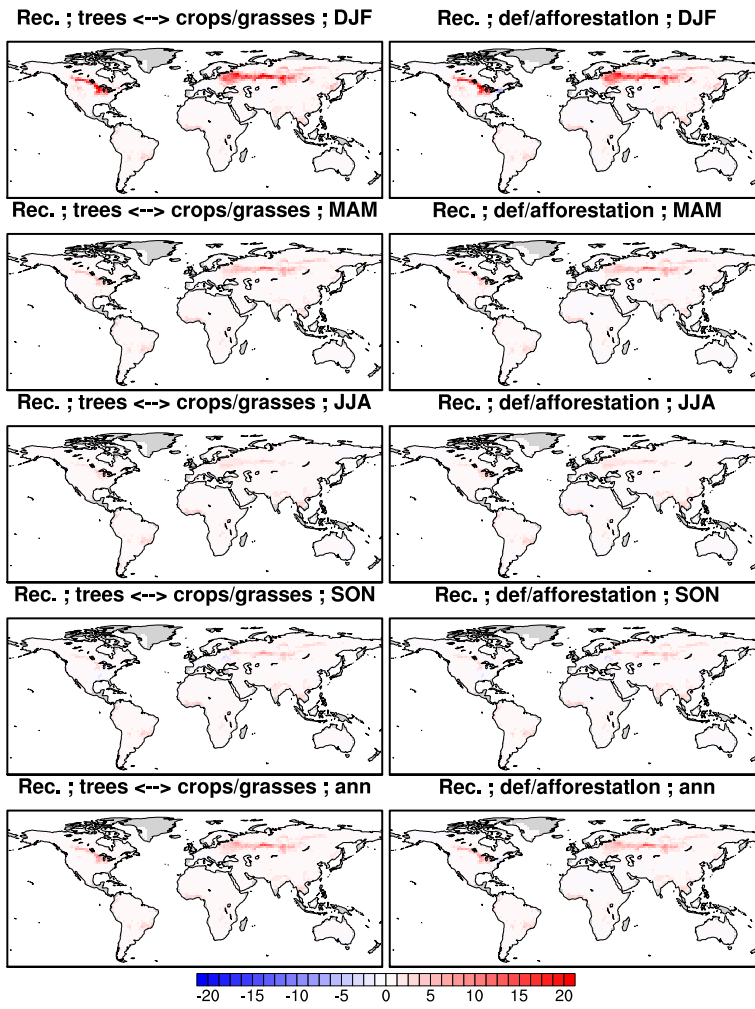
Albedo changes in NorESM1-M (X100)

Rec. ; trees <--> crops/grasses ; DJF   **Rec. ; def/afforestation ; DJF**

Rec. ; trees <--> crops/grasses ; MAM   **Rec. ; def/afforestation ; MAM**

Rec. ; trees <--> crops/grasses ; JJA   **Rec. ; def/afforestation ; JJA**

Rec. ; trees <--> crops/grasses ; SON   **Rec. ; def/afforestation ; SON**

Rec. ; trees <--> crops/grasses ; ann   **Rec. ; def/afforestation ; ann**
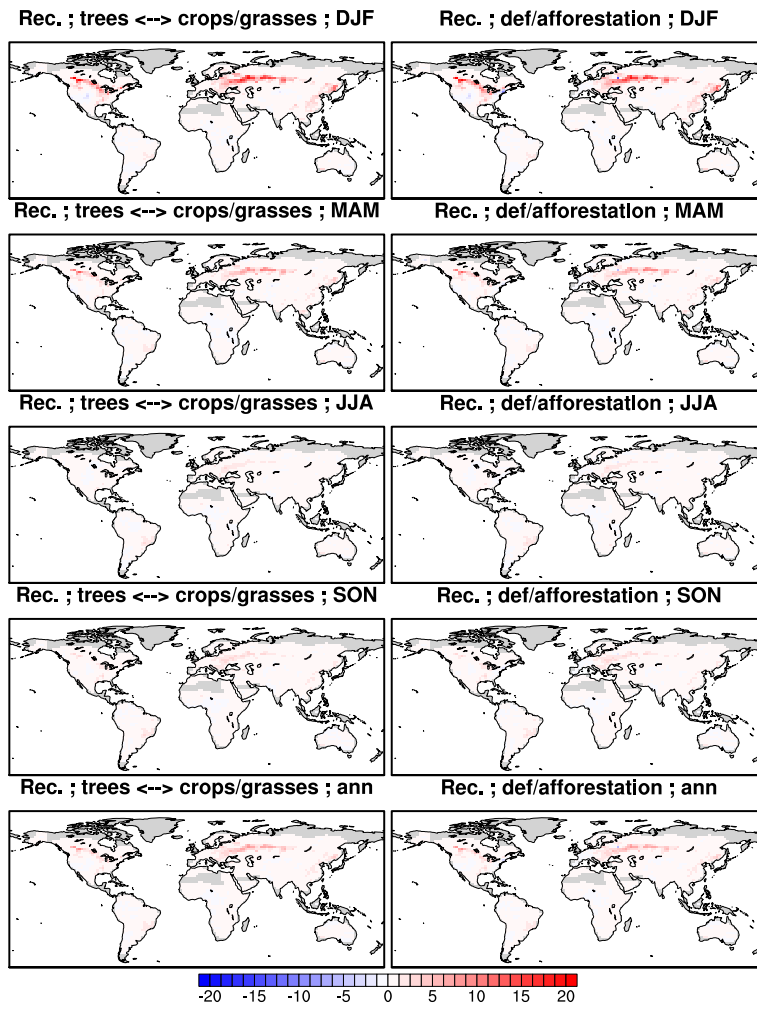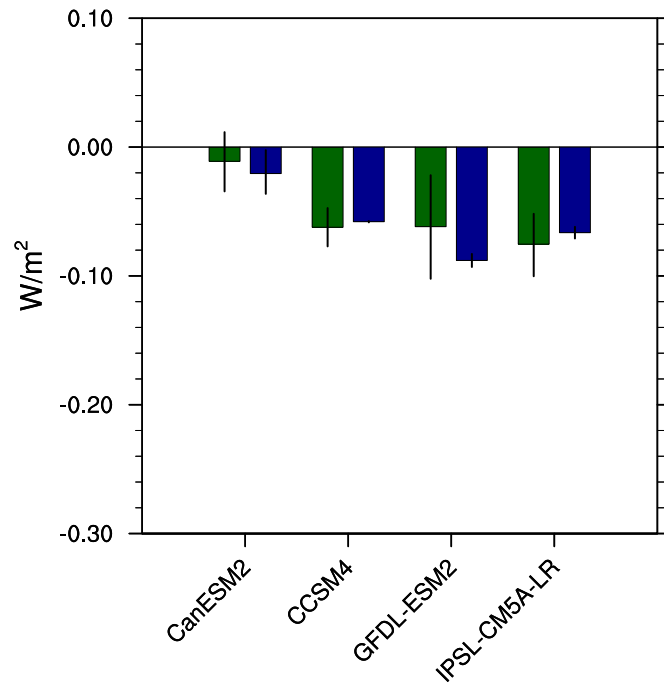
-20 -15 -10 -5 0 5 10 15 20

Figure S20: Same as Figure S8, but for NorESM1-M.

Figure S21: Comparison of the global Radiative Forcing from albedo changes due to historical conversions between trees and crops/grasses derived from our reconstructions (green bars), and due to all land-cover changes as computed with the factorial experiment method (blue bars). The black vertical lines indicate 90% of the spread in the reconstruction for the reconstruction method, or the spread between ensemble simulations for the factorial experiment one.