A benchmark of Europe climate response to land use transitions in regional climate model simulations

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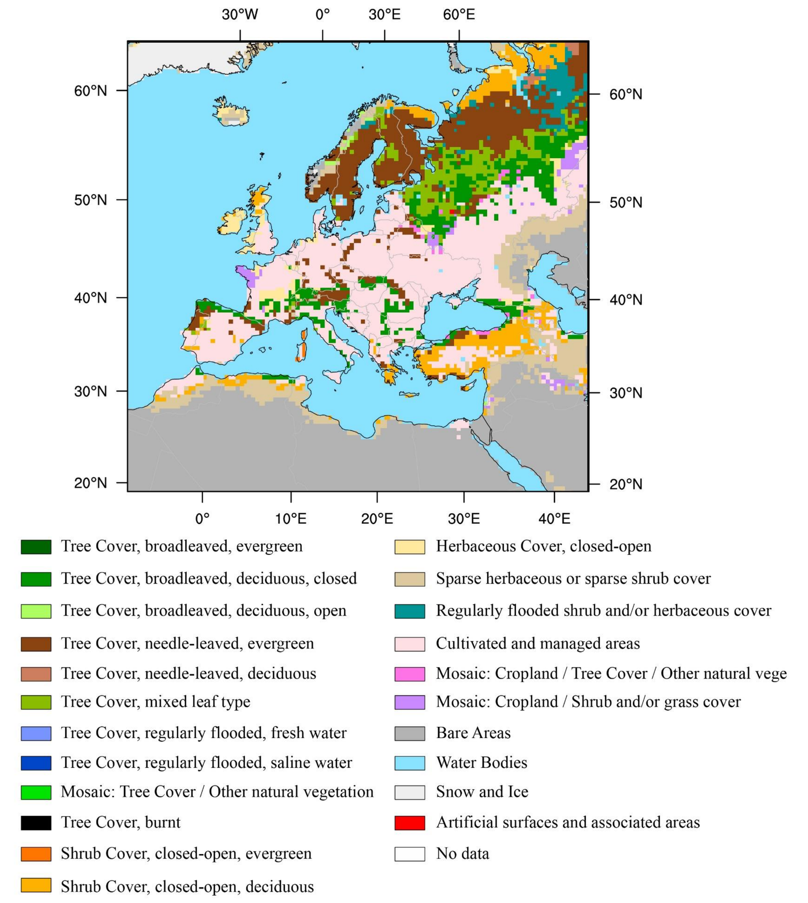
1. Introduction

Land use/cover change (LUCC) impacts the climate system from the local-to-regional scale. Previous studies do not have a similar conclusion of climate change caused by LUCC and even show some contrary result, especially in the mid-latitudes. A larger difference of mean climate effects can be found in deforestation experiments using a regional climate model instead of a global climate model. The change climate in model-based simulations are more significant than that in observations. These results cannot establish a full agreement of land use management. We want to quantify the climate response to extreme land cover changes with a regional model. The new findings can be used in assisting decision makers to design land management strategies in light of climate change mitigation and adaptation.

In this study, we use the regional climate model COSMO-CLM version 4.8 for the simluations. The COSMO-CLM is the climate version of the weather prediction model Consortium of Small-scale Modelling (COSMO). The further analyse will focus on the changes of temperature, precipitation, and frequency of temperature extremes at both the entire EURO-CORDEX domain (regional scale) and the changed grids (local scale).

2. Simulations



Model: COSMO-CLM4.8
Driven data: ERA-Interim
Simulation period: 1981-2010
Horizontal resolution: 0.44°

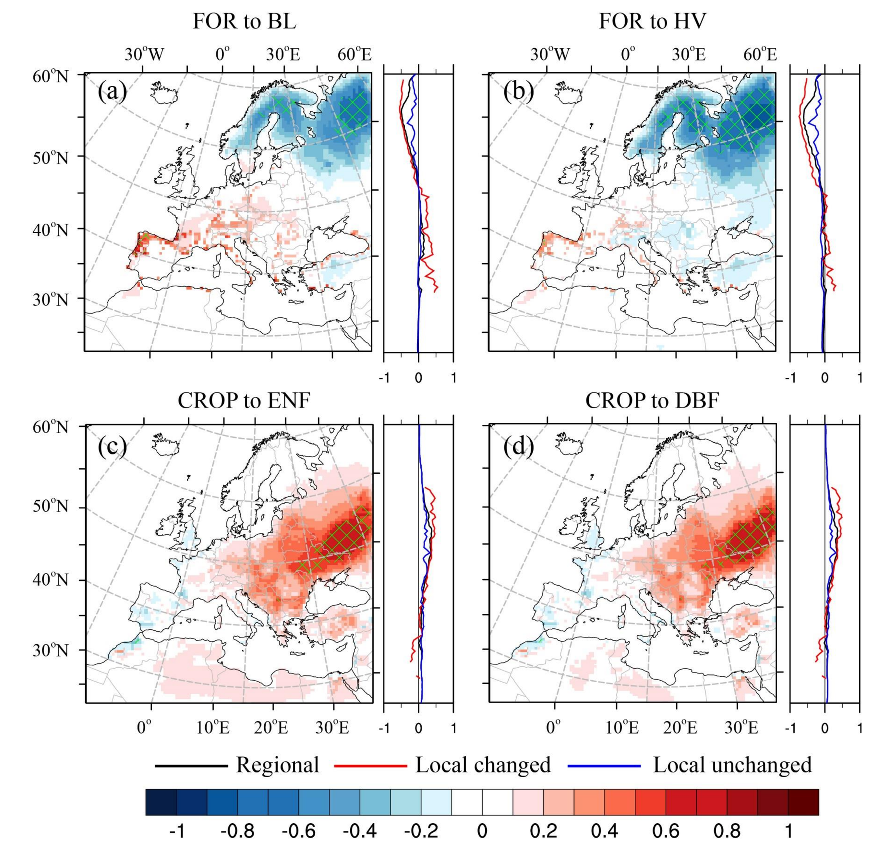
Simulations:
One control simulation (GLC2000)

Two deforestation simulations: forest to bare land (FOR to BL) and forest to herbaceous vegetation (FOR to HV)

Two afforestation simulations: cropland to evergreen needle-leave forest (CROP to ENF) and cropland to deciduous broad-leave forest (CROP to DBF)

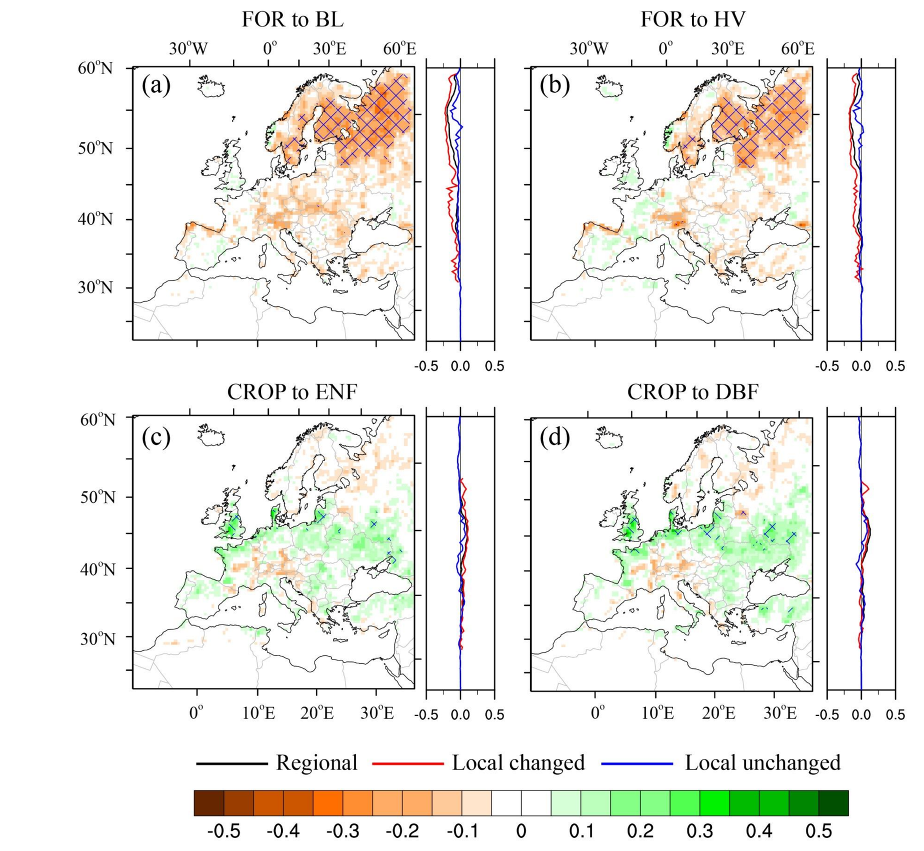
FOR to BL and FOR to HV: ***1527*** grid cell changed
CROP to ENF and CROP DBF: ***1835*** grid cell changed

3. Temperature response to land use change



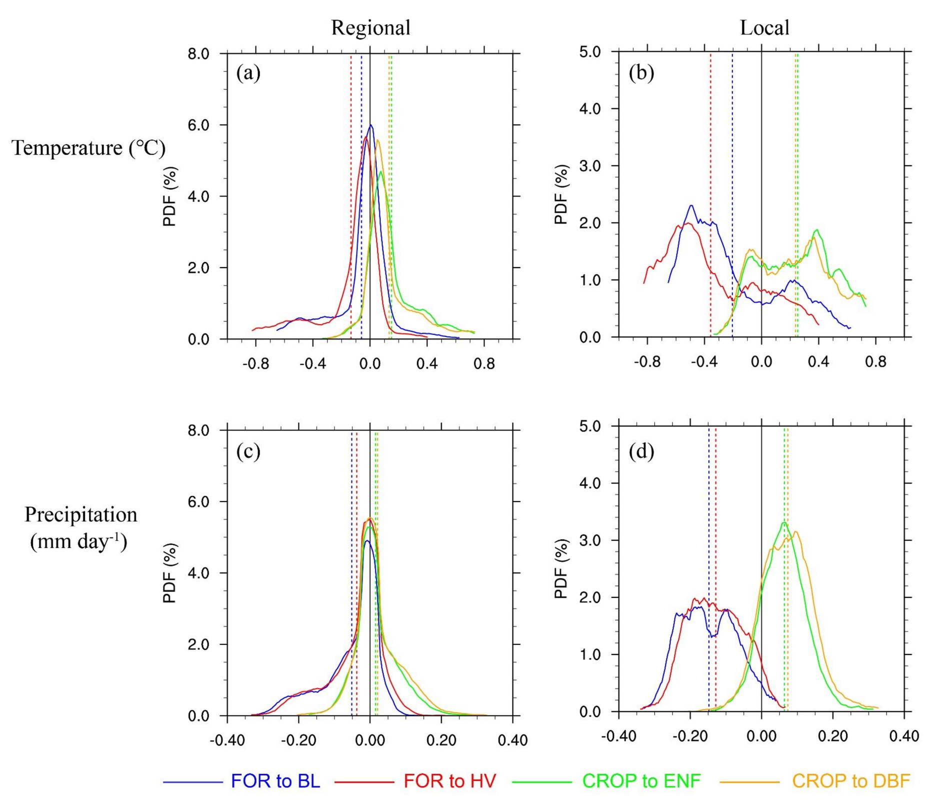
- Annual mean near surface air temperature (unit: °C) response to land use change
- Deforestation to bare land and herbaceous vegetation presents an annual mean regional cooling of -0.06 ± 0.09 (mean ± standard deviation) and -0.13 ± 0.08, respectively
- Afforestation to needle-leaf and broad-leaf forests leads to a mean warming of 0.15 ± 0.09 °C and 0.13 ± 0.09 °C, respectively
- Temperature response to deforestation changes between 50° and 55° latitude

4. Precipitation response to land use change



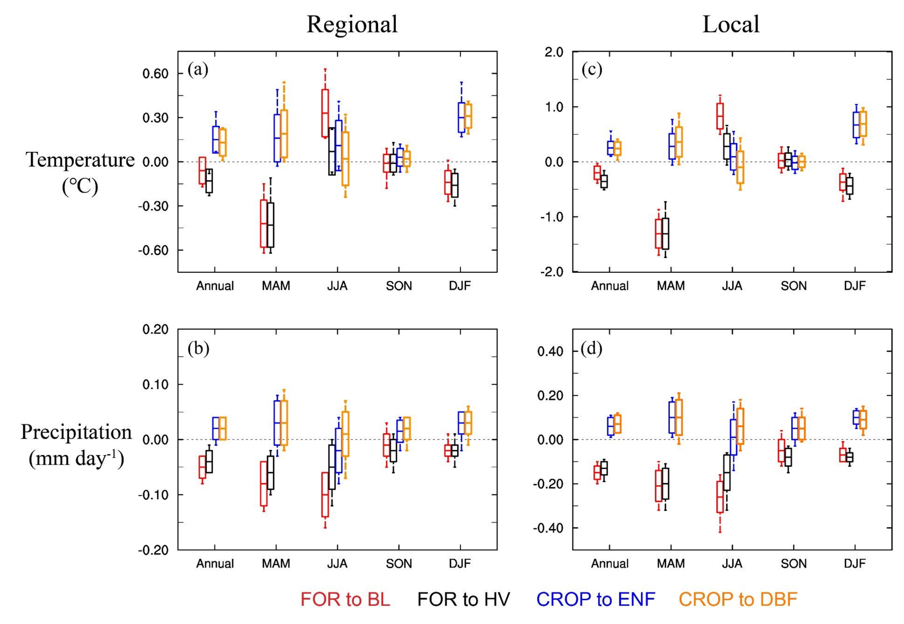
- The precipitation (unit: mm day^{-1}) response to the simulated extreme land cover changes has large spatial variability
- Deforestation causes a significant drier climate while afforestation leads to a slight wetter climate
- The annual mean difference across the entire domain is -0.05 ± 0.02 mm day^{-1} for FOR to BL, and -0.04 ± 0.02 mm day^{-1} for FOR to HV
- The average change across the domain is 0.02 ± 0.02 mm day^{-1} for both CROP to ENF and CROP to DBF experiments

5. Impact on regional and local scale



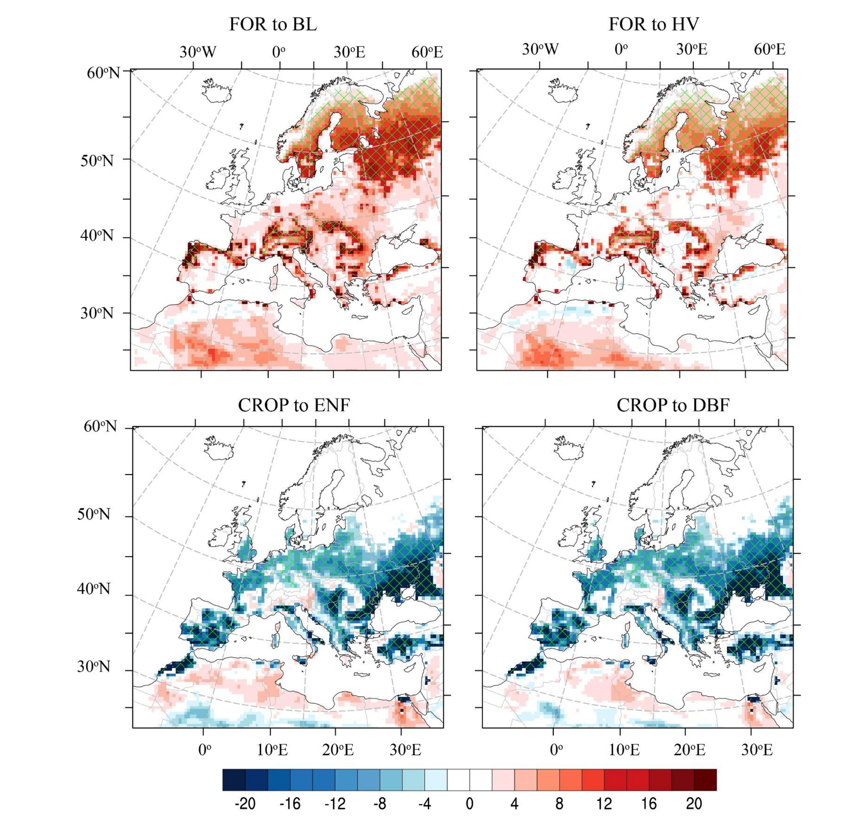
- The distribution of the climate signal is more spread at a local scale than at a regional scale
- In the deforestation experiments, the probability distribution of local temperature changes peak at around -0.5 °C, with the FOR to HV case exhibiting a distribution more translated towards higher temperature reductions
- Afforestation experiments show two similar peaks in local temperature changes, one around -0.1 °C and the other around +0.5 °C
- Precipitation changes are rather similar and follow a bell-like shape curve around the mean estimate

6. Seasonality



- Temperature impacts from deforestation show a cooling effect in winter and spring, but warming in summer and little differences in autumn
- Afforestation experiments show a temperature change that has lower variations over the year. The maximum warming is achieved in winter, followed by spring
- Deforestation tends to decreases average precipitation
- Afforestation experiments tend to increase rainfall, especially in spring

7. Impact on dryness and wetness



- Annual mean potential evapotranspiration (PET; unit: mm month^{-1}) changes in four extreme land use transition simulations
- Deforestation increases the water demand in the entire CORDEX-EURO domain, while afforestation reduces the water demand in central and eastern Europe
- A drier climate can be found in Europe when the FOR is replaced by BL or HV, especially in the northern Europe where the maximum PET change is around 20 mm month^{-1}
- Afforestation leads to a wetter Europe with a significant PET change (> 10 mm month^{-1} in most change grids from CROP to ENF or DBF)

8. Changes in extremes

	Season	FOR to BL	FOR to HV	CROP to ENF	CROP to DBF
Regional					
Tmax	Winter (DJF)			1.59	2.17
Tmax	Spring (MAM)				
Tmax	Summer (JJA)	6.72	1.2	3.74	1.22
Tmax	Autumn (SON)				
Tmin	Winter (DJF)	1.68	2.59	-2.22	-2.33
Tmin	Spring (MAM)	2.09	2.56	-1.93	-2.11
Tmin	Summer (JJA)				
Tmin	Autumn (SON)			-1.39	-1.28
Local					
Tmax	Winter (DJF)	-1.49	-1.62	4.46	5.54
Tmax	Spring (MAM)	-1.73	-1.71		
Tmax	Summer (JJA)	14.9	4.4	4.63	
Tmax	Autumn (SON)		1.73		
Tmin	Winter (DJF)	4.37	5.87	-3.61	-3.7
Tmin	Spring (MAM)	6.26	6.71	-3.17	-3.31
Tmin	Summer (JJA)	-1.34			
Tmin	Autumn (SON)			-1.99	-1.73

Legend (n = number of days)
- n > 4
- 2 < n < 4
- 1 < n < 2
- -1 < n < 1
- -2 < n < -1
- -4 < n < -2
- n < -4

- The average difference in number of hot/cold days is shown per season and at a regional or local scale
- Deforestation increases the number of hot days in summer, and increases cold days at similar rates for BL and HV, but spatial variability is still large
- Afforestation has an average warming effect in winter, where the occurrence of cold days is reduced and the number of hot days increases

8. Conclusion

- This study offers a quantification of the regional effects on temperature and precipitation of large-scale idealized land cover changes in Europe with COSMO-CLM
- The temperature response to deforestation shows a clear latitudinal pattern, whose signal is stronger than the contrast of the local vs. regional impact.
- Forest clearance generally tends to cool annual mean temperature values at high latitudes, and warm at lower latitudes. Deforestation increases the number of hot days in summer, and increases cold days at similar rates for BL and HV, but spatial variability is still large
- Afforestation generally warms the local surface, but results are highly spatially heterogeneous at mid latitudes

More details and additional references can be found in:

Cherubini, F., B. Huang, X. P. Hu, M. H. Tolle, and A. H. Stromman, 2018: Quantifying the climate response to extreme land cover changes in Europe with a regional model. *Environ Res Lett*, **13**, 074002. doi: 10.1088/1748-9326/aac974