CORDEX Flagship Pilot Study "LUCAS - Land Use & Climate Across Scales" - Impact of land use changes on climate in Europe across spatial and temporal scales

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Background

LUCAS (Land Use and Climate Across Scales) is an initiative on coordinated regional climate model experiments for Europe which includes land use change forcing (Rechid et al., 2017). It was initiated jointly by the European branch of the Coordinated Downscaling Experiments EURO-CORDEX and the global intercomparison study "Land-Use and Climate, IDentification of robust impacts" LUCID; and it has been approved by WCRP CORDEX as a Flagship Pilot Study (FPS).

Land use changes (LUC) are an important human forcing on climate, especially at the regional to local scale. The direct effects of LUC on local to regional climate can potentially exceed those associated with (downscaled) global mean warming. Up to now, LUC forcing is not accounted for in RCM ensemble climate change projections within CORDEX, while it is at those finer regional scales that they have the strongest impacts. In LUCAS, we step by step include this important human regional climate forcing into RCMs and investigate its direct biophysical effects on the climate in Europe.

Overall objective

The overall objective of LUCAS is to identify robust biophysical impacts of land use changes on climate across regional to local spatial scales and at various time scales from extreme events to seasonal variations and multi-decadal trends. In this context, land use changes (LUC) refer to anthropogenic land cover conversions as well as land management practices. We identified key science questions to be addressed:

• How sensitive are the regional climate models to LUC and how is this interrelated to land-atmosphere coupling in different regions among the suite of models?
• How large is the relative contribution of LUC compared to other forcings in the detection of the past and potential future climate trends?
• How do land use practices modulate climate variability? Can local LUC reduce or amplify extreme climate conditions?
• What is the effect of spatial resolution on the magnitude and robustness of LUC-induced climate changes?
• What errors do we make on the downscaled climate change if we ignore LUC? This is especially important for subsequent impact studies.
**LUCAS experiment strategy**

The LUCAS experiment strategy is designed in three phases: In **LUCAS phase 1**, idealized experiments are performed for the European continent in order to investigate and inter-compare model sensitivities to extreme land use change (LUC) forcing. In **LUCAS phase 2**, simulations driven by GCMs and dynamic land use changes are performed for past and future, including LUC forcing based on past re-constructions and future projections. The high resolution experiments in **LUCAS phase 3** shall be conducted over multiple gridded nests to refine the continental simulations down to resolutions below 5 km, in order to investigate feedbacks of local scale land use dynamics on climate.

**Status of LUCAS model intercomparison studies**

Multi-model simulations from LUCAS phase 1 idealized experiments are largely exploited in order to investigate effects of extreme land use changes in Europe. In 2019, simulations from 10 different RCM-LSM (Regional Climate Model - Land Surface Model) combinations are available: CCLM-TERRA, CCLM-VEG3D, CCLM-CLM4.5, RCA, RegCM-CLM4.5, REMO-iMOVE, WRFa-Noah-MP, WRFb-Noah, WRFb-CLM3.5, WRFc-Noah-MP. The first LUCAS RCM intercomparison study on "Biogeophysical impacts of forestation in Europe: First results from the LUCAS Regional Climate Model intercomparison" has been published at Earth System Dynamics (Davin et al., 2020). The study shows an agreement of RCMs in winter warming with consistently simulated albedo change, but no agreement on the sign of temperature response in summer, with disagreement in evaporative fraction, due to forestation in Europe (figure 1). Among others, it concludes that summer temperature response is dominantly driven by land processes, whereas atmospheric processes are important for winter response. The multi-model study on "The opposing effects of afforestation on the diurnal temperature cycle at the surface and in the atmospheric surface layer in the European summer" has been submitted to Journal of Climate (Breil et al., 2019), and is currently under review. Further multi-model analyses are done on a large variety of topics, such as "Changes in precipitation dynamics /cyclone activity due to extreme LUC" (Strandberg et al., in prep.), "Local and non-local effects induced by maximum deforestation/afforestation" (Strada S. et al., in prep.), "Land-atmosphere interaction at high latitudes through snow-temperature coupling" (Daloz et al., in prep.), "Forestation effects on soil temperature and soil carbon storage" (Sofiadis, Davin et al., in prep.), "Seasonal response of LUCAS RCMs to extreme land use changes under wet and dry conditions" (Hoffmann, Rechid et al., in prep.). Meanwhile, there are 7 PhDs working in the frame of FPS LUCAS on specific topics related to the overall LUCAS frame.

Currently, a new land use change data set based on land use change information from Land-Use Harmonized Dataset Version 2 (LUH2) is developed by Hoffmann et al. (2019). Annual land cover maps starting from a high resolution present-day land cover distribution are generated for the past period 1950-2015, and for land-cover scenarios 2016-2100, based on SSPs and RCPs, following the LUMIP / CMIP6 protocol. These new data sets will be implemented into RCMs as LUC forcing for GCM-driven LUCAS experiments at continental scale.
LUCAS meetings in the third project year

The annual LUCAS meeting 2019 was organised by GERICS in Hamburg. It took place from 25th - 26th Sep 2020. Regional Climate Modelers from Norway, Italy, Portugal, Germany, Switzerland, Sweden, Czech Republic & Greece visited GERICS to discuss simulated effects of extreme land cover changes in Europe, and joint publications were planned and discussed. The challenge of implementing new land cover data into each RCM individually and the deficiencies of investigated land cover data sets were addressed in detail. In January 2019, another LUCAS meeting was organised by GERICS, back to back with the annual EURO-CORDEX General Assembly 2020.

CORDEX FPS LUCAS Annual meeting 2019 at Climate Service Center Germany (GERICS) in Hamburg
Outlook 2020

Further model intercomparison studies based on extreme land use scenarios for Europe are planned for 2020. New high-resolution annual land cover maps based on LUH2, analogue to LUMIP in the frame of CMIP6, will be provided to the RCM community. The LUCAS phase 2 GCM driven simulations will be coordinated with the Euro-CORDEX simulation strategy. First RCM simulations for downscaling GCM simulations from CMIP6, by applying high-resolution dynamic LUC forcing may be started in 2020. The annual FPS LUCAS meeting is planned in September 2020 in Paris at IPSL.

FPS LUCAS Team

Around 20 European institutions are involved in LUCAS. It is coordinated jointly by:

- Diana Rechid, Climate Service Center Germany (GERICS)/Helmholtz Zentrum Geesthacht;
- Nathalie de Noblet-Ducoudré, Laboratoire des Sciences du Climat et de l'Environment, Institute Pierre Simon Laplace, France
- Edouard Davin at Eidgenössische Technische Hochschule Zurich, Switzerland
- Eleni Katragkou at Department of Meteorology and Climatology, School of Geology, Aristotle University of Thessaloniki, Greece.

If you are interested in this initiative, please contact diana.rechid@hzg.de

FPS LUCAS Website

See also our website here: https://www.hzg.de/ms/cordex_fps_lucas
Selected LUCAS publications


Breil M.; Rechid D; Davin E; de Noblet-Ducoudré N.; Katragou E; Cardoso R; Hoffmann P; Jach L; Soares P; Sofiadis G; Strada S; Strandberg G; Toelle M; Warrach-Sagi K: The opposing effects of afforestation on the diurnal temperature cycle at the surface and in the atmospheric surface layer in the European summer. submitted to Journal of Climate, 2019.


Sofiadis I, Katragkou E, Davin E, de Noblet N, Rechid D: Employing the ESA-CCI land cover product for regional climate simulations over Europe. Living Planet Symposium, 13-17 May 2019, Milan, Italy