

Annual report 2020 for 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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Status and progress during the year including scientific highlights, end to end perspective and participants engaged in the project

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 had 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 implement 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 practises. 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.

Multi-model simulations from LUCAS phase 1 idealized experiments had been extensively used to investigate effects of extreme land use changes in Europe. 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" had been published in 2020 with Earth System Dynamics (Davin et al., 2020). The study shows an overall 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 re-/afforestation on the diurnal temperature cycle at the surface and in the atmospheric surface layer in the European summer" had been successfully published in Journal of Climate (Breil et al., 2020). It shows opposite effects of forestation on the diurnal temperature range (DTR) at the surface and in the overlying atmospheric layer: Most RCMs simulate colder summer surface temperatures during the day and some warmer summer surface temperatures during the night, which is in line with observation based studies. In contrast, the DTR in the overlying atmospheric surface layer is increased – due to higher surface roughness which increases turbulent heat fluxes. The study indicates a limited usefulness of 2m temperature as diagnostic quantity to assess effects of LUC on European summer climate. The use of temperature at surface and in lowest atmospheric level is recommended.

Further model intercomparison studies are done based on extreme land use scenarios for Europe, which investigate e.g. "Forestation effects on soil temperature across the European continent" (Sofiadis et al., 2020), "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" (Daloze et al., in prep.), impacts on extreme compound events (Cardoso et al. in prep.), changes in precipitation dynamics /cyclone activity due to extreme LUC (Strandberg et al., in prep), and seasonal response of LUCAS RCMs to extreme land use changes under wet and dry conditions (Hoffmann et al. in prep.). There are currently 5 PhDs working in the frame of FPS LUCAS on specific topics related to the overall LUCAS frame.

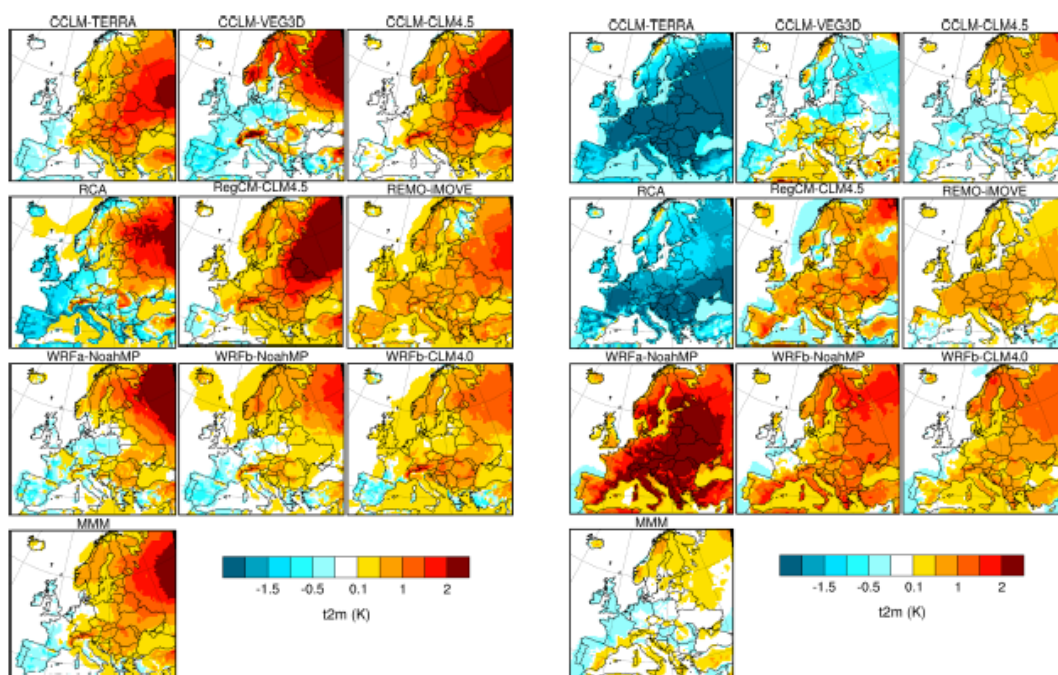


Figure 1. Simulated seasonally averaged 2m temperature response to forestation in winter DJF (left), and in summer JJA (right) (Source: Davin et al., 2020)

Lots of efforts have been put into generating high-resolution Land Use Land Cover Change (LULCC) information for use in RCM experiments for downscaling CMIP6 GCM simulations: the „LUCAS LUC dataset“ (Hoffmann et al., in prep.). Annual land cover maps starting from a high resolution present-day PFT distribution 2015 (figure 2) derived from ESA-CCI Land Cover data (Reinhart et al., in prep.) are generated for the past period 1950-2015 based on LUH2 dataset, and for land-cover scenarios 2016-2100, based on LUH2 dataset for different SSPs/RCPs, following the LUMIP / CMIP6 protocol. These new data sets are currently tested with RCM modelling groups. During a virtual workshop in October 2020, the challenges of implementing the new land cover maps into different RCM modelling families had been discussed. The new LUCAS LUC dataset will be used as land use change forcing for GCM-driven LUCAS experiments over Europe.

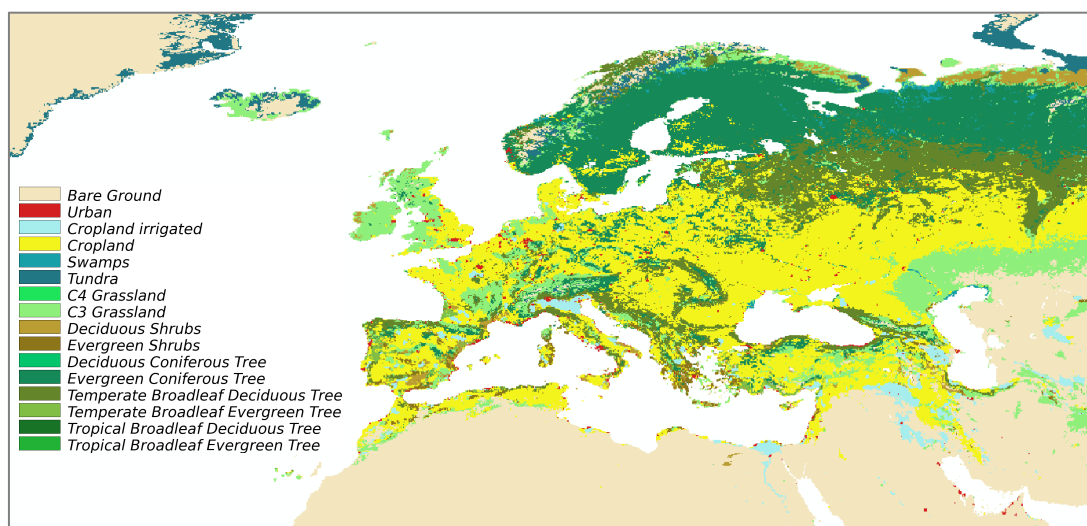


Figure 2. LUCAS PFT distribution 2015 derived from ESA-CCI Land cover data (Source: Hoffmann et al., in prep., Reinhart et al., in prep.)

Summary of each workshop/activity held during the year

Title, date, short description, location, website, links	Responsible person/-s	Funder
FPS LUCAS meeting back to back with EURO-CORDEX General Assembly 2020 28 th /29 th January 2020, in Hamburg at GERICS incl. PhD session and planning of activities in 2020 https://www.gerics.de/about/news_and_events/news/084601/index.php.de	Diana Rechid, supported by Peter Hoffmann, Vanessa Reinhart, Christina Asmus	GERICS
FPS LUCAS Interim Meeting 2020 18th June 2020, virtual meeting Interim results of ongoing multi-model studies had been exchanged, and requirements of the individual RCM Modelling groups for the high resolution LULCC data set had been elaborated. https://www.gerics.de/about/news_and_events/news/086271/index.php.en	Diana Rechid, supported by Peter Hoffmann, Vanessa Reinhart, Christina Asmus	-

FPS LUCAS annual meeting 2020 17th – 18th September, virtual conference Results of multi-model studies on the effects of land use change on regional climate in Europe were presented and LUCAS phase 2 experiments for downscaling CMIP6 simulations using high-resolution land use data were discussed.	Diana Rechid, supported by Peter Hoffmann, Vanessa Reinhart, Christina Asmus	-
LUCAS LUC data workshop 30th Oct 2020, virtual workshop Discussing the challenges of implementing the new LULCC dataset into RCMs	Peter Hoffmann, Vanessa Reinhart, supported by Christina Asmus, Diana Rechid	-

Related publications during the year

Title, journal and link to publication	Author/-s	Date
Davin, E. L., Rechid, D., Breil, M., Cardoso, R. M., Coppola, E., Hoffmann, P., Jach, L. L., Katragkou, E., de Noblet-Ducoudré, N., Radtke, K., Raffa, M., Soares, P. M. M., Sofiadis, G., Strada, S., Strandberg, G., Tölle, M. H., Warrach-Sagi, K., and Wulfmeyer, V (2020) : Biogeophysical impacts of forestation in Europe: First results from the LUCAS Regional Climate Model intercomparison, Earth Syst. Dynam., 11, 183–200, 2020, https://doi.org/10.5194/esd-11-183-2020	Davin, E. L., Rechid, D., Breil, M., Cardoso, R. M., Coppola, E., Hoffmann, P., Jach, L. L., Katragkou, E., de Noblet-Ducoudré, N., Radtke, K., Raffa, M., Soares, P. M. M., Sofiadis, G., Strada, S., Strandberg, G., Tölle, M. H., Warrach-Sagi, K., and Wulfmeyer, V	20.02.2020
Breil, M., Rechid, D., Davin, E.L., de Noblet-Ducoudré, N., Katragkou, E., Cardoso, R.M., Hoffmann, P., Jach, L.L., Soares, P.M.M., Sofiadis, G., Strada, S., Strandberg G., Tölle, M.H., Warrach-Sagi K. (2020): The opposing effects of re/af-forestation on the diurnal temperature cycle at the surface and in the lowest atmospheric model level in the European summer. J. Climate 1–58. https://doi.org/10.1175/JCLI-D-19-0624.1	Breil, M., Rechid, D., Davin, E.L., de Noblet-Ducoudré, N., Katragkou, E., Cardoso, R.M., Hoffmann, P., Jach, L.L., Soares, P.M.M., Sofiadis, G., Strada, S., Strandberg G., Tölle, M.H., Warrach-Sagi K	24.09.2020
Reinhart V., Fonte C., Hoffmann P., Bechtel B., Rechid D., Böhner J. (2020): Comparison of ESA Climate Change Initiative Land Cover to CORINE Land Cover over Eastern Europe and the Baltic States from a regional climate modeling perspective. Int. J. Earth Obs. 94, 102221. https://doi.org/10.1016/j.jag.2020.102221	Reinhart V., Fonte C., Hoffmann P., Bechtel B., Rechid D., Böhner J.	09.09.2020

Hoffmann P., Rechid R., Reinhart V., Asmus C., Davin E.L., Katragkou E., De Noblet-Ducoudré N., Bechtel B., Böhner J. (2020): Long-term high-resolution land-use/land-cover change dataset for regional climate modeling. AGU Annual Meeting 2020, GC007-0008 https://agu.confex.com/agu/fm20/meetingapp.cgi/Paper/709275	Hoffmann P., Rechid R., Reinhart V., Asmus C., Davin E.L., Katragkou E., De Noblet-Ducoudré N., Bechtel B., Böhner J.	07.12.2020
Reinhart V., Hoffmann P., Rechid D., Böhner J. (2020): Uncertainties in plant functional type (PFT) products for use in regional climate models - assessing the sensitivity of global PFT time series to different input data and cross-walking procedures. AGU Annual Meeting 2020, GC018-07 https://agu.confex.com/agu/fm20/meetingapp.cgi/Paper/721156	Reinhart V., Hoffmann P., Rechid D., Böhner J.	08.12.2020

Planned activities for next year

Outlook 2021

There are many ongoing model intercomparison studies based on extreme land use scenarios for Europe, from which several results will be presented at vEGU 2021. The new high-resolution annual land cover maps LUCAS LUC based on LUH2 will be tested by the different RCM modelling groups, and recommendations for implementing LUC into regional climate change projections will be derived. Selected RCM simulations for downscaling GCM simulations from CMIP6 will apply the new high-resolution dynamic LUC forcing. A virtuell LUCAS Interim Meeting 2021 is planned in Spring, the final FPS LUCAS meeting is planned in autumn 2021.

Additional relevant information

FPS LUCAS Website

Please find our website here: https://www.hzg.de/ms/cordex_fps_lucas



Contact person/-s

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'Environnement, 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***

If more space is needed just add rows in the table.

The report is due the 15th of February each year and should be sent to ipoc@cordex.org.