SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Land Management for Climate Mitigation and Adaptation (LAMACLIMA)
Computer Project Account:	SP_NLCOUM
Start Year - End Year :	2019 - 2023
Principal Investigator(s)	Dim Coumou
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Other Researchers (Name/Affiliation):	Iris Manola VU Amsterdam

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

VU Amsterdam is partner in the JPI-Climate/AXIS funded project LAMACLIMA (https://climateanalytics.org/projects/lamaclima/) that aims at advancing the scientific and public understanding of the coupled climate effects of land cover and land management (LCLM) options. The project aims at elaborating sustainable land-based adaptation and mitigation measures.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

For the current EC-Earth-CC simulations we had to migrate to the Atos system. In general the transition went rather smoothly. There were some issues with transforming the scripts to the Slurm workload, but in this the ECMWF support and the specialized personnel of KNMI helped us in order to start running EC-Earth there.

For the first set of runs with EC-Earth-CC in 2023 we discovered a bug in the model and the runs had to be re-run. The allocation of SBU was not enough to complete those and therefore we had to send a new special request to ask for an increase in our budget.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The experience throughout the 4 years of the project duration was very good. For example when we recently had to increase our SBU budget the application was read fast by the ECMWF personnel, we got an honest and fast response and soon we were granted what we asked for. That was very important to us. Questions for technical issues are also fast and adequately answered via emails. The application procedure is rather straightforward and the given forms are quite explanatory (like the one I am filling out at the moment). Uploading or emailing them is also not hard and we get rather quick responses to them.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

As summary of results I cite the abstracts of the published papers that were published within the LAMACLIMA framework:

From the “Changes in land cover and management affect heat stress and labor capacity”:

Global warming is expected to exacerbate heat stress. Additionally, biogeophysical effects of land cover and land management changes (LCLMC) could substantially alter temperature and relative humidity locally and non-locally. Thereby, LCLMC could affect the occupational capacity to safely perform physical work under hot environments (labor capacity). However, these effects have never been quantified globally using a multi-model setup. Building on results from stylized sensitivity experiments of (a) cropland expansion, (b) irrigation expansion, and (c) afforestation conducted by three fully coupled Earth System Models (ESMs), we assess the local as well as non-local effects on heat stress and labor capacity. We found that LCLMC leads to substantial changes in temperature; however, the concomitant changes in humidity could largely diminish the combined impact on moist heat. Moreover, cropland expansion and afforestation cause inconsistent responses of day- and night-time temperature, which has strong implications for labor capacity. Across the ESMs, the results are mixed in terms of sign and magnitude. Overall, LCLMC result in non-negligible impacts on heat stress and labor capacity in low-latitude regions during the warmest seasons. In some locations, the changes of monthly average labor capacity, which are induced by the local effects of individual LCLMC options, could reach −14 and +15 percentage points. Thus, LCLMC-induced impacts on heat stress and their consequences for adaptation should be accounted for when designing LCLMC-related policies to ensure sustainable development.

A summary from “Effects of idealised land cover and land management changes on the atmospheric water cycle”:

Land cover and land management changes (LCLMCs) play an important role in achieving low-end warming scenarios through land-based mitigation. However, their effects on moisture fluxes and recycling remain uncertain although they have important implications for the future viability of such strategies. Here, we analyse the impact of idealised LCLMC scenarios on atmospheric moisture transport in three different ESMs: the Community Earth System Model (CESM), the Max Planck Institute Earth System Model (MPI-ESM) and the European Consortium Earth System Model (EC-EARTH). The LCLMC scenarios comprise of a full cropland world, a fully afforested world, and a cropland world with unlimited irrigation expansion. The effects of these LCLMCs in the different ESMs are analysed for precipitation, evaporation and vertically integrated moisture flux convergence to understand the LCLMC-induced changes in the atmospheric moisture cycle. Then, a moisture tracking algorithm is applied to assess the effects of LCLMCs on moisture recycling at the local (grid cell level) and the global scale (continental moisture recycling). Our results indicate that LCLMCs are generally inducing consistent feedbacks on moisture fluxes over land in all ESMs. Cropland expansion causes drying and reduced local moisture recycling in all ESMs, while afforestation and irrigation expansion generally cause wetting and increased local moisture recycling. However, the strength of this influence varies in time and space and across the ESMs and shows a strong dependency on the dominant driver: Some ESMs show a dominance of large scale atmospheric circulation changes while other ESMs show a dominance of local to regional changes in the atmospheric water cycle only within the vicinity of the LCLMC. Overall, these results corroborate that LCLMCs can induce large effects on the atmospheric water cycle and moisture recycling, but more research is needed to constrain the uncertainty of these effects within ESMs and better evaluate land-based mitigation strategies.

From “The biogeophysical effects of idealized land cover and land management changes in Earth system models”:

Land cover and land management change (LCLMC) has been highlighted for its critical role in mitigation scenarios, both in terms of global mitigation and local adaptation. Yet, the climate effect of individual LCLMC options, their dependence on the background climate and the local vs. non-local responses are still poorly understood across different Earth System Models (ESMs). Here we simulate the climatic effects of LCLMC using three state-of-the-art ESMs, including the Community Earth System Model (CESM), the Max Planck Institute for Meteorology Earth System Model (MPI-ESM) and the European Consortium Earth System Model (EC-EARTH). We assess the LCLMC effects using four idealized experiments: (i) a fully afforested world, (ii) a world fully covered by cropland, (ii) a fully afforested world with extensive wood harvesting, and (iv) a full cropland world with extensive irrigation. In these idealized sensitivity experiments, performed under present-day climate conditions, the effects of the different LCLMC strategies represent an upper bound for the potential of global mitigation and local adaptation. To disentangle the local and non-local effects from the LCLMC, a checkerboard-like LCLMC perturbation, i.e., alternating grid boxes with and without LCLMC, is applied. The local effects of deforestation on surface temperature are largely consistent across the ESMs and the observations, with a cooling in boreal latitudes and a warming in the tropics. However, the energy balance components driving the change in surface temperature show less consistency across the ESMs and the observations. Additionally, some biases exist in specific ESMs, such as a strong albedo response in CESM mid-latitudes and a soil thawing driven warming in boreal latitudes in EC-EARTH. The non-local effects on surface temperature are broadly consistent across ESMs for afforestation, though larger model uncertainty exists for cropland expansion. Irrigation clearly induces a cooling effect, however; the ESMs disagree whether these are mainly local or non-local effects. Wood harvesting is found to have no discernible biogeophysical effects on climate. Our results overall underline the potential of ensemble simulations to inform decision making regarding future climate consequences of land-based mitigation and adaptation strategies.

From “TIMBER v0.1: a conceptual framework for emulating temperature responses to tree cover change”:

Society is set to experience significant land cover changes in order to achieve the temperature goals agreed upon under the Paris Agreement. Such changes carry both global implications, pertaining to the biogeochemical effects of land cover change and thus the global carbon budget, and regional/local implications, pertaining to the biogeophysical effects arising within the immediate area of land cover change. Biogeophysical effects of land cover change are of high relevance to national policy- and decision- makers and their accountance is essential towards effective deployment of land cover practices that optimises between global and regional impacts. To this end, ESM outputs that isolate the biogeophysical responses of climate to land cover changes are key in informing impact assessments and supporting scenario development exercises. Generating multiple such ESM outputs, in a manner that allows comprehensive exploration of all plausible land cover scenarios however, is computationally untenable. This study proposes a framework to agilely explore the local biogeophysical responses of climate under different land cover scenarios by means of a computationally inexpensive emulator, TIMBER v0.1. The emulator is novel in that it solely represents the land cover forced, biogeophysical responses of climate, and can be used as either a standalone device or supplementary to existing climate model emulators that represent greenhouse gas (GHG)- or Global Mean Temperature (GMT)- forced climate responses. We start off by modelling local minimum, mean and maximum surface temperature responses to tree cover changes by means of a month- and Earth System Model (ESM)- specific Generalised Additive Model (GAM) trained over the whole globe. 2-m air temperature responses are then diagnosed from the modelled minimum and maximum surface temperature responses using observationally derived relationships. Such a two-step procedure accounts for the different physical representations of surface temperature responses to tree cover changes under different ESMs, whilst respecting a definition of 2-m air temperature that is more consistent across ESMs and with observational datasets. In exploring new tree cover change scenarios, we employ a parametric bootstrap sampling method to generate multiple possible temperature responses, such that the parametric uncertainty within the GAM is also quantified. The output of the final emulator is demonstrated for the SSP 1-2.6 and 3-7.0 scenarios. Relevant temperature responses are identified as those displaying a clear signal in relation to their surrounding parametric uncertainty, calculated as the "signal-to-noise" ratio between the sample set mean and sample set variability. The emulator framework developed in this study thus provides a first step towards bridging the information-gap surrounding biogeophysical implications of land cover changes, allowing for smarter land-use decision 25 making.

From “Overcoming global inequality is critical for land-based mitigation in line with the Paris Agreement”:

Transformation pathways for the land sector in line with the Paris Agreement depend on the assumption of globally implemented greenhouse gas (GHG) emission pricing, and in some cases also on inclusive socio-economic development and sustainable land-use practices. In such pathways, the majority of GHG emission reductions in the land system is expected to come from low- and middle-income countries, which currently account for a large share of emissions from agriculture, forestry and other land use (AFOLU). However, in low- and middle-income countries the economic, financial and institutional barriers for such transformative changes are high. Here, we show that if sustainable development in the land sector remained highly unequal and limited to high-income countries only, global AFOLU emissions would remain substantial throughout the 21st century. Our model-based projections highlight that overcoming global inequality is critical for land-based mitigation in line with the Paris Agreement. While also a scenario purely based on either global GHG emission pricing or on inclusive socio-economic development would achieve the stringent emissions reductions required, only the latter ensures major co-benefits for other Sustainable Development Goals, especially in low- and middle-income regions.

List of publications/reports from the project with complete references

Journal Publications:

· Orlov, A., De Hertog, S., Havermann, F., Guo, S., Luo, F., Manola, I., Thiery, W., Lejeune, Q., Pongratz, J., Humpenöder, F. and Windisch, M., 2023. Changes in land cover and management affect heat stress and labor capacity. Earth's Future, 11(3), p.e2022EF002909.

· Steven J. De Hertog, Carmen E. Lopez Fabara, Ruud van der Ent, Jessica Keune, Diego G. Miralles, Raphael Portmann, Sebastian Schemm, Felix Havermann, Suqi Guo, Fei Luo, Iris Manola, Quentin Lejeune, Julia Pongratz, Carl-Friedrich Schleussner, Sonia I. Seneviratne, and Wim Thiery. Effects of idealised land cover and land management changes on the atmospheric water cycle, submitted to Earth System Dynamics.

· De Hertog, S. J., Havermann, F., Vanderkelen, I., Guo, S., Luo, F., Manola, I., Coumou, D., Davin, E. L., Duveiller, G., Lejeune, Q., Pongratz, J., Schleussner, C.-F., Seneviratne, S. I., and Thiery, W.: The biogeophysical effects of idealized land cover and land management changes in Earth system models, Earth Syst. Dynam., 14, 629–667, https://doi.org/10.5194/esd-14-629-2023, 2023.

· Nath, S.; Gudmundsson, L.; Schwaab, J.; Duveiller, G.; De Hertog, S. J.; Guo, S.; Havermann, F.; Luo, F.; Manola, I.; Pongratz, J.; Seneviratne, S. I.; Schleussner, C. F.; Thiery, W. & Lejeune, Q. TIMBER v0.1: a conceptual framework for emulating temperature responses to tree cover change, EGUsphere, 2022, 2022, 1-36

· Humpenöder, F., Popp, A., Schleussner, C.F., Orlov, A., Windisch, M.G., Menke, I., Pongratz, J., Havermann, F., Thiery, W., Luo, F. and Dietrich, J.P., 2022. Overcoming global inequality is critical for land-based mitigation in line with the Paris Agreement. Nature Communications, 13(1), pp.1-15.

Conference Abstracts:

Manola, I., Coumou, D., Luo, F., Guo, S., Havermann, F., De Hertog, S., Lejeune, Q., Menke, I., Pongratz, J., Schleussner, C., Seneviratne, S., and Thiery, W.: Summer jet stream response to global af-/reforestation and deforestation , EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-14529, https://doi.org/10.5194/egusphere-egu23-14529, 2023.

· De Hertog, S. J., Lopez-Fabara, C. E., van der Ent, R., Keune, J., Miralles, D. G., Portmann, R., Schemm, S., Havermann, F., Guo, S., Luo, F., Manola, I., Lejeune, Q., Pongratz, J., Schleussner, C.-F., Seneviratne, S. I., and Thiery, W.: Effects of idealised land cover and land management changes on the atmospheric water cycle, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-953, 2023.

· DOI: 10.5194/egusphere-egu22-11533, Guo, S., Havermann, F., De Hertog, S., Thiery, W., Luo, F., Manola, I., Coumou, D., Lejeune, Q., Schleussner, C.-F., and Pongratz, J.: Simulated unintended biogeochemical effects of idealized land cover and land management changes, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-11533, https://doi.org/10.5194/egusphere-egu22-11533, 2022.

· DOI: 10.5194/egusphere-egu22-412, De Hertog, S., Lopez Fabara, C. E., Havermann, F., Guo, S., Pongratz, J., Manola, I., Luo, F., Coumou, D., Davin, E. L., Seneviratne, S. I., Lejeune, Q., Schleussner, C.-F., and Thiery, W.: Sensitivity of global surface moisture dynamics under changed land cover and land management, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-412, https://doi.org/10.5194/egusphere-egu22-412, 2022.

· Iris Manola, Dim Coumou, Fei Luo, Suqi Guo, Felix Havermann, Steven De Hertog, Quenting Lejeune, Inga Menke, Julia Pongratz, Carl Schleussner, Sonia Seneviratne, and Wim Thiery, Summer jet stream response to global af-/reforestation and deforestation, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU23-14529

· Guo, S., Pongratz, J., Havermann, F., De Hertog, S., Thiery, W., Manola, I., Coumou, D., Lejeune, Q. and Schleussner, C.F., 2021, April. Simulated biogeochemical effects of idealized land cover and land management changes. In EGU General Assembly Conference Abstracts (pp. EGU21-9826).

· De Hertog, S., Havermann, F., Vanderkelen, I., Manola, I., Guo, S., Coumou, D., Davin, E., Duveiller, G., Lejeune, Q., Luo, F. and Pongratz, J., 2021, December. Potential Biogeophysical Effects from idealized Land Cover and Land Management Changes. In AGU Fall Meeting Abstracts (Vol. 2021, pp. GC44B-06).

· De Hertog, S., Vanderkelen, I., Havermann, F., Guo, S., Pongratz, J., Manola, I., Coumou, D., Davin, E., Seneviratne, S., Lejeune, Q. and Menke, I., 2021, April. Biogeophysical effects of idealised land cover and land management changes on the climate. In EGU General Assembly Conference Abstracts (pp. EGU21-2818).

· Manola, I., Coumou, D., Alessandri, A., Davin, E., Guo, S., Havermann, F., De Hertog, S., Lejeune, Q., Menke, I., Pongratz, J. and Schleussner, C., 2020, May. Impacts of global re-/afforestation and deforestation on large scale atmospheric circulation. In EGU General Assembly Conference Abstracts (p. 19444).

· Guo, S., Pongratz, J., Havermann, F., Alessandri, A., Coumou, D., Davin, E.L., De Hertog, S., Lejeune, Q., Manola, I., Menke, I. and Schleussner, C., 2020, May. Biogeochemical effects of land cover and land management. In EGU General Assembly Conference Abstracts (p. 19737).

· De Hertog, S., Vanderkelen, I., Havermann, F., Guo, S., Pongratz, J., Manola, I., Coumou, D., Davin, E., Seneviratne, S., Lejeune, Q. and Menke, I., 2020, May. Local biogeophysical effects of deforestation. In EGU General Assembly Conference Abstracts (p. 1248).

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

Currently there is no future project planned related to LAMACLIMA project.
More publications are expected to be submitted during the second half of 2023.