SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	………………2022………………………………….……
Project Title:	Land Management for Climate Mitigation and Adaptation (LAMACLIMA)
Computer Project Account:	…………… **SP_NLCOUM**…………………………….……
Principal Investigator(s):	…Dim Coumou …………………………………….…… ………………………………………………………….……
Affiliation:	VU Amsterdam……………………………….……
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….…… ………………………………………………………….……
Start date of the project:	……01/11/2019………………………………..……
Expected end date:	………31/08/2023………………………………..……

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)		1,975,270	Asked for 82 MSBU	
Data storage capacity	(Gbytes)				

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 (10 lines max)

In the past months we migrated to the Atos system and in general the transition went rather smoothly. There were some issues with changing 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.

Summary of plans for the continuation of the project (10 lines max)

In the year 2023 the WP4 simulations of the project LAMACLIMA will take place.
In WP4, EC-Earth3-CC will use the land-use scenario data as input to simulate the implications on climate and the carbon cycle. A setup parallel to the CMIP6 emission-driven SSP simulations will be applied. This includes the full climate and carbon cycle implications by coupling land, atmosphere, and ocean, representing interactions between LCLM-altered climate and LCLM biogeophysical and carbon cycle effects. Different from the idealised simulations of WP1, the climate/carbon cycle implications are transient 21-century projections for a LCLM scenario that is optimised for mitigation, adaptation, and socioeconomic benefits. EC-Earth3-CC will also perform an ensemble of three simulations to account for uncertainties related to climate variability. We will perform four scenario simulations: A historic control, a future control, a future sustainability land use and a future inequality land use scenario.

List of publications/reports from the project with complete references

Journal Publications of LAMACLIMA:

- DOI: 10.5194/esd-13-1305-2022, 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. & Thiery, W. The biogeophysical effects of idealized land cover and land management changes in Earth system models. Earth System Dynamics, 2022, 13, 1305-1350.

- 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

- Anton Orlov, Steven De Hertog, Felix Havermann, Suqi Guo, Fei Luo, Iris Manola, Wim Thiery, Quentin Lejeune, Julia Pongratz, Florian Humpenöder, Michael Windisch, Shruti Nath, Alexander Popp, Carl-Friedrich Schleussner, Changes in Land Cover and Management Affect Heat Stress and Labour Capacity, Earth's Future (under review).

- 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.

And soon to be submitted:

- 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, to be submitted at Earth System Dynamics.

Conference Abstracts:

- 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).

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

As summary of results I cite the abstracts of the published papers that were published within our project in the year 2022:

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 5 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 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.