REQUEST FOR A SPECIAL PROJECT 2021–2023

MEMBER STATE: Netherlands

Principal Investigator[1]**:** Dim Coumou

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Project Title: Land Management for Climate Mitigation and Adaptation (LAMACLIMA)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** NLCOUM	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2021-2023: (To make changes to an existing project please submit an amended version of the original form.)		**2021**	**2022**	**2023**
High Performance Computing Facility	(SBU)	18 MSBU	10 MSBU	
Accumulated data storage (total archive volume)[2]	(GB)	35000	35000	

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

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Extended abstract

The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF as well as the Scientific Advisory Committee. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages). Large requests asking for 10,000,000 SBUs or more might receive a detailed review by members of the Scientific Advisory Committee.

VU Amsterdam is partner in the new 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.

The Royal Netherlands Meteorological Institute (KNMI) is chairing the Land and Vegetation Working Group in the frame of EC-Earth, aiming among other activities to achieving improved Earth system predictions and projections on multiple time scales by filling the gap between the models used for short-term prediction (verification-based) and the latest developments in the Earth System Models (process-based).

There is now strong evidence that anthropogenic changes in LCLM are substantially affecting climate through the release of carbon to the atmosphere (biogeochemical effects), the alteration of local energy and water fluxes at the land surface, and their interaction with large-scale atmospheric dynamics (biogeophysical effects). Accounting for coupled LCLM-climate effects is thus very relevant for future climate mitigation and adaptation efforts. However, the coupled nature of these effects overall receives limited consideration in land use decision making processes. LAMACLIMA will investigate the local and remote biogeophysical and biogeochemical effects of three key changes in LCLM (**re/afforestation**, **irrigation** and **wood harvest**) on climate and their implications for several sectors (agriculture, water availability, forestry and economic productivity). This will be achieved by comparing the results of coordinated sensitivity experiments with three Earth System Models (ESMs) including EC-Earth coupled to LPJ-GUESS. For the EC-Earth-LPJ-GUESS simulation runs we would like to request compute time at the ECMWF's HPC.

State of the art

The scientific analysis of the consequences of global land use changes largely rely on integrated assessments, which have traditionally regarded the influence of climate on land as a unidirectional process, without explicitly accounting for the feedback of changes in LCLM on climate. There is now solid evidence however that this feedback is significant, not only for carbon dioxide concentrations (Erb et al. 2017; Quéré et al. 2018), but also for the energy and water fluxes locally (De Noblet-Ducoudré 2012; Thiery et al. 2017; Lejeune et al. 2018), as well as remotely (Vrese et al. 2016;

Winckler 2018). The regional climate effects of projected future changes in LCLM are indeed comparable with those of a global mean temperature increase of 0.5°C (Schleussner et al. 2017; Hirsch et al. 2018). Given the importance of 0.5°C global warming increments and associated impacts in the context of the Paris Agreement, and the substantial changes in LCLM expected under scenarios compatible with it (Seneviratne et al. 2018b), an integrated multi-model intercomparison of LCLM-climate feedbacks in ESMs is of high scientific and policy relevance (Seneviratne et al. 2018a). The effects on energy and water fluxes, if regarded at all, are however usually seen as unintended side effects of land use decisions that focus on carbon stocks. Nevertheless, it has been recognized that these fluxes should be included in a comprehensive assessment of the coupled land use-climate system.

Planned Simulations

The interactions between LCLM and climate will be quantified by conducting a set of sensitivity experiments using EC-Earth3-Veg. The output of these simulations will be analysed for (i) local climate impacts of changes in LCLM through biogeophysical effects such as changes in albedo or evapotranspiration, (ii) remote biogeophysical impacts through atmospheric teleconnections and (iii) biogeochemical impacts on the carbon cycle. Three key LCLM options for climate – i.e. for which strong potential biogeochemical and biogeophysical effects were identified – will be considered: re/afforestation, irrigation and wood harvesting. Furthermore, selected output fields will be used to quantify additional or avoided economic impacts of LCLM.

We will generate simulations with the coupled-model **EC-Earth3-Veg** over the period 2014-2174 (**160 years including 10 years of spin-up**). We use the latest frozen version EC-Earth 3.2 at T255 resolution. There will be Tier 1 simulations, for present day GHG forcing and Tier 2 simulations for future RCP scenarios. For Tier 1, a control run is already generated and **four scenario runs** of 160 years each will follow. All runs include all major anthropogenic and natural external forcings from year 2014. The control run includes the LCLM of 2014, excluding irrigation and wood harvest. The first scenario (FRST) simulation will consist of an extension of forest over all pixels where vegetative fraction exceeds a certain threshold. Through this approach the local and non local effects can be gained for a 100% forested world. The second scenario (CROP) simulation will consist of an extension of cropland over all pixels where vegetative fraction exceeds a certain threshold. Through this approach the local and non local effects can be gained for a 100% deforested world. The third scenario (HARV) simulation will build upon the FRST simulation however applying a certain amount of wood harvesting on all forests. Subsequently through a comparison with FRST simulation the effects from applying wood harvesting on climate can be gained. Finally, the fourth (IRR) simulation will build upon the CROP simulation however applying irrigation on all croplands (lands). By comparing IRR to CROP the effects from irrigation on climate will be gained.

For Tier 2, all simulations will be repeated with RCP8.5 scenario, branching off from the respective CMIP6 simulations in the year 2100. Each ESM will repeat 5 times the fully coupled simulations for 160 years using constant CO2 concentrations of the year 2100 in the RCP 8.5 scenario (126.1 Gton CO2), constant over time, under the same LCLM options as in Tier 1 simulations.

The four sensitivity experiments thereby represent an extreme yet feasible implementation of a single LCLM scenario. All simulations will be greenhouse gas concentration-driven and performed in fully coupled mode, consistent with the Land-Use Model Intercomparison Project (LUMIP) simulation protocol. Simulations will be branched from the CMIP6 historical simulations and each ensemble will contain five unique realisations (i.e. members) in terms of natural variability but with an identical representation of the underlying physical processes. The 4 remaining simulations in Tier 1 consist of a total 640 modelled years and the 5 simulations of Tier 2 consist of a total amount of 800 modelled years. The CTL ensemble will be evaluated for its ability to represent (i) surface energy balance components using e.g. GEWEX-SRB GLEAM and LandFlux-EVAL, (ii) near-surface climate using e.g. ERA5, CRU and GPCP, and (iii) carbon stocks and fluxes using the ILAMB and/or ESMValTool benchmarking systems. The three LCLM options will be addressed in sequential order. The experiments run will enable us to quantify the impact of the three investigated LCLM options on a series of variables such as air temperature, precipitation, rainfed and irrigated crop yields, and surface runoff. The derived spatially explicit relationships between LCLM implementation and these variables will be used for further impact and policy relevant analyses.

Computational Requirements

In order to accurately estimate the computational requirements, a set of experiments has been specifically designed and performed using the same codes that will be used in the production phase. The aim is to verify the performance of the codes and determine the better processors configuration. Large scalability is not an issue in our case, since we plan to run different experiments at the same time. Therefore, we limited our tests to a maximum of 444 parallel tasks. We have performed several tests of 2 simulation years duration each to conclude on the optimum model setting in terms of SBU and runtime, with the model in coupled configuration (ocean-atmosphere-LPJ-GUESS). Based on the optimized outcome we estimate that the configuration uses about 26000 SBU per simulation year. With the total number of years to be run, the total estimate will be of 37 million SBU.

All data for the project will be stored on the original grid and in NetCDF4 format (CF compliant). A total of 5 3-Dimensional (3D) and 24 2-Dimensional (2D) variables will be saved for the atmosphere and likewise about 24 2D variables for LPJ-GUESS. The time frequency of the outputs spans from 3-hourly data to daily and monthly averages, depending on the variable considered. A realistic estimate of the storage for one year of simulation gives a total of 85 GB of data to be stored. The data afterwards will be cmorized. Therefore, the overall data storage capacity required for the project amounts to 30TB. Right after the end of the data cmorization all data will be quickly transferred to the storage capacity that is available for the LAMACLIMA consortium, so we can quickly free the ECMWF storage system after the end of each simulation run.

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