REQUEST FOR A SPECIAL PROJECT 2023–2025

MEMBER STATE: Sweden

Principal Investigator[1]: Wilhelm May

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Sweden

Other researchers:

Project Title: The role of forest management and land-use changes for anthropogenic climate forcing

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** SEMAY_____	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2023	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2023-2025: (To make changes to an existing project please submit an amended version of the original form.)		**2023**	**2024**	**2025**
High Performance Computing Facility	(SBU)	2,000,000	3,000,000	4,000,000
Accumulated data storage (total archive volume)[2]	(GB)	100,000	120,000	160,000

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

Need for computer resources

The project described below incorporates numerous simulations with the LPJ-GUESS terrestrial ecosystem model as well as, in the second half of the project, simulations with the EC-Earth earth system model, which includes LPJ-GUESS to simulate the state of the terrestrial ecosystems. Given the relatively fine resolution of both LPJ-GUESS (most simulations need to cover several centuries in order to reach equilibrium) and EC-Earth, this creates a considerable demand for computing resources over, ideally, the three-year period of the project. It is worth noting that ECMWF's HPC (cca at the moment and aa during most of the project) is one of the systems, where EC-Earth is fully supported and running smoothly.

Given that I have limited experience with running LPJ-GESS off-line and no experience with the performance of EC-Earth on the ATOS system, the values of the requested SBUs are best guesses based on my experience with running EC-Earth and the offline version of the land component of EC-Earth (H-TESSEL+LPJ-GUESS) on cca. Depending on the model configuration, the costs of running EC-Earth for about 50 years on cca were up to 1,000,000 SBUs.

Purpose and aims

The purpose of the project is to assess the role that forest management and land use change play for anthropogenic climate forcing by considering both the terrestrial carbon balance that affects the atmospheric concentration of CO_2 (biogeochemical effects) and the state of the vegetation that affects albedo, roughness length and evapotranspiration (biophysical effects). This will be done by means of the LPJ-GUESS terrestrial ecosystem model and the EC-Earth earth system model, which incorporates LPJ-GUESS to simulate the terrestrial ecosystems. The specific aims are two-fold with some overlap and synergies, in accordance with two externally funded projects.

For the interdisciplinary GreenPole project ('Green forest policies - a comparative assessment of outcomes and trade-offs across Fenno-Scandinavia') funded by NordForsk the aims are to:

- Update LPJ-GUESS to improve the simulated state of the forests in Northern Europe (species distribution as well as size and age distribution),
- Develop and test specific forest management practices and land use changes in accordance with recent changes in forest policies in the Nordic countries, and
- Simulate the effects of the recent changes in forest policies in the Nordic countries on the climate forcing (carbon pools and fluxes and state of the forests).

For the OptimESM project ('Optimal high-resolution earth system models for exploring future climate changes') funded by the European Commission are to:

- Update LPJ-GUESS to improve the simulated state of the Amazon rain forest (species distribution as well as size and age distribution),
- Simulate the effects of severe drought on the state of the Amazon rainforest (carbon pools and fluxes and state of the forest) and assess the risk of reaching the tipping point of Amazon dieback, and
- Simulate the effects of changes in forest management and land use in accordance international climate policies (reforestation vs. deforestation) on the climate forcing (carbon pools and fluxes and state of the forest).

Project description

Background

In order to avoid dangerous climate change, the Paris Agreement aims at limiting global climate warming to 1.5 °C compared to pre-industrial times and not exceeding 2 °C. To achieve this, the current anthropogenic emissions of greenhouse gases need to be considerably reduced.

In Northern Europe, in particular Sweden and Finland, with its vast forests and its important forestry sectors, forests and forestry are expected to substantially contribute to the national climate mitigation efforts. On one hand, forests act as a sink of carbon, on the other wood products are increasingly used in various sectors to replace fossil fuels, i.e. as construction material, as biomass for electricity production and heating, or as feedstock in the chemical and petrochemical industry, as well as in forest industries (pulp and sawmills).

Such transitions in the use of forests and forest products are governed by national and international policies, affecting forests in different ways. Policies governing climate mitigation, for instance, might aim at more production forests to provide biomass while policies aiming at the protection of biodiversity might focus on more forests close to their natural state and more sustainable management practices. The introduction of national forest policies will effect forests and forestry through changes in land use and forest management, which, in turn, have impacts on climate via biogeochemical and biophysical effects (Bonan 2016).

The Amazon rainforest is under severe pressure because of anthropogenic land-use change (i.e. deforestation) and ongoing global warming, making the Amazon Dieback one of the proposed tipping points in the climate system. The latter involves complex positive feedback processes, where an initial tree loss (as a consequence of global warming) leads to less evapotranspiration and precipitation, longer and warmer dry seasons, more fires and further tree losses (Malhi et al. 2009). This feedback has already turned the Amazon rainforest from a carbon sink into a source (Gatti et al. 2021), further enhancing the global warming (positive feedback). Continuing deforestation will amplify the positive feedback and increase the risk for the Amazon Dieback. Reaching this tipping point would have profound effects on the climate in the region and globally (Nobre et al. 2016).

Model components

The terrestrial ecosystem model LPJ-GUESS simulates the state of the natural and managed vegetation (Smith et al. 2001, 2014). The model is a second-generation dynamic vegetation model that explicitly represents the size and age structure properties and temporal dynamics of woody vegetation stands. It captures landscape heterogeneity in terrestrial vegetation properties resulting from land use (crops and pasture) and stochastic disturbances such as wind storms and wildfires. In addition to broad classes of trees, the model is able to represent specific tree species (Hickler et al. 2012). LPJ-GUESS incorporates anthropogenic land-use and land-cover changes (Lindeskog et al. 2013) and detailed presentations of forest management (Lindeskog et al. 2021). In the project, the most recent version 4.1 will be used.

The earth system model EC-Earth combines the ECMWF IFS global atmospheric general circulation model with the NEMO global ocean circulation model and the LIM dynamical sea-ice model and the LPJ-GUESS terrestrial ecosystem model (Döscher et al. 2022). EC-Earth (version 3) has extensively contributed to the Coupled Model Intercomparison Project Phase 6 (CMIP6). For the OptimESM project, the version of EC-Earth used for CMIP6 will be updated in various aspects, including the shift to version 4.1 of JPJ-GUESS.

Northern Europe

In the GreenPole project, the LPJ-GUESS terrestrial ecosystem model will be used to simulate the effects of changes in forest policies in the Nordic countries on the state of forest in Northern Europe and the ecosystem services provided by these forests. The focus will be on two aspects, namely the role of the forest for climate mitigation (carbon sequestration and wood for construction and bioenergy) and for biodiversity (bird habitats).

For one of the Nordic countries, Sweden, we have access to the detailed data from the National Forest Inventories, which will enable us to thoroughly evaluate the simulation of the state of the forests (i.e. the species distribution as well as size and age distribution) in Sweden and update LPJ-GUESS to improve the simulation of these aspects. These updates are valid for Finland and Norway that cover the same climate zones and to some extent to Denmark, with a similar climate as southernmost Sweden. This phase requires numerous simulations with LPJ-GUESS covering Sweden in order to test revisions of LPJ-GUESS.

The updated version of LPJ-GUESS will then be applied to four Nordic countries (Sweden, Finland, Norway and Denmark) to assess the effects of selected recent national forest policy changes in these countries. To do so, the national forest policies need to be ‘implemented’ as changes in land use or changes in forest management, which both are included in LPJ-GUESS. This preparation stage will also require various simulations to develop and test the appropriate changes in forest management and land use. In the next ‘production’ stage the effects of the selected and resolved changes in forest management will be assessed four the four Nordic countries, requiring more simulations with LPG-GUESS. Estimates of the effects on carbon pools and fluxes in forest ecosystems and on the species distribution as well as on the size and age distribution

of the trees provide essential input for other activities in the GeenPole project, such as life-cycle-assessments of wood products or bioenergy or modelling the diversity of forest birds.

Amazon rainforest

Although having a quite different focus, the project work related to forests and forestry in Northern Europe, is relevant for the work on the Amazon rainforest, which is addressed in the OptimESM project. That is, on one hand, the methodology of both evaluating the forest composition and characteristics against forest inventories and of developing and applying forest management and land use in accordance with forest policies. On the other hand, the insights gained during the work on Northern Europe will be valuable for the work on the Amazon rainforest.

In support for the OptimESM project, on one hand, the LPJ-GUESS terrestrial ecosystem model be used to simulate, on one hand, the effects of changes in land use and forest management on the climate forcing. On the other hand, the EC-Earth earth system model will be applied to estimate the biophysical effects of the changes in vegetation as simulated by LPJ-GUESS on regional and global climate on the other.

To begin with, simulations with LPJ-GUESS for the Amazon rainforest will be evaluated against the data available from forest inventories, and the model will be improved where relevant. In addition, we will use the ecosystem model to investigate the effects of severe drought on the Amazon rainforest and estimate the risk of an Amazon dieback under future climate change, i.e. due to prolonged severe drought conditions. To do so, several simulations forced with climate conditions from future scenarios or idealized climate scenarios need to be performed.

LPJ-GUESS will then be applied to assess the effects of changes in land use and forest management by prescribing land-use changes associated with specific goals for reforestation, namely the effects on carbon pools and fluxes and on the characteristics of vegetation. The latter will be used as forcing for EC-Earth to simulate the biophysical effects of the vegetation changes in the Amazon region on regional and global climate.

List of simulations

Given the open character of the two research projects, it is at this stage not possible to provide a list of simulations with LPH-GUESS or EC-Earth with the corresponding numbers for the computing resources needed. The simulations with EC-Earth, which are the most demanding, will be performed in the second half of the project (mid-2024 to the end of 2025).

Benefits from the project

In addition to its scientific values for the two associated research projects, the proposed project supports the development and improvement of the LPJ-GUESS terrestrial ecosystem model with a special focus on the role of forests (in Northern Europe and in the Amazon region) and the effects of forest management and land use changes on the state of these forests. These effects result in a climate forcing via biogeochemical (carbon fluxes) and biophysical effects (albedo, evapotranspiration and roughness length) and, thus, affect regional and global climate. These developments and improvements of LPJ-GUESS will also feed into the development of the next generation (version 4) of the EC-Earth earth system model, which builds on ECMWF's OpenIFS system.

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