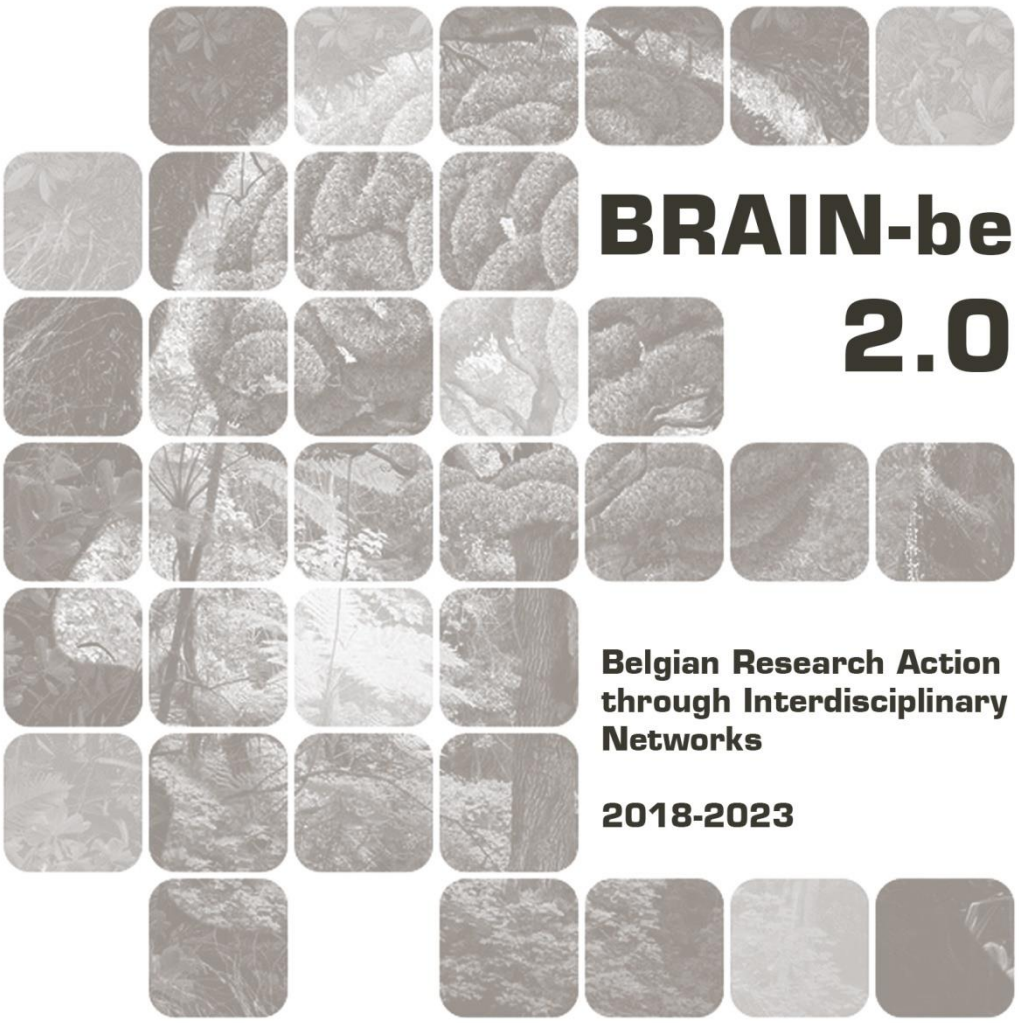

LAMACLIMA

LAnd MAnagement for CLImate Mitigation and Adaptation

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Pillar 1: Challenges and knowledge of the living and non-living world

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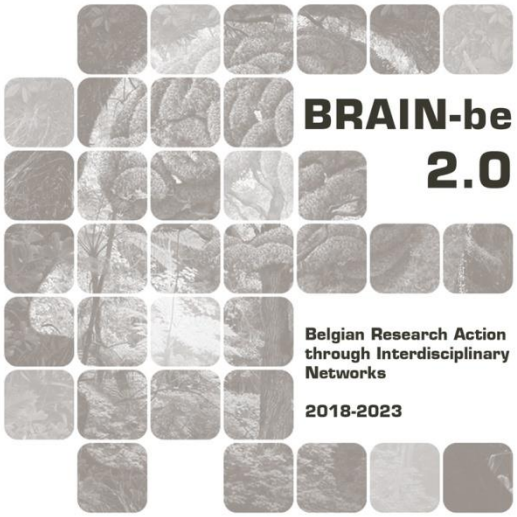

NETWORK PROJECT

LAMACLIMA

LAnd MAnagement for CLImate Mitigation and Adaptation

Contract - B2/181/P1

FINAL REPORT

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ABSTRACT

The LAMACLIMA project was initiated with the primary goal of deepening our understanding of the intricate relationship between land-use practices and climate dynamics, with a specific focus on supporting the objectives outlined in the Paris Agreement and broader sustainability endeavours. This endeavour necessitated a collaborative effort spanning multiple disciplines, including climate science, economics, modelling, and stakeholder engagement. Through the integration of various expertise, the project aimed to unravel the complex impacts of land cover and management changes on critical climate variables such as water availability and carbon storage. Central to the project were Earth System Model experiments, which simulated the consequences of large-scale deployment of key land cover and management options, such as afforestation and irrigation, on both local and non-local climate dynamics. Complementing these simulations, statistical emulators were developed to facilitate efficient exploration of the repercussions of different land-use pathways on both climate and economic variables. A cornerstone of the project was continuous engagement with stakeholders, achieved through avenues like webinars and workshops, fostering meaningful dialogue between scientists and those directly impacted by the research. Additionally, scenario co-development efforts were undertaken to craft new narratives for future land cover and management strategies, extending the existing Shared Socio-economic Pathways. The project yielded significant insights, revealing profound impacts on global water and carbon cycles, as well as on factors like labour productivity and food security. These findings underscored the importance of considering biogeophysical effects in land-use planning and policy formulation. Technical advancements in models like MAgPIE and GRACE were instrumental in better representing land-use options and their economic ramifications, including adaptation measures and associated costs.

Keywords

Land use, modelling, adaptation, mitigation, land based solutions

1. INTRODUCTION

This report summarises the main outcomes of the project. It highlights the used methodology such as Earth System and economic modelling as well as the outcomes and implications those have on future land use policy related to climate mitigation and adaptation. At the end of the report a list of finalised and ongoing publications is included.

2. STATE OF THE ART AND OBJECTIVES

The objective of the LAMACLIMA project was to advance the scientific and public understanding of the coupled effects between land-use and climate and to help elaborate pathways for future global land use featuring land-based adaptation and mitigation measures allowing to reach the objectives of the Paris Agreement and broader sustainability objectives. This relied on an interdisciplinary collaboration between climate scientists from various sub-fields, namely climate economists, landuse modellers, Earth System modellers, as well as experts in statistical methods and stakeholder engagement. Research activities aimed to uncover the climate effects of changes in Land Cover and Land Management (LCLM) as well as on other biophysical and biogeochemical variables such as water availability, heat stress or carbon stored in the vegetation or the soil with idealised Earth System Model experiments. The integration of these results into land-use allocation and economic models then allowed the assessment of resulting sectoral impact such as on labour productivity and food security. A statistical emulator for these LCLM impacts on biophysical and economic variables was also developed to allow computationally efficient and flexible exploration of the local climate and economic consequences of any LCLM pathway. A continuous stakeholder engagement and knowledge brokerage process was conducted via webinars or dedicated workshops to bridge the knowledge gap between scientists and stakeholders on the issues investigated in the project. The project also included a scenario co-development process, which gathered stakeholders and modellers to design new scenario narratives for LCLM extending the Shared Socio-economic Pathways (SSPs). The land-use trajectories and emissions corresponding to these narratives were then modelled using a land-use allocation model, and subsequently served as input data for another round of Earth System Model experiments. These have eventually allowed investigation of the potentials of these contrasting narratives to achieve the objectives of the Paris Agreement and the Sustainable Development Goals (SDGs).

3. METHODOLOGY AND SCIENTIFIC RESULTS AND RECOMMENDATIONS

In WP1, a common experimental protocol was designed by LMU, VUB, VU and CA to quantify the effect of large-scale deployment of three key LCLM options (re/afforestation, irrigation, wood harvest) on climate and the carbon cycle in Earth System Models, and specifically aiming at separating its local and non-local contributions. LMU, VUB and VU then each implemented the corresponding land cover maps and ran simulations following this protocol using their in-house Earth System Model. LMU established a general data access point with more than 400 TB storage at DKRZ to allow access to all ESM output for all partners, and developed a script to separate local and non-local signals for all variables. VUB and LMU, in collaboration with PIK, CA and CICERO, prepared ESM output for use in WP2 and WP3.

The experimental protocol is described in de Hertog et al. (2023), who also describe the results of these simulations and thereby offer the first multi-ESM comparison of the local and non-local biogeophysical effects (related to changes in albedo, evapotranspiration and other physical land surface properties) of these three options on climate. Their results show that the local effects are represented rather consistently across the 3 ESMs, and highlight that the non-local effects can be of similar magnitude than the local ones, although their representation differs more strongly across models. A few more publications describing the results of these experiments have been prepared and are either focusing on the impacts on the global water cycle (de Hertog et al., preprint), or on the global carbon cycle (Guo et al, in prep.).

The work in WP2 started with some technical development in the land-use allocation model MAgPIE and the Computable General Equilibrium Model GRACE. CICERO modified the core version of GRACE to incorporate irrigated and rainfed growing methods and depict land heterogeneity and conversion costs of land allocation, as well as to better depict structural change in economies. These modifications now allow to better represent adaptation options and transaction costs in the agriculture sector as well as to conduct long-term model runs (i.e., SSP-RCP scenarios). PIK implemented a forestry sector in MAgPIE so that it can represent the LCLM option ‘wood harvest’, while PIK and CICERO developed a concept to split production cost in MAgPIE into labour and capital costs, to be able to assess the impact of climate change on labour productivity and their relief potential by LCLM adaptation options based on WP1 data.

By including a method to endogeneously account for the economic impacts brought by the biogeophysical effects of afforestation on temperature in their land-use allocation model MAgPIE, a team lead by PIK was able to assess quantitatively that this would provide incentives for more afforestation in the future, especially in the tropics (Windisch et al. 2022). This work also directly addressed one of the objectives of WP4, namely the analysis of the characteristics of global land-use in an alternative SSP derived by including LCLM-induced climate changes in socioeconomic optimisation (D4.1-1).

Using the macro-economic model GRACE, Orlov et al. (2021) concluded that the future global GDP response to heat stress impacts from global warming on worker productivity in the agriculture sector is comparable in magnitude to that expected from changes in crop yields. This work led by CICERO was extended by further investigating the potential consequences of large-scale deployment of LCLM as implemented in the ESM simulations run by LMU, VUB and VU on heat stress around the world, as

well as resulting impacts on labour productivity (Orlov et al. 2023a). The magnitude of the impacts they quantified renders these aspects worth of consideration by land-use planners and other relevant policymakers in the agriculture sector, although the findings also show that the spread in the climate impacts simulated by the ESMs prevent from finely quantifying these effects. The importance to account for such aspects and the need for future research to be better able to quantify them, as well as in general the impacts of LCLM changes on health, is detailed in a follow-up Perspectives paper (Orlov et al., 2023b).

In WP3, CA used the simulation output generated by LMU, VUB and VU to build a statistical model able to emulate the relationships between changes in local tree cover and surface temperature in the ESMs that generated that output. This lightweight tool called TIMBER offers the potential to explore changes in monthly temperature for any type of future tree cover changes around the globe as they would be simulated by those ESMs, but in a much more computationally-efficient manner (within minutes on a laptop, versus weeks on a high-performance cluster). This work conducted by Nath et al. (2023) complements the development of MESMER-M, an ESM emulator that was developed as part of LAMACLIMA and that generates projections of monthly temperature changes as they would be simulated by ESMs, for any greenhouse gas emission scenario (Nath et al. 2022, led by CA together with ETH).

Some work also started at CA during the project lifetime to extend the TIMBER framework and be able to emulate the relationships between irrigation deployment and changes in surface temperature in the ESMs that were used to run the WP1 simulations. Some more work was also conducted at CA to develop an additional module for MESMER that would be able to statistically emulate the local changes in wet-bulb globe temperature and resulting changes in labour productivity in response to a given greenhouse gas emission trajectory. Both of these workstreams have advanced well and CA plans to write publications on those in the coming months.

CA also led the stakeholder engagement activities conducted within LAMACLIMA. Beyond communication and dissemination activities (detailed in section 7), a scenario co-development effort was conducted so that scientists from the consortium and land-use stakeholders co-design new scenario narratives for future LCLM extending the Shared Socio-economic Pathways (SSPs). Stakeholders were identified based on a mapping of potentially relevant contacts and interest expressed in previous activities, then input was provided by consortium scientists during dedicated webinars, before a 2-day workshop (10 hours in total) organised and moderated by CA enabled to outline narratives of interest to the stakeholders that could be later on implemented in the MAgPIE model and the ESMs used in the project.

The global land-use trajectories arising from these narratives were in turn modelled by PIK using MAgPIE as part of WP4. Their results described in Humpenöder et al. (2022) highlight that the two codeveloped narratives (Global Inequality vs. Global Sustainability) would lead to very different trajectories for the AFOLU sector especially in the Global South (deforestation is increased in Global Inequality, but halted in Global Sustainability), but with global implications as the latter scenario would bring the land sector in line with what is required according to the IPCC to meet the objectives of the Paris Agreement, while the former would not.

LMU, VUB and VU in turn implemented these modelled trajectories in their respective ESMs to simulate the local consequences of these two scenarios for climate, as well as heat stress and resulting

impacts on labour productivity and mortality. Their results are being presented in two scientific publications (Havermann et al. and de Hertog, Orlov et al., both in preparation).

4. DISSEMINATION AND VALORISATION

General

● General stakeholder outreach for participation in webinars and workshops: Through a screening and mapping of the network of LAMACLIMA consortium partners and members, that of Climate Analytics obtained via previous stakeholder engagement activities, and a targeted Google search for experts in related areas, the Climate Analytics stakeholder engagement team reached a group of approximately 400 stakeholders for its public webinar series (May-June 2020), and 22 key stakeholders for further engagement via stakeholder webinars (February-March 2021) and a workshop (April 2021) aiming at co-designing future LCLM scenarios. This scenario co-development effort also enabled dissemination of the scientific results and the functioning of state-of-the-art models used in the project.

● The Lead Project Investigator Carl-Friedrich Schleussner as well as the WP1 and WP3 leaders Wim Thiery and Quentin Lejeune attended the JPI AXIS Project Launch Meeting in Brussels on November 5-6, 2019, where they exchanged with representatives from the funding agencies and from other projects funded by JPI-AXIS. Several consortium partners also attended the JPI-AXIS mid-term event, while Carl-Friedrich Schleussner and Quentin Lejeune also attended the final JPI-AXIS event in person in Dublin.

● The lead-PI Carl-Friedrich Schleussner has presented core LAMACLIMA results on the importance of sustainable land-use futures (Humpenöder et al. 2023) for achieving the SDGs and the goals of the Paris Agreement in a series of presentations and background briefings for civil society stakeholders (including NGOs), governments (including German government representatives), and the private sector (including through the Network of Greening the Financial Sector, NGFS), contributing to the further mainstreaming of the outcomes.

● The lead-PI Carl-Friedrich Schleussner has attended an IPCC Workshop on the Use of Scenarios in the Sixth Assessment Report and Subsequent Assessments in April 2023 where results of LAMACLIMA have informed the discussions on the future of land use scenarios in the IPCC.

● The lead-PI Carl-Friedrich Schleussner, as well as the SAB member Dave Lawrence, have attended a CMIP workshop on the future of ScenarioMIP to inform the design of the next generation of core climate scenarios (the successor of the AR6 SSP/RCP framework). LAMACLIMA results (Humpenöder et al. 2023) were key inputs informing the discussions on the design of a Paris and SDG compatible future sustainability scenario (see workshop report here) that explicitly considers sustainable land futures.

Public webinars

● A series of public webinars were held from May-June 2020 on the following topics: The Future of Land Cover, Land Management and Climate Change, Effects of Irrigation on Climate Change, and Forest Management and Land Cover Change under Changing Climate. All webinars were recorded, with recordings available on the Climate Analytics YouTube channel and on our project webpage. They were advertised through short videos via Twitter and Facebook, leading to a high number of sign-ups (250-400 for each webinar). 250 people eventually attended the webinars in total. After the webinar

was completed, the team published a blog article about the complex relationships between land and climate tackled in LAMACLIMA, and the potential of the project to address those.

● A final webinar was held in June 2023 to share key project findings, both with the current wider stakeholder group and toward new relevant audiences. Scenarios developed and the related methodology were key topics presented, along with topics such as emulator development. Besides dissemination, the final webinar offered opportunities to capture future research interest and input on results not yet published. The event was recorded and uploaded on YouTube to offer wider reach.

LAMACLIMA newsletter

● Following the public webinars, the WP3 team started a LAMACLIMA newsletter to give project updates to interested stakeholders. More than 460 people signed up to receive it. The first edition was distributed in July 2020 and provided updates on new results from the LAMACLIMA consortium, informed about stakeholder engagement activities, advertised the presence of LAMACLIMA partners in conferences and papers recently published by consortium partners. A total of 5 newsletters were published throughout the project duration. All newsletter editions can be viewed on the LAMACLIMA project page.

Contribution to the JPI newsletters

● LAMACLIMA has contributed to the JPI-Climate newsletters in May, September, and December of 2020 (viewable here). Some of these updates were also shared on the JPIClimate news page (viewable here).

LAMACLIMA engagement in conferences

● 2020, 2021, 2022, 2023 General Assembly of the European Geosciences Union,

● American Geoscience Union Fall Meeting 2020, 2021

● Study day on 'Belgian contributions to Earth Sciences in a Changing World', May 2022.

● Land Model & Biogeochemistry Working Group Winter Meeting (organised by NCAR), February 2022

● Aspen Global Change Institute Workshop on Linking Human and Earth System Models, July 2021

● International Environmental Modelling and Software Society, September 2020

● Gingko Workshop: "Opportunities from New Data for Vegetation Modeling", 2020,

● EPFL ML4 Earth Workshop 2020,

● ETHZ Data Science in Climate and Climate Impact Research Workshop 2020.

● Scenarios Forum 2022, IIASA, Austria

● 60th edition of the Greater Horn of Africa Conference, 2022

5. PUBLICATIONS

- Orlov, A., et al. (2021), Global Economic Responses to Heat Stress Impacts on Worker Productivity in Crop Production. Econ. Dis. Cli. Cha. 5, 367–390. https://doi.org/10.1007/s41885-021-00091-6

- Windisch et al (2022) ,Accounting for local temperature effect substantially alters afforestation patterns. Windisch et al 2022 Environ. Res. Lett. 17 024030

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- Humpenöder, F., et al (2022), Overcoming global inequality is critical for land-based mitigation in line with the Paris Agreement. Nat Commun 13, 7453. https://doi.org/10.1038/s41467-022-35114-7

- Orlov, A. et al. (2023a), Changes in Land Cover and Management Affect Heat Stress and Labor Capacity. Earth's Future, 11, e2022EF002909. https://doi.org/10.1029/2022EF002909

- Orlov A. et al (2023b), Neglected implications of land-use and land-cover changes on the climate-health nexus Environ. Res. Lett. 18 061005

- Nath, S., et al. (2023), TIMBER v0.1: a conceptual framework for emulating temperature responses to tree cover change, Geosci. Model Dev., 16, 4283–4313, https://doi.org/10.5194/gmd-16-4283-2023.

- De Hertog, S. et al. (2023), 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

- De Hertog et al., (2023), Effects of idealised land cover and land management changes on the atmospheric water cycle. de Hertog et al., EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-953

- Guo et al. (in preparation). Significant effects of land cover and land management change on unchanged remote vegetation and soil carbon pools.

- Guo et al. (in preparation). The different perspectives of land use impacts on climate and the carbon cycle.

- Havermann et al. (in preparation). Climate impact of global policy relevant land-use change transformation scenarios in a low fossil emissions warming scenario: results from ESMs and IAMs

- De Hertog, Orlov et al. (in preparation). Impacts of future land cover scenarios on heat stress, labour and human health

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