Project: **1202**
Project title: **Modelling the impact of global change on the terrestrial biosphere with LPJ-GUESS**
Principal investigator: **Matthew Forrest**
Report period: **2022-11-01 to 2023-10-31**
Maximum of 2 pages including figures. 9 pt minimum font size.

Project 1202 currently comprises three separate but synergistic subprojects (two funded projects and LPJ-GUESS contributions to ISIMIP3). Each are reported separately below, followed by a summary.

FirEUrisk

FirEUrisk is a large EU-funded consortium which aims to reduce future fire risk across Europe with a particular focus on large fires. One of the deliverables in the project is to provide maps of simulated changes in fire regimes under difference SSP scenarios and the accompanying changes to the vegetation. This was planned with LPJ-GUESS-SPITFIRE and LPJmL-SPITFIRE. However, project partners at PIK found some fundamental errors in the implementations of the Rothermel equations at the heart of SPITFIRE affecting both the LPJmL-SPITFIRE and LPJ-GUESS-SPITFIRE implementations (Oberhagemann, Forrest et al. *in prep*). To work around new approach was taken whereby the PIK group would attempt to fix the SPITFIRE implementation in LPJmL-SPITFIRE (high risk strategy), PI M Forrest would develop an alternative burnt area model to implement in LPJ-mL-SPITFIRE (fall back option circumventing the use of the Rothermel equations entirely) and the Senckenberg post-doc employed on FirEUrisk (J Hetzer) would produce maps of the Canadian Fire Weather Index to quantify changes in climate-only fire-risk (independent of the vegetation model and fire models, also more robust and better understood by the target community). All three of these tasks have been completed and the deliverable currently being finalised.

Attention now turns to scientific output for peer-reviewed publication and the computational power required. Unfortunately, applying the SPITFIRE fixes to LPJ-GUESS-SPITFIRE's will not be straightforward due to the model structure (specifically the representation of litter C pools) and is not feasible in the time scale of the project. The new plan is to implement the new burnt area model, termed Burnt Area Simulator for Europe (BASE), in LPJ-GUESS. The structure of BASE is similar to the global burnt area model developed for FURNACES (see below and Fig. 1) but specifically focussed on Europe. The BASE burnt area will be used in LPJ-GUESS with fire effects from BLAZE (forming LPJ-GUESS-BASE-BLAZE). We plan still plan to test two fuel management scenarios and two planting scenarios as before. In addition to investigating the specifics of these scenarios, the default simulations will be combined with LPJ-mL simulations from PIK project partners to form a mini-ensemble giving a range of future fire and vegetation projections over Europe. We are therefore requesting compute time for a suite of LPJ-GUESS-BASE-BLAZE simulations. Note that we do not plan to use LPJ-GUESS-SIMFIRE-BLAZE as model skill of the SIMFIRE model in Europe was not deemed sufficient. Furthermore, project partners only provided land use projects for two rather than three SSP scenarios, so we reduced the ensemble accordingly. All of these changes are reflected in this year's request.

FURNACES

The key goal of FURNACES is to better include the effects of humans on fire regimes in fire-enabled dynamic global vegetation models (DGVMs), and then to simulate the impacts of fire under future scenarios. To this end we are developing a new statistical burnt area model (see Fig 1.) to replace the burnt area component of SPITFIRE (whilst maintaining the combustion and plant mortality from SPITFIRE). This also serves to side-step the recently-discovered issues mentioned above with SPITFIRE's burnt area calculation.

This model uses Human Development Index as a proxy for socio-economic factors such as agricultural practices, fire-fighting capacity, infrastructure, legislation and public awareness in line with the FURNACES goals. Model performance is similar to other recent global statistical or machine learning models (Haas *et al.* 2022, Kuhn-Régnier *et al.* 2021), with the key advantage that it is suitable for integration into a DGVM as it functions on a monthly time step and uses a GLM framework with easily transportable coefficients.

Unfortunately, the FURNACES project has been beset with personnel difficulties. Firstly, the original PI (Gitta Lasslop) left about one year into the project (M Forrest took over the PI role). Then the post-doc employed on the project did not return after maternity leave in February 2023 as was expected. Fortunately, we were able to hire a replacement starting in June 2023 to continue working on the project for the remainder of its duration. The new post-doc is responsible for the work in Fig. 1 above, which is now being finalised for inclusion into LPJ-GUESS. However, he does not have experience with C++ or process-based modelling. It therefore falls to PI M Forrest to implement, test and run this new burnt area formulation with the DGVM framework. Due to the aforementioned changes in personnel and resulting delays, and other time constraints, these simulations have not been performed and

will likely be performed early next year, so the compute resources are being re-requested. We also request resources for a complementary set LPJ-GUESS-SIMFIRE-BLAZE runs, in order to contrast with a model without emphasis on the human effects on fire.

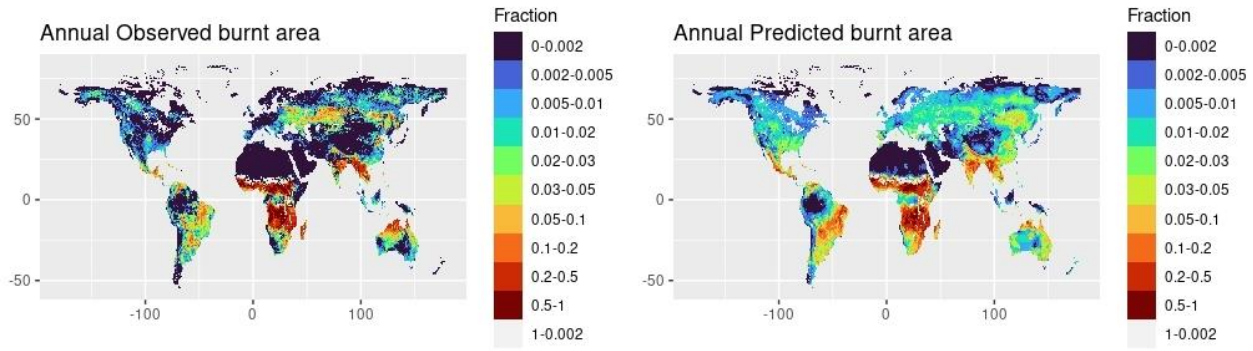

Figure 1. Mean annual burnt area (fraction of gridcell) from 2011-2020 from observation (GFED5, Chen *et al.* in review) and the new burnt area model currently under development. Model was trained on data from 2001-2010 (not shown in plot).

ISIMIP3

ISIMIP3a simulations from this project comprise two out the seven models in the ISIMIP3a ensemble analysed in a paper entitled "Global burned area increasingly explained by climate change" by Burton, Lampe, Forrest *et al.* currently undergoing revision in Nature Communications. It is expected that other papers will also use these simulations results. Uploading model output to the ISIMIP data repository (where they will receive a DOI) is underway to facilitate wider accessibility of these data.

The ISIMIP3b simulations with LPJ-GUESS have not been started. This is mostly due to the fact that the so-called "Group 3" simulations are not yet possible because the appropriate "Direct Human Forcing" (DHF) data in which human factors vary in the future is not yet available. There has been no interest in the fire or biome sectors to analyses future simulations without these varying factors included. We assume that the Group 3 DHF will be available from ISIMIP next year, so repeat the request for compute resources to do the runs then. However, we only request for LPJ-GUESS-SIMFIRE-BLAZE - we omit global SPITFIRE runs given the current problems in LPJ-GUESS-SPITFIRE described above.

Summary

Due to personnel changes, issues with the SPITFIRE model and multiple project data delays (as well as the delay to the ISIMIP3b DHF data there was also repeated problems with the climate data in the FirEUrisk project), we used very little of the allocated resources in 2023. For this we apologise. However, the need for these simulations is still valid, and some existing simulations from 2022 are making their way into publications. Furthermore, all the existing technical preparation work on Levante remains valid and much other work (such as project deliverables and model development) is done or near completion. We therefore request further compute resources (with some adjustments to take into account recent findings which reduces the overall amount significantly).

References

Haas, O., Prentice, I.C. and Harrison, S.P., 2022. Global environmental controls on wildfire burnt area, size, and intensity. Environmental Research Letters, 17(6), p.065004.

Kuhn-Régnier, A., Voulgarakis, A., Nowack, P., Forkel, M., Prentice, I.C. and Harrison, S.P., 2021. The importance of antecedent vegetation and drought conditions as global drivers of burnt area. Biogeosciences, 18(12), pp.3861-3879.

Chen, Y., Hall, J., van Wees, D., Andela, N., Hantson, S., Giglio, L., van der Werf, G.R., Morton, D.C. and Randerson, J.T., 2023. Multi-decadal trends and variability in burned area from the 5th version of the Global Fire Emissions Database (GFED5). Earth System Science Data Discussions, 2023, pp.1-52.