Biogeosciences Discussions

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Reply on RC1

Vasileios Myrgiotis et al.

Author comment on "The carbon budget of the managed grasslands of Great Britain - informed by earth observations" by Vasileios Myrgiotis et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-144-AC3, 2021

Response to general comments :

We would like to thank the reviewer for their comments. We would also like to apologise for the presence of many "?" in the submitted manuscript. These are not unresolved comments. They are certain references to the literature (and manuscript figs/tables) that the LaTex-based software, which was used to produce the manuscript, failed to print in the submitted pdf file.

This reviewer shares the concern of the other two reviewers regarding the clarity of the materials and methods section. We propose to revise the entire materials and methods section by adding new text and figs. We have attached here 2 figures that will be used to show (1) how the data and the model are used in the study and (2) a schematic of the DALEC-Grass model.

Comment 1 : It is not clear why and how the two sets of remote-sensed LAI were used in the study…

Response : The ESA sentinel-2 mission provides optical imagery every 5-10 days at high resolution (10/20/60m). This means in-field vegetation management can be inferred from satellite data and can be simulated using the inferred information. DALEC-Grass is implemented in this study on a weekly time step. This means that an estimate of standing vegetation (or a proxy of it) at the beginning and at the end of every simulated week is needed in order for the model to simulate : either (1) no vegetation removal or (2) vegetation removal via grazing or (3) vegetation removal via cutting. In places with frequent cloud coverage, such as the UK, there is no guarantee of weekly cloud-free Sentinel-2-based data; and therefore of weekly LAI and vegetation reduction estimates. Interpolating between the available Sentinel-2 data is one way to deal with gaps in the required weekly time series. We argue that in the CGLS LAI time series : (1) this interpolation is done in a robust way i.e. machine learning-based filling of no-data (cloud, haze, shadow-covered) pixels using information from past years and/or neighbouring pixels; and (2) provides information on vegetation biomass obtained from a different satellite mission (Proba-V) in addition to Sentinel-2. Also, we argue that the "predictive accuracy cost" caused by low spatial resolution (300m) of the CGLS vegetation reduction data is smaller than the respective cost of applying interpolation methods (eg linear interpolation) on the Sentinel-2 time series. This is because for many UK locations and certain key periods like spring and summer (when cutting typically takes place) there could be very few cloud-free images available from Sentinel-2.

Comment 2 : After going through the Materials and methods section, it is still not clear e.g., how the different models/frameworks were connected; how and where the EO-based data were used; how the model parameters were optimized; how the C fluxes were estimated.

Response : Our proposal to revise the materials and methods using new text and schematics will include the provision of details on these aspects.

Comment 3 : It is not clear how grazed/cut events (as a critical result of this study and an important component of the C budget) were identified, and grazed/cut biomass was simulated.

Reponse: Indeed, we do not describe this process in detail. A recent paper (https://doi.org/10.1016/j.agrformet.2021.108466), that we refer to in the manuscript (L132), presents the process but we propose to revise the manuscript by adding a paragraph that will describe how the grazing-vs-cutting inference works.

Vegetation reduction model inputs tell the model how much LAI should be removed during every simulated week. Through the model-data fusion algorithm the Sentinel-2-based LAI value at the beginning of every simulated week (before any vegetation removals) is assimilated i.e. the satellite-observed LAI should fit with the simulated LAI as closely as possible. The model decides whether to simulate each weekly vegetation reduction input as grazing or cutting based on the facts that : 1) cutting should remove at least 1.5 t.DM.ha-1 to be worth implementing in grassland farming; 2) cutting can only occur between May and October; and 3) whatever the model simulates should lead to a "good" fit with the Sentinel-2-based LAI data not only for the examined week but for the preceding and following weeks (since the entire observed LAI time series is assimilated). This mechanism of vegetation removal-type inference allows us to detect and simulate cutting by relying on observations and biophysical modelling rather than on statistical analyses of observational data alone. For this reason every predicted cutting date/intensity per simulated field has probability/uncertainty attached to it. This uncertainty reflects the lack of continuous EO-based data since neither the CGLS nor the Sentinel-2 LAI data products are frequent enough i.e obtained every 2-3 days. Our long term aim is to produce such continuous EO data as the only way to drastically reduce the uncertainty around cutting timing and intensity.

Comment 4 : The components of C budget were only very briefly mentioned. It is not clear how each component was estimated. Especially for manure, I cannot find how it was estimated (or derived from another dataset).

Response : We propose the addition of a materials and methods section (and a schematic) that will clarify all C-balance terms so that that the reader understands what each term means before reaching the results section. On the manure inputs issue, manure-C is estimated based on grazed biomass (see attached DALEC-Grass schematic). We do not simulate/consider external manure transport/addition as this cannot be inferred from EO data and doing so will require us to use spatially/temporally uncertain data on manure use e.g. national-scale estimates of manure application per ha. All the manure that is simulated as being added to the soil is produced by the simulated grazing livestock using conversion factors from the relevant literature (see attached DALEC-Grass schematic). This mechanism will be clarified in "Materials and Methods / DALEC-Grass".

Response to specific comments

Comment : How the sampling of grassland fields can result in only 1-5 simulated fields per cell? **Response** : Each cell varies in size depending on the number of simulated fields within it. Larger cells include more fields. The smallest cells in the presented cartograms include just 1 simulated field.

Comment : What are the Metropolis-Hastings (MH) method and the Simulated Annealing (SA) algorithm? What is the difference between them. **Response** : Considering this issue in the manuscript will require significant text space. We propose adding a brief description of the simulated annealing technique and removing any reference to Metropolis-Hastings since readers interested in MCMC algorithms can find details in 10.1016/j.agsy.2020.102907 (which is among our references)

Comment : How the mean C fluxes across the GB were calculated? Area weighted? If so, how? Whether the selected points are representative for all grassland grid cells? **Response** : GB-average C fluxes show the mean cumulative annual values across all simulated fields. We argue that the ~2000 simulated fields are representative as they are randomly sampled from a geo-database (UK land cover map) of grassland fields (polygons). The process used for sampling the fields (section 2.2.1) ensures that areas with large managed grassland coverage are more represented than areas with small managed grassland coverage. Strictly speaking, we would have to (1) draw a much larger sample (>10000) of fields from the geo-database, (2) examine how predicted GB-average C fluxes (e.g. GPP, NEE,NBE) change relative to the number of fields included in the calculation of the GB-average and (3) identify the best number of sampled fields. This is fasible but computationally very expensive. We argue that the comparison of MDF predictions with the census-based livestock maps and the literature-based GB-average yield data is a fair assessment of the representativeness of our sample of grassland fields.

Comment : It would be necessary to provide the maps of rough grazing, permanent and temporary grassland, and the maps of resulted management type (e.g., grazed only field or grazed + cut field), grazed, and cut biomass for users to understand the management intensity. **Response** : Such maps would have been a great validation dataset but maps of UK grasslands classified by management intensity type are not available (to our knowledge). Our methodology has the potential to produce such maps if sufficient ground data are available for validation of the MDF predictions; i.e. using predicted yields to infer if each field is rough grazing, permanent or temporary grassland..

Comment : It is strange that NEE/NBE were negatively related to both GPP and REco. **Response** : We use the micrometeorological convention in which fluxes from the biosphere to the atmosphere are positive i.e. negative NEE/NBE shows a C sink and positive NEE/NBE shows a C source. A negative relation suggests that more photosynthetically productive grasslands tend to be stronger C sinks (i.e. higher GPP -> lower NEE). REco = heterotrophic respiration + autotrophic respiration. Autotrophic respiration is ~45% of GPP and, therefore, REco and GPP have very similar correlation coefficients

Comment : As the uncertainty for LAI is nearly half of mean LAI, the robustness of the prediction should be further discussed. **Response** : This issue has been raised by reviewer CC1 as well. We propose to discuss it further in the revised manuscript and we would like to clarify, here, what our uncertainty estimates present (Fig.8). The relative confidence range (RCR) presents the uncertainty around the MDF-predicted variables (e.g. LAI) as a %. It shows how wide the 95% confidence intervals (i.e. 2 standard deviations, assuming normality) are relative to the mean value. The cartogram shows the distribution or RCR across Great Britain and the violin plots the distribution or RCR grouped according to whether grazing or cutting was the main removal method (i.e. most biomass was removed via grazing or via cutting). The assimilated LAI data come from processing Sentinel-2-based images (20m resolution) and have an uncertainty attached to them. This means that every 400m2 of a field has an uncertainty that is attributed to "instrument error" (remote sensor). This uncertainty is not always examined in the relevant literature but studies suggest a value 15%; the standard deviation around each LAI data point per 400m2 is 15% of the value which converted to RCR is 30%. We use a field-mean LAI for each simulated field which means that uncertainty is amplified when we calculate a field-average LAI. Taking this fact into account and considering that MDF predictions incorporate model parametric uncertainty a mean LAI RCR = ~40-50% is proportional to the observational uncertainty.

Please also note the supplement to this comment:
https://bg.copernicus.org/preprints/bg-2021-144/bg-2021-144-AC3-supplement.zip