

Grasslands constitute a significant portion of agricultural landscapes in Europe and store substantial amounts of carbon. Effective management of these ecosystems serves as a nature-based solution for enhancing carbon sequestration. This study presents a unique long-term dataset spanning 20 years, encompassing flux, biometeorological, and detailed management data from an eddy covariance site in a Swiss grassland. It addresses the gap in understanding the temporal dynamics and development of CO₂ drivers by employing machine learning models, as opposed to the predominantly linear models used previously.

This research contributes to a detailed understanding of the impact of various management practices on the carbon budgets of mid-latitude grasslands. The use of state-of-the-art machine learning models provides an extended understanding of non-linear and dynamic relationships between CO₂ flux and its drivers. The study is methodologically sound, with comprehensive descriptions of the eddy covariance setup, the data processing, and statistical analyses. However, some concepts require further clarification. The results are well discussed, figures are well-described and visually comprehensible.

Specific comments:

Methods & Results:

1. Line 147: the soil variables are averaged across depths - what is the reasoning behind that? Especially for the soil water content measurements were taken in very different depths, and soil water fulfill different functions in the top soil layer than in the deep soil layer, depending on how available it is to microbes or plant roots-> why not use separately and see which layer is important in which times to gain more process understanding?
2. Line 114-115: DailyN is calculated as a daily average across the regrowth period. However, not the same amount of N would be available to the plants each day, maybe in the beginning more and later less, depending also on environmental factors such as strong rain events and leaching – please elaborate in how far this has implications on your results.
3. Line 140: The gaps in flux data were filled with a random forest model. Might these confound the driver analysis that is conducted later? E.g. if gap-filling is based on other environmental variables such as Tair or VPD, of course the driver analysis shows high dependence of ecosystem fluxes on these variables. Please clarify, and if there might be confounding effects elaborate on that in the discussion.
4. Figure 4:
For the partitioning of GPP and Reco the nighttime partitioning method by Reichstein et al (2005) was used. In this method, This means, Reco is modelled depending on temperature. GPP is calculated as the difference between measured NEE and modelled Reco. Of course there will be dependencies then of the component fluxes to temperature and GPP, and their

contribution in explaining the fluxes might be partly conceptually introduced. Does it “even out” since you integrate over regrowth periods?

I would suggest to quickly test another partitioning method (e.g. hybrid partitioning method introduced by Nguyen et al (2025), code available on github) to confirm if the main drivers are the same or if the results are confounded the partitioning method.

Nguyen, N. B., Migliavacca, M., Bassiouni, M., Baldocchi, D. D., Gherardi, L. A., Green, J. K., Papale, D., Reichstein, M., Cohrs, K.-H., Cescatti, A., Nguyen, T. D., Nguyen, H. H., Nguyen, Q. M., and Keenan, T. F.: Widespread underestimation of rain-induced soil carbon emissions from global drylands, Nat. Geosci., <https://doi.org/10.1038/s41561-025-01754-9>, 2025.

Technical corrections:

Line 95: how many times per year/ in which times fertilizer is applied? Please specify. One fertilizer application per regrowth period?

Line 128: “For more detailed information on instrumentation, see ...”

Line 205: mean annual temperature and precipitation is a repetition from lines 91-92, can be removed here or just put in brackets, e.g. “mild temperate climate (9.9 °C, 1147 mm)”

Line 354-356: the two parts of the sentences are not necessarily connected, I would suggest to split it up into two sentences. First part (“Often, studies focused on natural ecosystems or
355 forests at regional and global scales (Anav et al., 2015; Cai and Prentice, 2020; Davi et al., 2006; Norby et al., 2010)”) fits better in the Introduction.

Line 380-383: please improve for more clear language: “Such observations, albeit rare, are impactful in terms of C dynamics, and underscore the necessity to include ~~such~~ these infrequent destructive management practices in long-term flux studies ~~and~~ as well as modelling frameworks.”

Line 392-393: sentence is unnecessarily long and not so well understandable, please split it up into two shorter sentences

Line 428: what do you mean with “explanatory outputs which enhanced interpretability”? It sounds a bit generic, please specify

Line 436: in line 431 you state that during extreme events “SWC strongly reduced GPP”, but later you state that “more significant negative effects of droughts on grassland CO₂ fluxes compared to those of heatwaves”. It seems a bit contradictory, maybe you can clarify this section.

Line 457-460: complicated sentence structure, please simplify or split into two sentences

Line 462: please mention briefly what precision-farming is (and please mind consistent terms – in L. 477 precision farming is written without “-”)