The referee comments are upright, and our responses are in italics.

General comments

RC2: The title of the study sets a high expectation for drought impact on grassland productivity in the pre-Alpine region of Southern Germany. This was also expressed in the stated main objective, which aims to link the modeled yield to the environmental parameters. Overall, the study seems to be lacking and does not meet the title and objective. Focus was mostly given to the model evaluation, rather than equally explaining the soil, climate, and management factors.

Response: *We thank the referee for this general observation. Our impression is that the messages about the interaction of soil, climate, and management, which are given in Sec. 3.5 and Sec. 3.4, are too hidden between more detailed parts of the study, like method description, model validation, and regional evaluation. We are therefore planning to extend the discussion by better linking soil organic carbon and nitrogen dynamics, as well as plant available water in respect to drought and their influence on grassland yields. We will also deepen the results and discussion on individual numbers of cuts and years, like in Fig. 10 for soil organic carbon and elevation.*

RC2: The study also needs to further justify the use of LandscapeDNDC. Are there existing similar and related models that can provide the same outputs?

Response: *As a biogeochemical model, LandscapeDNDC simulates not only grassland yields but also nitrogen, carbon, and water fluxes. In contrast to a crop model, the detailed description of soil processes allows the representation of drought effects on nitrogen turnover and plant nitrogen uptake and hence on productivity. Additionally, nitrous oxide emissions and nitrate leaching are included in the paper (compare Fig. A4 and A5). In a revised version of the manuscript, we will strengthen the discussion of drought effects on nitrogen fluxes. There are other models, like daycent, which can provide similar outputs (compare dos Reis Martins et al., 2024). We still believe that LandscapeDNDC is the best model for this study, since it is calibrated on the lysimeter data within the study region. We will add a couple of sentences regarding the justification of the use of LandscapeDNDC in the revised manuscript.*

RC2: Similarly, the study can further give highlights to the Sentinel-2 extracted cutting dates. How is this better than using SAR-based, or SAR-and-MSI extraction methods for cutting dates? The ability to generate the grassland management information for a large-scale study is indeed significant.

Response: *We thank the referee for the question. It was partly answered in Reinermann et al., 2022, where it was found that the additional inclusion of SAR (Sentinel-1) does not improve the detection of cutting events. Please note, that the cutting data was not* *generated in this study, which is why we do not want to include too many details on the methods.*

Specific comments

RC2: In relation again to the title, the study could have quantified the drought events with indices such as SPIE or SPI. For instance, the opportunity to provide more information about drought can allow for a better visualization of the impacts in 2018. How does the study define drought? Is it simple related to temperature? Drought is a continuous phenomenon that ignores a defined border of years. Certain drought events may start in year 1, and end in year 2. Instead of annual assessment, would a seasonal assessment provide more realistic results? Such is the argument with the increased spatial resolution. Simply identifying 2018 as a drought year limits the degree of comparison with 2019, and 2020.

Response: *We thank the referee for the suggestion to employ drought indices. We agree that our analysis of the drought severity in 2018 was rather superficial and we are very motivated to improve this in a revised manuscript. We are planning to determine drought indices (SPI, SPIE, or similar) per field and clearly define drought in a more quantitative manner. This framework will be used to extract the periods and areas of drought, which can then be contrasted to the non-drought periods. We will also include the drought indices in the correlation analysis. We hope that this approach will pin-down more clearly, which effects stem from drought and how soil (carbon, nitrogen, water dynamics), management, and climate factors influence yields under drought.*

RC2: The study has the potential to show the influence of various factors and the importance of incorporating grassland management when determining drought impact. It should maximize the available data and add information. For example, the time of cuts can also be determined. The harvest of biomass in grasslands is related to the optimum growth of the vegetation, the time of harvest may reflect adaptive practices (management) by farmers.

Response *: *The referee suggests to relate the time of cuts with drought and yields. We looked into this already and tried to elaborate if the trends in yield increase with day of cut differ between the years, which is shown in Fig. 1 and 2 for 3 and 5 cuts. We did not find convincing trends. The only clear feature was an increased number of cuts in 2018 compared to the other years (Sec. 2.3.2). We will pick up on these analyses after determining the drought indices, since their inclusion might lead to more conclusive results. For instance, by only contrasting fields under drought conditions to the ones not suffering from drought.*

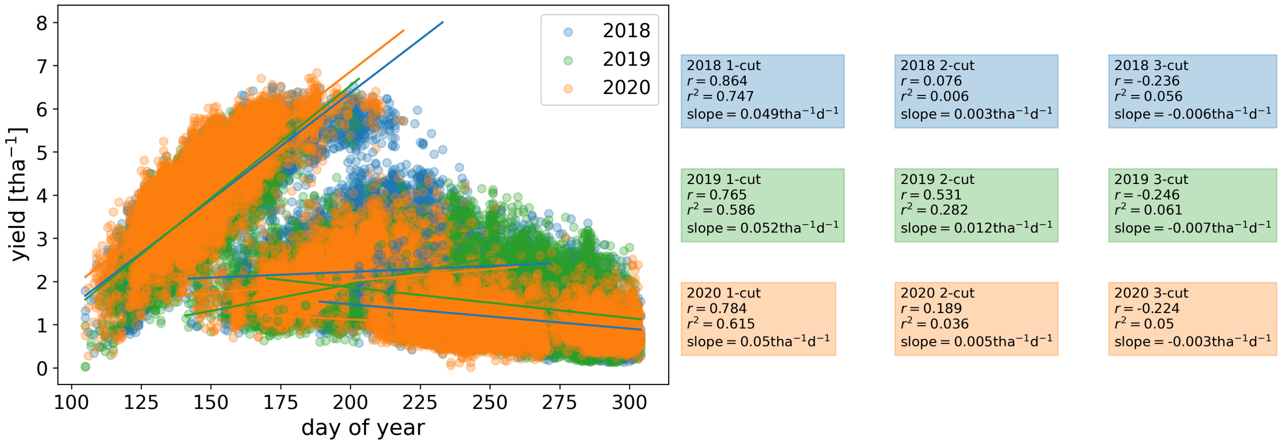

Figure 1: For all field-year pairs with 3 cuts in the year, the harvested dry weight biomass of individual cutting events is plotted against the day of the year of the cut. The years 2018, 2019, and 2020 are shown in different colors. On the right hand side of the plot, the Pearson correlation coefficients, coefficients of determination, and the slope of the regression are given.

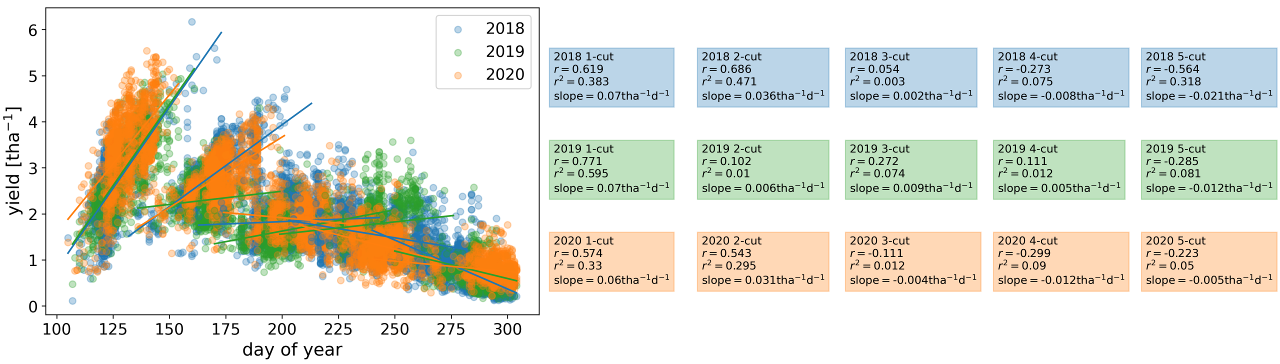

Figure 2: Same as Fig. 1 but for all field-year pairs with 5 cutting events.

RC2: The environmental factors and results can be summarized in table forms. These can show what were all the considered factors, sources, and resolution.

Response: *We will add such a summarizing table.*

Technical corrections and minor comments

RC2: These are some observed writing concerns.

RC2: Line 37 missing sentence or phrase. Or the need to remove of parenthesis for in-text citations that are part of the sentence.

Response: *We will reformulate the sentence to: "As additional ecosystem services, especially extensively used grasslands support biodiversity (Wilson et al., 2012; Väre et al., 2003) and permanent grasslands support water retention and reduce erosion (White, 2000; Bengtsson et al., 2019)." to clarify the references.*

RC2: Line 54 Missing year of cited study by De Boeck et al.

Response: *The year 2016 will be added.*

RC2: Line 55 Consistency with the use of space between values and units of measurement. Some lack space, others have space.

Response: *We will add spaces.*

RC2: Line 93 For the n=28202; how high is the spatial resolution as compared to other European scale studies?

Response: *As a comparison, in Carozzi et al., 2022 European grassland simulations were performed on a 0.25° grid relating to squared cells of 772 km^2. The Ammer catchment has a total area of approximately 4600 km^2 for which we performed 28202 simulations on field-scale ranging up to 0.5 km^2 as a maximum with a mean simulation domain size of 0.02 km^2 (2 ha). We thank the referee for the question and will include the comparison in a revised version of the manuscript.*

RC2: Line 175 The table tile on top of the table.

Response: *All table captions will be shifted to the top of the table.*

RC2: Line 238 missing word or phrase

Response: *The sentence will be corrected to: "These values are multiplied by the amount of rainfall at days of precipitation and nitrogen loads are added to the first soil layer."*

RC2: Line 330 Missing figure number

Response: *Figure number 4 will be added.*

RC2: Line 346 In-text citation before the presentation of the figure

Response: *The sentence will be restructured to: "In Fig. 5, the monthly mean temperatures (a) and sums of precipitation (b) averaged over all fields are shown."*

RC2: Consistency, for some parts the corresponding letters were written before the data (Line 317); while for others these were written after (Line 343)

Response: *Thank you for noticing. We will always mention the letters after the data in the revised manuscript.*

RC2: Line 320 Why were hexagons used? What are the unit of the other input values? For instance, Sentinel 2 pixels are in squares.

Response: *We chose hexagons as the unit of aggregation, since in a hexagon the distances from the edges to the center are more similar than in a square and the variation of data to be aggregated can be expected to be smaller (for instance, lower climatic gradients per aggregation unit). In other words, a hexagon is more similar to a circle than a square, but still space-filling. For further explanations, see Birch et al., 2007. Model inputs were given as follows: climate data 500x500 m grid of virtual stations, field scale* *cutting dates (aggregated beforehand from 10 m resolution, Reinermann et al. 2022 and 2023), soil data was provided at varying polygon sizes (from sub-field to larger-field).*

RC2: Line 374 The decreasing trend in mean yield in 2018 may also be related to the optimal vegetation growth. The timing of cuts might be relevant.

Response: *see answer marked with * above*

RC2: Line 436 It is believed that the basic statistical assumptions were tested. Maybe results can be provided as supplementary material or appendix.

Response: *This is indeed true. The according p-values will be provided in the Appendix in a revised version.*

RC2: Line 440 For the multiple correlation, why was Principal Component Analysis (PCA) or its equivalent not utilized? It is better to show how all parameters were related.

Response: *We thank the referee for the suggestion of principle component analysis (PCA) as the tool for multiple correlation analysis. We believe that PCA is not beneficial here, because, on the one hand, our data set contains outliers (compare Fig. 10c) and partly discrete values (compare Fig. 10 a and b), which challenge the PCA, on the other hand, it is not straightforward to interpret the results and employ them in empirical models.*

RC2: A number of results were not included in the paper, maybe these can be included as supplementary materials or in the appendix.

Response: *We will include results for which no figures were given in the appendix of the revised version. A few of these are shown already below in Fig. 3 – Fig. 5. Additionally, we will include the regressions of all field-year pairs with 3 and 5 cuts against soil organic carbon, mean annual temperature, elevation, as well as a plot linking soil organic carbon and nitrogen content.*

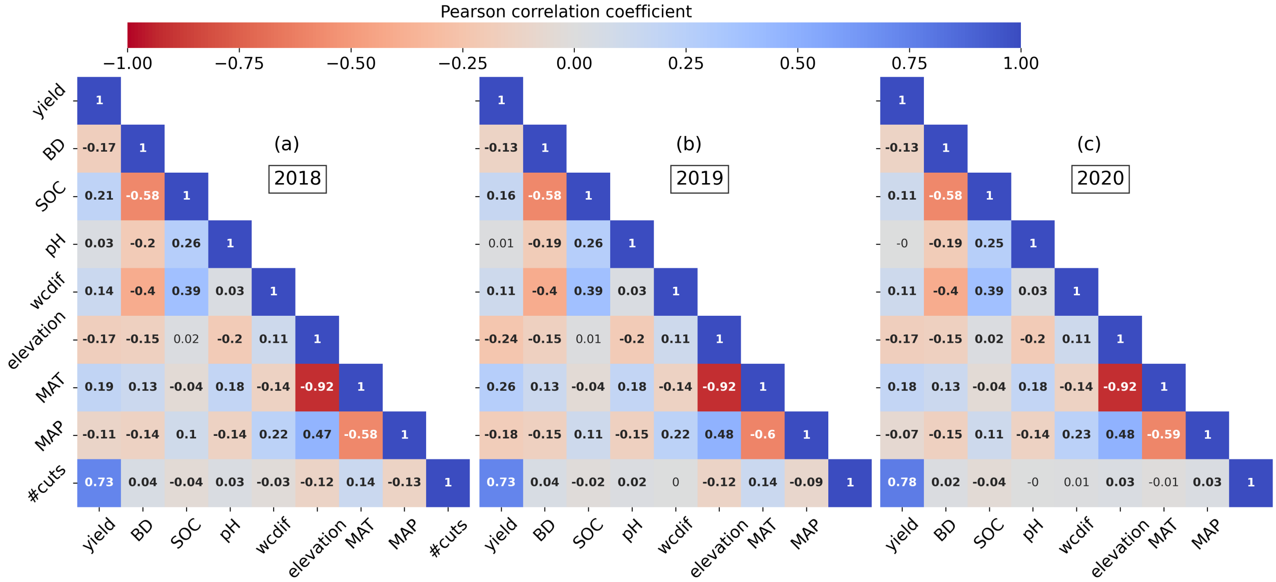

Figure 3: Correlation matrices for field data linking soil properties (BD, SOC, pH, plant available water [wcdif]), elevation, climatic parameters (MAT, MAP) averaged over 2018–2020, as well as the number of cuts in the year (#cuts) with yearly harvested biomass (yields). Coefficients written (not) in bold indicate a p-value smaller (equal or larger) 0.01. All fields in 2018 (a), 2019 (b), and 2020 (c) are included.

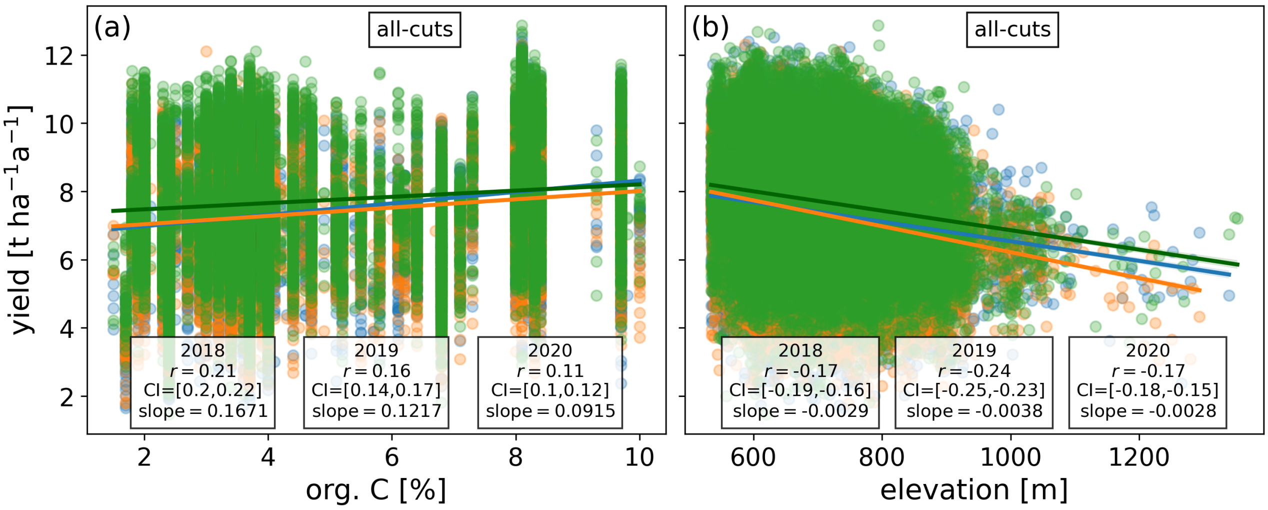

Figure 4: Yields as DWBM in individual years plotted against SOC (a) and elevation (b). Every point represents a single field-year pair. Fitted regression and associated correlation coefficients and slopes are given in the boxes for each year. All regressions are significant (p<0.0005).

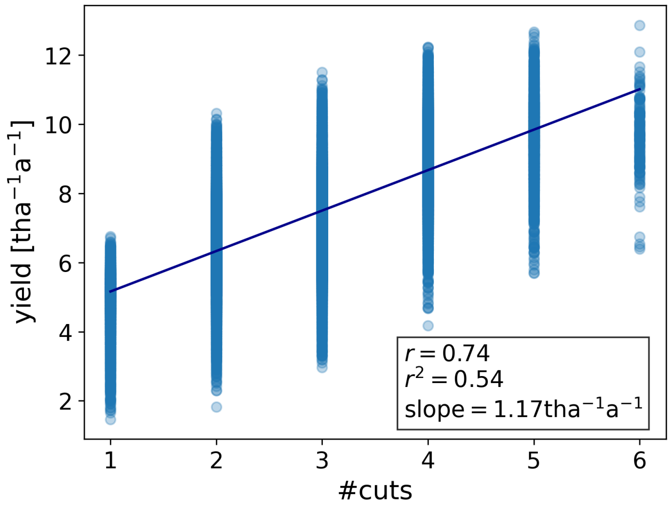

Figure 5: Annual yields of all field-year pairs are plotted against the number of cuts. Correlation coefficient, coefficient of determination, and slope are given in the box.

RC2: Line 478 I commend the possible inclusion of plant functional traits.

Response: *We are not sure about this comment, since line 478 deals with plant functional types and not traits. Regarding plant functional traits, these are covered by model species input parameters and therefore included in the simulations. If the referee suggests plant functional types, we want to point out, that there is only sparse data on plant species composition linked to other properties like management or elevation, and yields. However, this kind of data would be required to come up with regional model inputs and model validation without adding further uncertainties. We think, that future developments in remote sensing models on plant species composition may allow a regional differentiation between plant functional types. These aspects were already included in the discussion section.*

RC2: Line 580 Review the sentence, "Another reasons" – very minor

Response: *It should be: "Another reason for rather low yields in 2019 is the spatially uneven distribution of precipitation (compare Fig. 4)."*

RC2: Line 620 Use of "a" and "an" – very minor

Response: *Will be adapted.*

Mentioned references

Birch, C. P.D., Oom, S. P., and Beecham, J. A.: Rectangular and hexagonal grids used for observation, experiment, and simulation in ecology. Ecological Modelling, Vol. 206, No. 3–4., pp. 347–359, 2007.

Carozzi, M., Martin, R., Klumpp, K., and Massad, R. S.: Effects of climate change in European croplands and grasslands: productivity, greenhouse gas balance and soil carbon storage, Biogeosciences, 19, 3021–3050, https://doi.org/10.5194/bg-19-3021-2022, 2022.

dos Reis Martins, M., Ammann, C., Boos, C., Clanca, P., Kiese R., Wolf, B., Keel, S.G.: Reducing N fertilization in the framework of the European Farm to Fork strategy under global change: Impacts on yields, N2O emissions and N leaching of temperate grasslands in the Alpine region. Agricultural Systems, Vol. 219, 104036, 2024.

Reinermann, S., Gessner, U., Asam, S., Ullmann, T., Schucknecht, A., and Kuenzer, C.: Detection of Grassland Mowing Events for Germany by Combining Sentinel-1 and Sentinel-2 Time Series, Remote Sensing, 14, 1647, https://doi.org/10.3390/rs14071647, 2022.

Reinermann, S., Asam, S., Gessner, U., Ullmann, T., and Kuenzer, C.: Multi-annual grassland mowing dynamics in Germany: spatio-temporal patterns and the influence of climate, topographic and socio-political conditions, Front. Environ. Sci., 11, https://doi.org/10.3389/fenvs.2023.1040551, 2023.