RC1: 'Comment on egusphere-2024-1702', Anonymous Referee #1, 08 Jul 2024 reply

Auerswald et al. HESS

General comments:

The authors present a provocative piece that positions land and soil use processes at the landscape scale as important drivers of the climate change effects on floods and droughts. The manuscript reviews the relevant processes and makes a convincing argument. Only at the beginning is the piece set up in a way that suggests landscape factors to be more important than CO2-driven climate change effects. I'm not convinced by this framing, especially as the relevant evapotranspiration argument is not fully explained. I suggest positioning the two strands of impacts – via CO2 and via landscape factors – as complementary, and maybe the landscape processes have been overlooked. But the manuscript doesn't disentangle the two in my opinion. It would also be good to triangulate the arguments with timeseries data, specifically ET data from eddy-flux towers or lysimeters, soil sealing timeseries, soil compaction timeseries. I know especially the latter two are hard to come by, but maybe for the case study in Bavaria.

Unfortunately, we did not fully convince the reviewer that, at present, the CO_2-driven climate change is much weaker than the land-use-driven climate change because he had not found the long-term hydrological modeling in the supplement (see his second review submission). This hydrological modeling was set up by a working group of governmental hydrological authorities and the German Weather Service ("KLIWA"; www.kliwa.de) to detect climate change influences on hydrology. Now, we moved the results of this modeling from the supplement, describing the natural boundary conditions in Bavaria, to the main part of the manuscript. This also avoids the frequent reference to a figure in the supplement that we had in our original submission.

Furthermore, we now include a reference to the latest analysis of return periods of heavy rain by the German Weather Service covering 1960 to 2020, which has just appeared. This analysis applied sophisticated statistical tools to detect a CO_2-driven climate change signal (Willems, et al., 2023; Shehu, et al., 2023). However, the data until 2020 did not clearly show such a signal, and stationarity still had to be assumed (Haberlandt, et al., 2023). Thus, we conclude the section about meteorological changes by stating, "These minor changes in annual rainfall, seasonal rainfall, or event rainfall do not align with the severity of floods and droughts experienced".

In contrast to the still lacking CO_2-driven climate change signal on hydrology, the land-use-driven changes like sealing or drainage are statistically without doubt. The only clear and pronounced CO_2-driven change except the rising temperatures is the increase in rain erosivity, which was identified by some of the authors of this manuscript (Fiener et al., 2013, Auerswald et al., 2019). Rain erosivity, however, quantifies sediment detachment and transport.

We do not include data on eddy covariance measurement for two reasons. (i) Long-term measurements that could detect a climate change signal do not exist. (ii) A climate change signal would say nothing about whether it is derived from CO_2 effects or land-use effects. In fact, eddy covariance measurements are strongly influenced by land-use effects due to the large fetch. We have therefore included references to eddy covariance results in the chapter where we describe the effects of horizontal energy advect in heterogeneous landscapes.

The request for eddy covariance data points to the central message of this manuscript. Changes in hydrological behavior, such as those potentially identified by eddy covariance measurement, cannot prove CO_2-driven effects without meticulously considering all other effects as well. Premature assignments to CO_2 effects without considering other effects can be frequently found in hydrology. Still, it is not enough to show that CO_2 increases over time and that some hydrological parameters also change over time. We need clear and quantitative cause-and-effect analyses in order not to overlook important drivers.

Auerswald, K., Fischer, F. K., Winterrath, T., and Brandhuber, R.: Rain erosivity map for Germany derived from contiguous radar rain data, Hydrol. Earth Syst. Sc., 23, 1819–1832, https://doi.org/10.5194/hess-23-1819-2019, 2019.

Fiener, P., Neuhaus, P., and Botschek, J.: Long-term trends in rainfall erosivity – analysis of high resolution precipitation time series (1937–2007) from Western Germany, Agr. Forest Meteorol., 171–172, 115–123, 2013.

Haberlandt, U., Shehu, B., Thiele, L., Willems, W., Stockel, H., Deutschländer, T., Junghänel, T., and Ostermöller, J.: Methodische Untersuchungen für eine Neufassung der regionalisierten Starkregenstatistik KOSTRA-DWD [Methodological investigations for updating the regionalised extreme rainfall statistics KOSTRA-DWD], Hydrologie & Wasserbewirtschaftung 67, 138-159, 2023, https://doi.org/10.5675/HyWa_2023.3_1, 2023.

Shehu, B., Willems W., Stockel H., Thiele L.B., and Haberlandt U.; Regionalisation of rainfall depth–duration–frequency curves with different data types in Germany, Hydrol. Earth Syst. Sci., 27, 1109-1132, 2023.

Willems, W., Stockel, H., Haberlandt, U., Shehu, B., Junghänel, T., Ostermöller, J., and Deutschländer T.: Betrachtungen zur Instationarität extremer Niederschläge in Deutschland [Reflections on the instationarity of extreme rainfalls in Germany], Hydrologie & Wasserbewirtschaftung, 67, 151-159, 2023.

Specific comments:

L23: The "imbalance" suggested here needs more explanation.

We replaced imbalance by alteration.

L49-61: In this section, land use and soil use seem to be conflated. I suggest to be clear about the focus.

The paragraph, like the entire manuscript, covers both: changes in land use, like converting cropland to urban land, and in soil use, like tilling straw in or leaving it on the surface. We think that our wording is correct.

L127-129: The argument for a small effect of rising T on ET is crucial and hence needs more explanation. Maybe unpack the Penman-Monteith equation to pinpoint all the influences of T on ET and then convincingly show how these may be smaller than conventional wisdom holds.

We follow the reviewer's suggestion and include a chapter in the supplement on the Penman equation of evapotranspiration to explain why an increase in vapor pressure deficit caused by a temperature increase roughly results in a less than half as strong increase in evapotranspiration. This is, however, a very simplistic, stationary view that neglects feedback mechanisms on a global scale (e.g., decreasing wind with increasing polar temperatures). This small effect is unequivocal in the climate-change community and is the outcome of all climate projections. We had already cited three publications but added another.

Lambert, F.H., and Webb, M.J.: Dependency of global mean precipitation on surface temperature, Geophys. Res. Letters, 35, L16706, doi:10.1029/2008GL034838, 2008.

Figure 3 also misses the ET argument.

The reviewer is correct. Integrating ET into the graph is difficult because other arrows would be required. Hence, we changed the caption of the figure.

If we draw an analogous graph for ET, the effect of land use would be twofold (increasing temperature and decreasing air humidity due to unvegetated surfaces or drained, formerly wet spots). In contrast, the CO2 effect only increases the temperature.

L142-143: How to disentangle CO2-driven climate change from land use-driven climate change?

This is difficult, and it is work in this is what we want to stimulate. As long as we are not able to disentangle both drivers, it is improper to assign effects to one of both causes. This is, however, frequently done with potentially misleading results.

In some cases, disentangling is relatively easy. For example, the influence of land use on heavy rain should be minimal (but for this parameter, we still do not see significant effects; see above), while land use and CO_2-driven climate change will influence runoff and flooding. In the public discussion, flooding is presently almost exclusively associated with CO-driven climate change despite the lack of measurable effects on heavy rain. More efforts of science to disentangle both drivers are urgently needed.

We did not make a change here because the question raised by the reviewer will require many publications, and our manuscript also raises it.

L150-151: What about open water evaporation from ponding on sealed surfaces?

We modified the text. It reads now: “Except for the small amount of water left on sealed surfaces after a rain, sealed surfaces do not contribute to evaporation but partition their radiant energy uptake almost exclusively into sensible heat.”

Some of the reference in section 3.1 are also quite old. Do recent studies confirm these findings?

We deleted Oke (1989), which we had put in to honor the pioneering work of Oke, but we keep Oke (1982), Calder (1949), Drivas and Shair (1974), and McNaughton (1976, 1978). There are no newer studies that would invalidate these old studies and justify removing them. More importantly, these old studies show that we have known the effects of energy advection in great detail for many decades but do mostly not include them in hydrological modeling or consider them in landscape planning. We had also cited newer references from 1995, 1996, 2000, 2007, 2018, 2021. We now expanded this chapter to include more recent publications. In particular, we also added references to the vast literature on eddy covariance measurement, for which the lateral effects of advection are central (called fetch in this context). And, we added the motivation to use old references.

Baldocchi, D.D. and Rao, K.S.: Intra-field variability of scalar flux densities across a transition between a desert and an irrigated potato field, Boundary-Layer Meteorol., 76, 109–136, 1995.

Grossiord, C., Buckley, T.N., Cernusak, L.A., Novick, K.A., Poulter, B., Siegwolf, R.T.W., Sperry, J.S. and McDowell, N.G.: Plant responses to rising vapor pressure deficit, New Phytol, 226, 1550-1566, https://doi.org/10.1111/nph.16485, 2020.

Klaassen, W., Van Breugel, P.B., Moors, E.J. and Nieveen, J.P.: Increased heat fluxes near a forest edge, Theor. Appl. Climatol, 72, 231–243, 2002.

Leclerc, M.Y. and Thurtell, G.W.: Footprint prediction of scalar fluxes using a Markovian analysis, Boundary-Layer Meteorol., 52, 247–258, 1990.

Panin, G., Tetzlaff, G. and Raabe, A.: Inhomogeneity of the land surface and problems in the parameterization of surface fluxes in natural conditions, Theor. Appl. Climatol., 60, 163–178, https://doi.org/10.1007/s007040050041, 1998.

Raatz, L., Bacchi, N., Pirhofer Walzl, K., Glemnitz M., Müller M.E.H., Joshi, J., and Scherber, C.: How much do we really lose?—Yield losses in the proximity of natural landscape elements in agricultural landscapes, Ecology Evolution, 9, 7838–7848, https://doi.org/10.1002/ece3.5370, 2019.

Savage, M.J., McInnes, K.J., and Heilman, J.L.: The 'footprints' of eddy correlation sensible heat flux density, and other micrometeorological measurements. South African J. Sci., 92, 137–142, 1996.

And how do the timelines of CO_2 in the atmosphere and soil sealing compare? Does a comparison support the argument of a soil sealing-driven climate change?

This comment has three independent aspects. (i) Both, CO_2 and soil sealing continuously increase. Hence they correlate closely as many other timelines do. (ii) In this specific case, there is not only a correlation but also a causal relation because more sealing means more traffic and more cement production and, in turn, more CO_2 release. (iii) In this manuscript we do not focus on the CO_2 release by sealing but on the climate effect of sealing caused by the modified allocation of radiation energy to heat and evaporation.

No change was made to the manuscript.

L244-248: What about outflow from the river to the groundwater?

Usually and initially, we have gaining rivers in Bavaria that should receive their water from the groundwater. However, due to the widespread lowering of the groundwater, loosing rivers were created. Consequently, many small rivers have disappeared while others have become perched due to colmation (clogging) of the river bed.

We added "…and caused many small rivers to disappear (Reckendörfer et al., 2013, Zerbe, 2013)"

L264-266: How does soil compaction look over time?

This is an open question because no consistent monitoring over decades exists. However, in a recent German-wide survey in an 8×8 km grid analyzing 16778 soil samples, 51% of the arable land had root restrictions caused by compaction (Schneider and Don, 2019). This value is similar to the 43% of overcompacted soils found in the Netherlands (Brus and van den Akker, 2018).

We now include reference to the work of Schneider and Don (2019) and Brus and van den Akker (2018) in the revised version of the manuscript.

Brus, D. J. and van den Akker J. J. H.: How serious a problem is subsoil compaction in the Netherlands? A survey based on probability sampling, Soil, 4, 37–45, https://doi.org/10.5194/soil-4-37-2018, 2018.

Schneider, F. and Don, A.: Root-restricting layers in German agricultural soils. Part I: extent and cause, Plant Soil, 442, 433-451 (2019), https:doi.org/10.1007/sII104-019-04185-9

L342: What is meant by "unfavourable behaviour" here?

We added "like increasing complexity, instability and exponential growth or oscillations"

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