[Reviewer comments in normal font; *Author replies in itialic*]

**General comments:**

- The net irrigation over two severely water-stressed basins (Indus and Ganges) is estimated by subtracting the satellite-based actual evapotranspiration (ET) from a baseline rainfed ET estimated through hydrological modeling. This study is a follow on to a previous study by Koch et al., 2020, with one significant enhancement of using an ensemble approach in which multiple precipitations and RS-based ET data are used to create an ensemble model simulation to estimate net irrigation and its uncertainty. The results are nicely presented and the manuscript is well-written. However, I believe the authors should distinguish between consumed irrigation by the crops (what is estimated in this study) and net irrigation water use which can be significantly higher than consumptive water use (based on irrigation efficiency). I am also concerned about replacing the observed LAI with the rainfed LAI climatology to calculate the rainfed component of ET. This can potentially lead to false baseline ET estimation by removing the irrigated crop characteristics. Details on these main concerns along with some other moderate and minor comments are provided below. Addressing all these comments I suggest the acceptance of the paper.

***Reply:*** *We thank the reviewer for their overall positive and constructive feedback to our work. We will carefully address the point related to the irrigation definition and the LAI correction.*

**Specific comments:**

- L44: There is an important distinction between the irrigation water consumed by crops and the net irrigation. ET is a measure of consumptive water use which is consumed irrigation water over the irrigated area. In many cases of flood or surface irrigation, a substantial portion of irrigation is lost to drainage (not consumed by the crops). This is especially important in your case studies where the irrigation efficiency is reported to be less than 52% on average (Simon et al., 2020). Please clearly mention in the manuscript that what is estimated here is consumed irrigation and not net irrigation. Simons, G. W. H., et al. "A novel method to quantify consumed fractions and non-consumptive use of irrigation water: Application to the Indus Basin Irrigation System of Pakistan." Agricultural Water Management 236 (2020): 106174.

***Reply:*** We agree with the reviewer, that there are multiple definitions of irrigation. *In our case, by using the term "net irrigation" we are actually referring to the part of the total irrigation that has evapotranspirated. By using an ET-based method our irrigation estimates contain both irrigation water consumed by crops (transpiration) and irrigation water evaporated from the soil and crop surface. Since we expect transpiration to dominate over evaporation from soil and water surfaces in such heavily farmed settings, we also expect that our definition of net irrigation comes very close to the reviewer's*

*definition of irrigation consumption. In our definition, we expect the net irrigation to be substantially lower than actual applied irrigation. There can be reinfiltration leading to recharge or surface drainage. We thank the reviewer for sharing the relevant reference with us which we will add to our discussion of the results.*
***Plan for revision**: We will make a clarification of our and alternative ways to define irrigation in the manuscript and discuss that the actual total irrigation is expected to be substantially higher than our net irrigation.*

- The problem with replacing LAI over irrigated agriculture with climatology LAI over rainfed areas: The only place where the crop or land cover type is incorporated in the actual ET estimation in the hydrological model is in the downscaling of ET potential using the LAI data. Here I quote from a reference study (Demirel, et al., 2018) that is cited here for this part of the methodology: "The DSF (vegetation dynamic coefficient) is parametrized using spatiotemporal LAI component accounting for the effect of characteristics that separate the actual vegetation from a reference grass. These characteristics include specific landcover, albedo and aerodynamic resistance ...," here, you are replacing the main component of crop and landcover characteristics over the irrigated area with a rainfed climatology LAI which has different characteristics (land cover, crop type, albedo, etc.). This can lead to a false baseline ET estimate and consecutively net irrigation and can be a major source of error that needs proper attention and discussion in the manuscript. Please comment on the possible impact of this replacement on the final net irrigation estimation.

***Reply:** The first reviewer stated their concern about an introduced uncertainty of our ET estimate by lowering the LAI over irrigated areas to rainfed conditions. By replacing the main component of crop and landcover characteristics over the irrigated area with a rainfed climatology LAI we will probably underestimate the rainfed ET baseline, thus potentially overestimating the net irrigation. Based on the reviewers' careful observations, we have reached the conclusion that we want to change our methodology in the manuscript, as we want to subtract rainfed ET from a managed scenario (this will result in higher ET baselines, lower net irrigation) and not subtract rainfed ET from a non-managed scenario (what we are during now).*
***Plan for revision**: We will run all the models without the LAI correction to estimate rainfed ET in a managed scenario. We expect this to decrease our net irrigation estimates. The two approaches will be briefly discussed in the discussion section of the revision.*

- L233: part of uncertainty can be attributed to the simplified model physics and the heterogeneity of land cover which is not mentioned in the manuscript. Please discuss these other sources of uncertainty in the manuscript as well.

***Reply:** Correct, the model uncertainty and land cover parameter uncertainty are not addressed/quantified in our uncertainty analysis. The first could be addressed by including alterative model codes in the ensemble and the second on by using alternative LAI datasets. We believe that the precipitation input and ET dataset are most crucial for the*

*irrigation quantification which we address in our submitted work and extending the analysis to included additional sources of uncertainty would go beyond our scope. Nevertheless, we agree with point raised and will add additional sources of uncertainty to our discussion.*
***Plan for revision:*** *Discuss that we are not doing a complete uncertainty analysis, but also emphasize that we believe that we address to dominant sources.*

- L34: there is also a more recent study on irrigation mapping using SMAP-Sentinel1 1kmsoil moisture data that can be cited here: E. Jalilvand, R. Abolafia-Rosenzweig, M. Tajrishy and N. N. Das, "Evaluation of SMAP/Sentinel 1 High-Resolution Soil Moisture Data to Detect Irrigation Over Agricultural Domain," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 10733-10747, 2021, doi: 10.1109/JSTARS.2021.3119228.

***Reply:*** *Thanks, we will take a careful look at the shared reference and it will be incorporated in the revised manuscript.*

- L44: some other disadvantages of using ET that are not mentioned here: a. Limitation of ET estimation in cloudy weather situations b. The ET is an estimation of consumptive water use not irrigation

***Reply:*** *We agree that RS-based ET can not estimate the total amount of irrigation as some of the irrigation water potentially could leave the catchment through river discharge or recharge the groundwater. What the RS-based actual ET can give us is the amount of irrigation that evaporates and transpires. We are not too concerned with clouds since we aggregate the ET data to monthly timescale, which alleviates many of issues related to cloud coverage*
***Plan for revision****: Further describe the abovementioned disadvantages of using RS-based ET in the manuscript.*

- L 62: There are many other studies on the satellite-based ET and consumptive water use estimation over the Indus and Ganges basins which can be referred to in the introduction or the discussion section of the paper.
  Karimi, P., Bastiaanssen, W. G. M., Molden, D., and Cheema, M. J. M.: Basin-wide water accounting based on remote sensing data: an application for the Indus Basin, Hydrol. Earth Syst. Sci., 17, 2473–2486, https://doi.org/10.5194/hess-17-2473-2013, 2013.
  Simons, G. W. H., et al. "A novel method to quantify consumed fractions and non-consumptive use of irrigation water: Application to the Indus Basin Irrigation System of Pakistan." Agricultural Water Management 236 (2020): 106174.
  Peña-Arancibia, Jorge L., Joel P. Stewart, and John M. Kirby. "Water balance trends in irrigated canal commands and its implications for sustainable water management in Pakistan: Evidence from 1981 to 2012." Agricultural Water Management 245 (2021): 106648.

***Reply:*** *It is very well possible that we have overlooked some key references for the Indus-Ganges basins.*
***Plan for revision****: We will do another literature check and will add relevant references to the introduction and discussion sections.*

- L113-114: a more recent Modis product version (v 061) was introduced at least a year ago (late 2020) and the research community is advised to use this product due to changes and improvements in the calibration approach. It is expected that the most recent product is used in a study that is going to be published in late 2022. It would be interesting if a test analysis were conducted using the v061 data and the differences were reported in the supplementary material.

***Reply:*** *Before we selected the three ET products (FLUXCOM, PML and NTSG) we analyzed 11 different ET products by comparing their annual and monthly variability. The suggested MODIS product version (v 061) was part of this analysis but the dataset was not included in the final ensemble because the yearly ET for the basins were half of what other products estimated. We attribute this clear shortcoming to a large amount of NO DATA during the monsoon season (cloud cover) and odd ET rates of 0 mm/day for most of the two catchments during the dry period. We tried to calibrate the hydrological model against MODIS but were unable to calibrate the model to a satisfying level, which indicates that there is a substantial inconsistencies between precipitation, potential ET and MOD16 based actual ET.*
***Plan for revision****: None.*

- L127: is there any time dimension in the optimization conducted in this study or the optimization is only done in the space domain and on one image (Snapshot)? Can you comment on how different it would be if the optimization were conducted for each pixel separately and in time and why not time series based objective function is used in your optimization?

***Reply:*** *The time dimension is part of both objective functions. MAE is calculated for each monthly timestep over the period of 2003 – 2012 and SPAEF is separated into wet and dry seasonal patterns. In this way, we believe that both the temporal and spatial performance of the model is addressed. Since the first reviewer also raised a related point, we will add a plot of the monthly MAE to the supplementary material.*
***Plan for revision:*** *We will clarify the calibration design and prepare an additional plot for the supplementary material.*

- L207: net irrigation is a misleading phrase as explained in the major comment (1).

***Reply:*** *See reply to major comment (1)*

- L290: please explain why the net irrigation precision is higher than the ensemble baseline rainfed ET.

***Reply:*** *The precision of the irrigation estimates is higher than the ET baselines because we by calibrating each hydrological model to the different ET products, are able to account for the large differences in rainfed ET.*
***Plan for revision:*** *We will try to clarify this in the manuscript.*

- L378: I assume here the Author meant RS-based actual ET by the reference ET which is again misleading as the reference ET has a different meaning in the evapotranspiration community. I suggest using different terminology.

*With reference ET we mean the ET dataset that was used as reference in the calibration, which is of course actual ET. We agree that the choice of terms can be misleading, but we have consistently used the term reference ET for the RS-based ET datasets used in calibration and for the subsequent irrigation quantification.*
***Plan for revision:*** *We will clearly define how reference ET should be understood in our study.*

- L19: 25 mm/season is the average of two basins? Please explicitly mention

***Reply:*** *Yes, the 25 mm/season is the average dry season uncertainty for both Indus and Ganges*
***Plan for revision:*** *This will be clarified.*

- L19: I think an “of” is missing after “the robustness”
- L46: Koch et al., 2020 …
- L261: 16th …

***Plan for revision:*** *Thanks, all three points will be corrected in the manuscript.*

- L265-266: this sentence is not clear to me please rephrase.

***Reply:*** *We are stating that the modelled ET baselines show the same yearly variability as the RS-based ET products they were calibrated against.*
***Plan for revision:*** *We will clarify this in the manuscript.*