Response to RC3

We thank the reviewer for the evaluation of our study. All raised points are very helpful and appreciated. Below you will find our collective responses to each part of the reviewer's comment (blue for our reply and purple for the proposed changes to the manuscript).

Summary:

This study introduces a new GGCM the ACEA which enables long-term global crop water footprint simulations with a case for maize over 1986-2016. The innovative aspect is shown in the separation between blue WF from irrigation and from shallow groundwater, rather than the historical trends simulation, given that there are already global studies available in recent two years (e.g. Chiarelli et al., 2020, https://doi.org/10.1038/s41597-020-00612-0).

Thanks for the positive reflections on our study. Time-explicit separation of green and blue crop WFs is indeed one of the main novel aspects of our study. However, we would like to emphasise the importance of historical coverage in our paper as we provide continuous timeseries of maize WFs. On the contrary, most of the available literature covers only some specific years (e.g. Chiarelli et al. (2020) only cover the period 1998-2002 and 2016) and/or provides less sophisticated estimations of green/blue CWU that exclude some crucial aspects such as the contribution of shallow groundwater, regional differences in crop phenology, and trends in harvested areas and crop yields. Our study tries to overcome these limitations, and thus provides a more comprehensive overview of global maize WFs. We will include the provided reference in the Discussion to compare our estimates to its findings.

Besides, there are some certain improvements can be made in the revision:

1. The authors mentioned many times the "accurate estimation". But there is not enough calibration or validation processes, especially for the ET simulations. It can be easily done by comparing the global remote sensing images. At least for some selected regions, to show the accuracy of the ET results (Gao et al., 2021, https://doi.org/10.1016/j.agwat.2021.107014).

   Thanks for this suggestion. However, we think that making such a comparison is not so straightforward as it may seem at first glance, since we only simulated the ET of maize during the maize growing season, whereas global remote sensing datasets typically show the ET of the current land cover in a grid cell (including also other vegetation than maize) during a full year. Nevertheless, we will try to add a comparison of our maize ET estimates to independent estimates/ observations in a revised version of the manuscript.

2. Fig. 1, the CO_2 concentration should belong to the Environmental inputs, right?

   Thanks for pointing this out. We will move CO_2 to the "environmental inputs" block.

3. In the section 2.1.3, it is highly recommended to add the details on how to separate the two components in blue WF, given it is the key innovative point.

   A brief description of this is provided in lines 112-117, but we will consider adding more details to this description.

Our model traces three water fluxes (components) within the soil profile during the whole simulation period (1984-2016): water from rainfall (green), water from irrigation (blue), and water from capillary rise (also blue). Therefore, we can calculate the precise daily composition of evapotranspired water. For example, a crop abstracts some water for transpiration on a specific day. The model checks at which soil depths this water was abstracted (depends on the rooting depth), this could be 1 mm of water from 0.3 m depth, 1 mm from 0.5 m, and 1 mm from 1 m for instance (3 mm of water in total). Because the model knows the composition of soil moisture at each of those depths, it is possible to calculate which fraction of those 3 mm of transpired water is green and which is blue. The same principle applies to soil water evaporation. At the end of the growing season, the model sums up ETs from three water components (i.e. CWU), so crop WFs can be estimated. More details can be found in Hoekstra (2019) who proposed this methodology:

- Hoekstra, A. Y.: Green-blue water accounting in a soil water balance, Advances in Water Resources, 129, 112–117, https://doi.org/10.1016/j.advwatres.2019.05.012, 2019.

4. Maybe I was wrong, I am very confused on the second equation in Eq. (4) and (6), how you can just use weight of area to multiply the unit WF to get the so-called average unit WF? Is it the right way of weighted average? Please carefully check.

   Let us first clarify the purpose of the mentioned equations. Eq. 6 is used to estimate the national scaling factors (see Eq. 5) that are used to adjust the simulated crop yields (see Eq. 3). Eq.4 is used to estimate rainfed and irrigated crop WFs in each grid cell. None of those equations has weighting by area in it.

   Now regarding the weighting. When estimating average values such as unit WF, CWU, or yields over multiple grid cells (e.g. country, region), we give more value to the cells with a larger production or larger harvested areas as explained in lines 169-170. We acknowledge that it might be difficult for a reader to understand the data processing procedures in ACEA, but we want to assure that the weighting is done properly and in accordance with the previous studies such as Mekonnen and Hoekstra (2011):

   - Mekonnen, M. M. and Hoekstra, A. Y.: The green, blue and grey water footprint of crops and derived crop products, Hydrol. Earth Syst. Sci., 15, 1577–1600, https://doi.org/10.5194/hess-15-1577-2011, 2011.

5. Line 283. What is the reason of the increased WF?

   Due to prolonged water and/or heat stresses, some rainfed areas experience years with very small accumulated biomass (and hence yields). As a result, there are relatively big fluctuations in maize yields in areas such as Kenya, Zimbabwe, Nigeria, and North-East China.

   If the yield is very small, the crop WF is very large and any fluctuations in the yield have a large effect on WF. These fluctuations can result in WF peaks of 10000 – 30000 m^3 t^{-1} y^{-1} in some cells which lead to high CV values as you can see in Fig. 9. At the same time, some areas have a decreasing trend in crop yields overall. For example, in Zimbabwe we can see both big fluctuations and decreasing crop yields (see the figure below). This leads to higher average WF values during 2012-2016 compared to 1986-1990 (i.e. maize WF increases in Fig. 6).

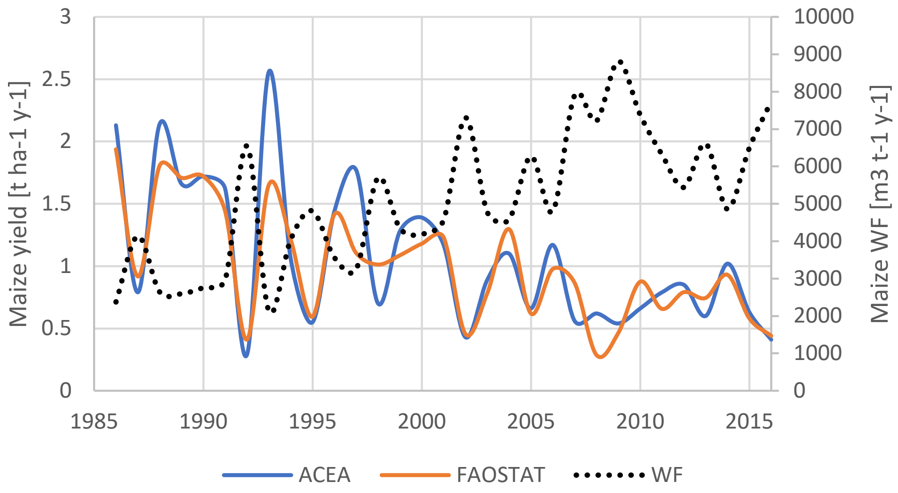

Figure: Average historical maize unit water footprint and yields (simulated in ACEA in blue, provided by FAOSTAT in orange) in Zimbabwe

Different dynamics can be observed in North Korea where maize yields have dropped dramatically since the mid-1990s (the period known as "*The North Korean famine*") and still have not recovered (FAOSTAT, 2021) resulting in higher maize WFs in 2012-2016. We will add more explanations to the manuscript in accordance with the above-mentioned text.