The authors thank the reviewer for the valuable comments and recommendations to improve our manuscript. The comments of the reviewer are in boldface, whereas our responses are in normal fonts. Italic text is quoted from the updated manuscript. Line numbers refer to the manuscript version with track changes.

Reviewer #2:

1. *Novelty*: **Several studies on irrigation water requirements today and in the future have been published since the first study by Döll et al 20 years ago. The study by Busschaert et al. (2022) would have been a welcomed addition to the literature 20 years ago, but in 2022 I am struggling to see where Busschaert et al. (2022) provides new insights in the scientific area. Several single model studies and multiple model studies have been presented, not the least coming out of ISIMIP, so what does this paper include that isn't well covered in the existing literature? My recommendation is that a more convincing presentations of why this study is needed must be included, if this paper is to be published in HESS.**

Answer: Thank you for highlighting this point. The novelty of this study has now been clarified in the following text.

L117-124:

"Compared to previous studies, the advantages are that the simulations are performed with (i) climate data from the latest generation of reanalysis and GCMs, (ii) the most recent set of future scenarios, and (iii) a crop model (AquaCrop), in which the dynamic interactions between water and vegetation are the main focus and where irrigation and management practices can be included with more detail than in a land surface or hydrological model. Future I_{net} projections could be used to inform on climate change adaptation strategies (e.g., climate-smart irrigation, crop type selection, water conservation). The new AquaCrop-ISIMIP3 model setup can be run at any spatial domain and resolution, providing future opportunities for further climate analysis, also including other irrigation practices and management options."

2. *Model setup*: **The authors have chosen to perform the study at a fairly coarse spatial resolution, and with only one crop type all over Europe. I agree with what reviewer #1 has said on the choice of crop type, and the fact that you analyze summer months only. These seems like questionable and outdated decisions.**

Answer: We understand that some elements in the applied methods were insufficiently clarified and motivated in the original submission. Therefore, we added an extra paragraph (in section 2.2) to explain and support our assumptions.

L134-155:

"Climate impact assessments are subject to large uncertainties, which increase with longer temporal projections. Therefore, several assumptions are made in this study to limit the uncertainty of other factors than climate. We will present net irrigation requirement values that are independent of the irrigated area, period, infrastructure and the exact crop type. First, simulations are performed over all pixels of the entire study domain (i.e. the main European continent), and the irrigation estimates for the entire hypothetically irrigated agricultural domain are normalized by area to make the results independent of the actual irrigated area. This avoids the need to include estimates of future hypothetical land use (Prestele at al., 2016), and the uncertain evolution of the extent of irrigated areas (Schaldach et al., 2012; Hurtt et al., 2020). Second, the spatial resolution of this study matches that of the ISIMIP input data resolution. In contrast to fine-scale agricultural studies, usually assessing actual

irrigation under historical conditions, future climate projections are dependent on the resolution of the driving climate models (or downscaled output). Such studies mainly aim at estimating the irrigation requirement that is needed for crop root uptake, thereby omitting the part of irrigation that is lost to the atmosphere, or retained on the soil surface or in the soil profile. Also, state-of-the-art global and continental-scale climate impact assessments are typically performed at the same resolution (e.g., Jägermeyr et al., 2021; Lange et al., 2020; Thiery et al., 2021). Third, each pixel is defined as a hypothetical homogeneous field, in which the vegetation conditions are identical. For future projections, the use of a representative field crop is supported by the current lack of detailed year- and location-specific crop maps, and by the unpredictability of changes and developments in crop type and distribution. Finally, the uncertainty and high spatial and temporal variability of the start and end of the growing season (King et al., 2018; Menzel and Fabian, 1999; Schadlach et al., 2012) restricts the modelling possibilities. Some previous studies (e.g., Elliott et al., 2014; Fader et al., 2016; Fischer et al., 2007; Konzmann et al., 2012) have used dynamic growing seasons, but the choice has been made to avoid this additional level of uncertainty for this study. Therefore, only the summer months are considered to make the future requirement directly comparable to the baseline I_{net}. On average, these are the months presenting the highest I_{net} (Siebert and Döll, 2010), and are expected to maintain important months for irrigation requirements, even if growing seasons might shift in the future."

For clarity, we now also express the results in mm month^{-1} (instead of mm year^{-1}), and mark that the values are computed on the summer months only.

***Evaluation – comparison to satellite observations*:**

3. **The evaluation (comparison to satellite observations) are performed at different timescales for SIM1 and SIM2, as you mention. However, if you are going to compare the comparisons, I think you must try to make them a little more comparable, e.g. by including similar comparisons for SIM1 as you have for SIM2. Also, and what really puzzles me, is that as far as I understand, for SIM1, no irrigation is included in the simulations, whereas in SIM2 it is. These simulation results are both compared to satellite estimates, and both are deemed "reasonable". Consequently, I will argue that irrigation doesn't really impact your evaluations much, is that true? What does this say about your irrigation water use and your evaluations? How does the coarse scale and your irrigated areas impact the evaluation results? In any case, I think you must do both comparisons with the same model setup.**

Answer: We agree that the description of the three types of simulations may have been unclear in the original submission. SIM1 and SIM2 are evaluation simulations and are both run without irrigation. SIM3 constitute a set of simulations intended to make I_{net} projections, and are run with irrigation turned on. The characteristics and purpose of each simulation type have now been clarified in the new Table 2 (below, replacing former Fig. 1). We hope this makes the simulation setup and assumptions clearer.

Table 2 Description of the different simulations with regard to the simulation periods, analyses, climate data, crop characteristics, soil fertility stress and the activation of the irrigation (ON/OFF).

Sim.	Period	Analysis	Climate data	Crop	Soil fertility stress (%)	Irrigation
SIM1	April 2015 - December 2016	SSM short-term evaluation	reanalysis	generic C3	30	OFF
SIM2	April 2015 - December 2020	SSM climatological evaluation	5 GCMs	generic C3	30	OFF
SIM3	1985-2014 2031-2060 2071-2100	I$_{net}$ projections	5 GCMs 5 GCMs x 3 SSPs	representative field crop	20	ON

Furthermore, the evaluation time periods have been adapted for consistency, as suggested by the reviewer. SIM2 SSM climatologies are now compared to satellite SSM climatologies for consistent time periods (i.e. from April 2015 through 2020).

About the influence of actual irrigation on the model, an analysis was performed (results are not shown in the manuscript) and discussed in the last paragraph of section 5.1. As explained, we did not find lower correlations between AquaCrop simulated SSM (run without irrigation) for pixels presenting a high percentage of area equipped for irrigation. The possible reasons for these results were explained in the original manuscript, and an reference has been added to support our findings.

L537-538:

"[...] and a recent study stressed the low potential to detect irrigation at coarse resolutions (Dari et al., 2021)."

4. **Also, for the evaluation of results using GCM input you state that you use climatology for 6-10 years, depending on the data product. I would argue that for GCMs, nether 6 nor 10 years is not enough to call it "climatology", and your results can be very much impacted of what happens in that 10-year period, and I do not think you should rule "reasonable" on the background of 6-10 years. Any thoughts?**

Answer: We understand this comment, and we agree that robust climatologies should be computed on longer time periods. However, we are limited by the availability of satellite data (SMAP SSM data is available from April 2015 onwards) for the evaluation period. For the same reason, other studies and applications (e.g., satellite data assimilation systems) are also computing climatologies on relatively short time periods. We added the following statement to support this.

L303-306:

"The computation of the climatology is restrained to the availability of reference satellite data (i.e. SMAP, data available from April 2015), as it is also the case in satellite data assimilation systems (e.g., SMAP Level 4 product; Reichle et al., 2019)."

5. **SIM1 and SIM2 are evaluated in very different ways, and I find it problematic that you still put the evaluations in the same figure and to some extent compare them in the text. Are you comparing apples and potatoes, and how can you make the evaluations and analyses more consistent?**

Answer: We agree that SIM1 and SIM2 should not be directly compared to each other. We therefore removed this comparison in the text and in the new Fig. 2 and 3 (replacing Fig. 4 and 5 from the original manuscript).

Minor issues:

***Clarifications needed*:**

6. I think you only model agricultural areas, and specifically agricultural areas that are irrigated, is that right? I can't, however, see that you refer to any dataset used to define these areas?

Answer: Since the future extent of irrigated areas is uncertain, we decided to simulate cropland across the entire domain (i.e. on every land grid cell). Irrigation estimates are normalized by grid cell area to make results independent of the actual irrigated area. Please see the answer to the comment R2#2 presenting this extra paragraph (L134-155).

7. Also, if I understand this right, you simulate the entire cells at 0.5x0.5 degrees with the C3 crop type. Do you account for this when comparing to satellite observations, or are the soil moisture estimates performed point by point without regarding how much is actually irrigated (see also above)? If you do not account for partially irrigated cells, don't you think that you overestimate soil moisture in many cells?

Answer: As mentioned in R2#6, we do not account for partially irrigated cells. For the evaluation simulations (SIM1 and SIM2), irrigation is not activated and the SSM is evaluated against satellite retrievals for all available (after screening bad quality retrievals, see section 2.4) data retrievals. Soil moisture is therefore not overestimated by AquaCrop. But it could have been underestimated in areas where irrigation is actually applied. Please see the answer to the comment R2#3 about the discussion on the impact of actual irrigation on the model performance.

8. *Evaluation*: Do you compare nearest neighbour of the satellites and simulation cells, or how is it done?

Answer: Indeed, nearest-neighbour sampling is used to compare AquaCrop simulated SSM to satellite retrievals. This is mentioned in the following sentence from the original manuscript.

L268-269:

"To compare the spatial and temporal patterns of SSM from 0.5° AquaCrop simulations with 36-km satellite data, nearest-neighbour sampling is used to spatially match simulated SSM with SMOS and SMAP retrievals."

9. *Irrigation method*: You inject water into the root system. Do you know how large part of the European irrigation is this efficient? Possibly add some thought on choice of irrigation method and how it may influence your results?

Answer: This is a very interesting suggestion. The following text has been added to reflect on this.

L590-595:

"Our study did not consider specific irrigation practices and efficiencies. The latter have been estimated around 50% in Europe (Fischer et al., 2007; Rohwer et al., 2007; Wada et al., 2013), meaning that the I_{net} values presented in this study could roughly be doubled to obtain the gross requirement. Sprinkler

irrigation remains the most widely used practice in Europe, but the share of drip irrigation is progressively increasing in southern countries such as Spain and Italy (Monaghan et al., 2013), aiming at improving irrigation efficiencies."

Discussion:

10. I miss some thoughts on your irrigation water use estimates compared to already published estimates. You write that comparisons are difficult, which I agree on, but I still think it should be included.

Answer: Thank you for this suggestion, we added a section including some comparisons (in absolute terms, and percentages).

L553-561:

"For the year 2050, Schadlach et al. (2013) estimated an average increase of 70 mm $year^{-1}$ (+15% compared to the baseline of 470 mm $year^{-1}$) of the I_{net} over the European continent under a high emission scenario. For the same scenario, Fischer et al. (2007) predicted an increase of 53 mm $year^{-1}$ (+36% compared to the baseline of 147 mm $year^{-1}$) over western Europe by 2080. These values are comparable to the results of this study, presenting a mean increase of 38 mm $year^{-1}$ (+17% compared to the baseline of 221 mm $year^{-1}$, integrated over the three summer months only) and 67 mm $year^{-1}$ (+30%) for 2050 and 2090, respectively, and for a comparable emission scenario (SSP3-7.0). Also, the evolution of I_{net} under SSP5-8.5 (+35%) can be related to the findings from Wada et al. (2013) for which increases larger than 25% are estimated over almost the entire European continent. Under this same scenario, the results show that France will face extreme increases in I_{net} (+75%) confirmed by Fader et al. (2016) (+80%)."

11. In the results part, you say you find decreases in Inet in locations along the Mediterrenean coast. To me this is surprising, and I think it deserves a sentence or two in the discussion. What are the underlying factors causing this?

Answer: This statement concerns some regions that present historical extreme evapotranspiration rates, and insignificant rainfall in the summer months. Following the AquaCrop calculation procedures, the effect of stomatal closure by 5% as response to CO2 concentrations above 550 ppm is stronger than the increase in ET for these regions (less than 5%). This has been clarified in the revised manuscript by adding the following text.

L410-413:

"Decreases in I_{net} (boxplot whiskers below 0, Fig. 4c) are only observed in a few southern coastal locations under the high and severe emission scenarios. In these historically warm and dry regions with insignificant rainfall in the summer months, the effect of stomatal closure by 5% as response to CO2 concentrations above 550 ppm is stronger than the increase in ET (less than 5%)."

12. What can these results be used for? You touch the topic slightly in the discussion, but it would be favourable if you could link your results to adaptation issues somewhat closer.

Answer: These results could be used to inform climate change adaptation strategies (e.g., climate-smart irrigation, crop type selection, water conservation). Also, the model setup itself can be run, with ISIMIP input data, to make projections at any resolution and over any study domain. This has now been clarified in the introduction. Moreover, further studies could elaborate on the impact of climate change on crop productivity, this has been added in the conclusion.

L121-124:

"Future I_{net} projections could be used to inform on climate change adaptation strategies (e.g., climate-smart irrigation, crop type selection, water conservation). The new AquaCrop-ISIMIP3 model setup can be run at any spatial domain and resolution, providing future opportunities for further climate analysis, also including other irrigation practices and management options."

L645-646:

"Our large-scale setup with AquaCrop is well suited to explore the effect of climate scenarios on crop productivity in future research."