Spatiotemporal responses in crop water footprint and benchmark under different irrigation techniques to climate change scenarios in China

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Authors' responses to Referees' comments

We appreciate very much for the opportunity to revise the study and the valuable comments and suggestions by the Editor and two Referees. We have carefully addressed all the comments and provided our detailed responses below them, responding point by point. The revised parts are colored in RED in the revised manuscript.

Editor

Comments to the author:

The manuscript has been revised by two highly qualified Reviewers. Both Reviewers consider the topic of the paper of potential interest for HESS readers and provide very detailed comments that I think will be extremely useful for the authors. Reviewer 2 also noticed that the methodologies employed in the current manuscript do not appear to be entirely novel.

If the authors decide to re-submit the manuscript to HESS, in addition to the reviewers' comments, I encourage the authors to:

- Highlight the key novel aspects of their work (in terms of monitoring or data analysis, process concepts, technology, and/or theoretical aspects).

- Revise the use of English language and grammar

Response: We are very grateful for the valuable opportunity to revise and improve the manuscript according to constructive comments and suggestions by Editor and two highly qualified Referees. We carefully address each of the comments and respond point by point.

-Specifically, in order to highlight the novel aspects of the current study, we revise the relative text in the end Introduction (Lines 101–104). "Compared to existing literatures, the innovations of the current research are embodied in two points. The present study clarifies large-scale spatiotemporal responses of WF to future climate change scenarios under different irrigation techniques for the first time. This analysis is also the first to explore large-scale changes in WF benchmarks under future climate change scenarios." Combined with revisions according to corresponding comment by Referee#1 to clarify the pros and cons of the methodology to setting WF benchmarks, we believe that the innovative aspects and unique results are clearer in the revision.

-Thank you very much for the suggestion on language editing. We asked for a third part English editing service to improve the language in the latest submission. They also helped to check the original version of the manuscript. We believe that the language issues are addressed in the revision. Please kindly find attached the editing certificate in the end of the document.

Thank you again for the chance of revision.

Referee #1

General comments

1. One could divide WFP benchmarking techniques into two methods. Method 1 compares the WFP of different producers (or grid cells) within the same region, ranks them and sets a benchmark based on some percentile. Method 2 compares the WFP at each location under different management practices and sets a benchmark based on best practices (those resulting in the smallest WF). Method 2 is for example applied in the studies by Chukalla et al. (https://doi.org/10.5194/hess-21-3507-2017 and https://doi.org/10.5194/hess-19-4877-2015). The drawback of method 1 is that no matter what spatial scope one takes in grouping producers, within that scope there will still be variability from place to place (section 4.3.2.1 in https://doi.org/10.1016/B978-0-12-822112-9.00006-0). Rainfall, for example, shows strong spatial variability over short distances, such that a few producers in a larger area simply had more favourable local circumstances. Therefore, one can always question the comparability of producers that operate in different locations and the WFPs they achieve. Method 2 overcomes this drawback. In this manuscript method 1 is applied, although different irrigation practices are simulated. What are your reasons for determining the benchmarks based on method 2? Why don't you determine the benchmarks (also) based on method 1? You seem to have the data/simulations for that.

Response: We deeply appreciate your valuable comment. Sure, we acknowledge that three are two methods of establishing WF benchmarks (Hoekstra, 2013). The reason why we chose Method 1 instead of Method 2 is that we mainly explore the responses of large-scale WFs for two grain crops to future climate changes under specific irrigation technique, that is, each irrigation technique has its corresponding WF benchmarks. If Method 2 was selected, what we concerned about was the responses of WF to future climate change under the optimal tillage plus irrigation techniques which would result in the smallest WF. It is inconsistent with the current research objectives. This is also relevant to your General comment 2. Method 2 has the higher requirements on the setting and simulation of different agricultural management practices. However, we focus on only one agricultural management practice here, i.e., irrigation. If we chose Method 2, the calibration of different agricultural management practices would be the key. The existing data cannot meet these requirements for such a large-scale study. Therefore, we choose Method 1 to determine WF benchmarks. And we also realized that the application of Method 1 does have some limitations. We add the consideration to Section 3.5 Discussion (Lines 415–433) on the choice of two WF benchmarking methods and different agricultural management practices in combination with your Specific comment 13. The content is as follows.

“Three are two methods of establishing WF benchmarks (Hoekstra, 2013). Method 1 is based on yield accumulation statistical analysis. Due to the variability of WFs found across regions and among producers within a region, for each crop, we can select the WF of 20 % or 25 % of the producers with the highest water productivity as the WF benchmark (Mekonnen and Hoekstra, 2014). Method 2 is based on the available optimal technique analysis. We can compare the WFs at each location under different agricultural management practices and take the WF associated with optimal practice, which results in the smallest WF, as the WF benchmark (Chukalla et al., 2015). Both methods establish WF benchmarks based on the maximum reasonable water consumption in each step of the product's supply chain (Hoekstra, 2014). Method 1 is suitable for large-scale application. The differences in environmental conditions (such as climate) and development conditions should be considered comprehensively (Mekonnen and Hoekstra, 2014; Zhuo et al., 2016a). The drawback of Method 1 is that no matter what spatial scope one takes in grouping producers, within that scope there will still be variability from place to place even if the differences in regional environmental and development conditions are taken into account (Schyns et al., 2022). Method 2 is suitable for smaller scale and overcomes this drawback of Method 1 to some extent. The Method 2's drawback is that it has the higher requirements on the setting and simulation of different agricultural management practices. We mainly want to explore the response of large-scale WF to future climate change under specific irrigation technique, that is, each irrigation technique has its corresponding WF benchmarks. And only one agricultural management practice, that is irrigation, is considered here. Therefore, we choose Method 1. A combination of methods should be established. If conditions permit, we strongly recommend that Method 1 and Method 2 are combined to establish small-scale WF benchmarks. Different agricultural management practices, such as irrigation, mulching techniques and so on, can be combined to further determine WF benchmarks."

2. AquaCrop provides crop parameters sets for maize and wheat which are to some degree calibrated for the conditions of recent history. How do you make sure the model produces reliable results for ET and Y under climate change scenarios?

Response: We are very sorry for our unclear expression and use of incorrect words. To some extent, we guaranteed how evapotranspiration (ET) and yield (Y) will develop in the climate change scenarios at the current production level. First, we chose the year 2013 as the baseline year, when the drought level came closest to the 15-year national average drought level over 2000–2014. Second, the simulated Y per grid for each crop in 2013 was calibrated via scaling model simulation outputs to accord with the crop yield statistics data at provincial level (NBSC, 2021), which was consistent with the widely used calibration method (Mekonnen and Hoekstra, 2011; Zhuo et al., 2016b, 2016c, 2019; Wang et al., 2019; Mialyk et al., 2022). For sure, the calibrated Y corresponded to the simulated ET. The crop parameters in the model represent the existing agricultural production level. Climate was the only variable for future scenario simulations. We add the above information in the Method (Lines 156–161).

3. Micro-irrigation results in the smallest WFP and largest Y (Figure 3). Yet how feasible (and profitable) is micro irrigation in maize and wheat production in practice? Is it commonly applied for these crops in some parts of the world? Or is micro-irrigation mostly used for cash-crops only? Some elaboration on this in the manuscript is needed to justify the research setup and to put the results into perspective.

Response: We appreciate your valuable suggestion. Due to the high cost and technical requirements, micro irrigation applications are limited and are mostly applied to cash crops. However, there is a serious shortage of water resources in some croplands in China. And the spatial and temporal distribution of water and soil resources is uneven. Developing water-saving irrigation has become an important way to alleviate the prominent contradiction between water resources utilization and grain production in China. According to NBSC (2021), the area of water-saving irrigation projects in China in 2019 was 37 million ha, including 7 million ha for micro irrigation. Therefore, micro irrigation does apply to food crops in China despite the limited irrigated area. For instance, in Xinjiang province, the area of micro irrigated maize and wheat was 0.033 million ha in 2009 (CIDDC, 2022), of which the wheat area dominated at up to 0.031 million ha (Wang et al., 2011). Meanwhile, some scholars are conducting research on micro irrigated maize (Bai and Gao, 2021; Guo et al., 2021) and wheat (Li et al., 2021; Zain et al., 2021) in China, especially in the North. We add the above information in the end Introduction (Lines 93–99).

4. What assumption do you take in terms of irrigation strategy/scheduling? This needs to be added to the methods. And how does this affect your results? This is important to address in the discussion, preferably with some quantitative substantiation. The more irrigation events you have, the more effect you will see from moving to a more efficient irrigation application technology (from furrow to drip). So I suppose your outcomes in terms of WFP for different irrigation technologies are quite sensitive to the assumption for the irrigation trigger (x% of

soil moisture depletion?) and amount (back to field capacity?).

Response: We are very sorry for our unclear expression and deeply appreciate your valuable comment. We realized that description of different irrigation techniques settings was missing in Section 2.3 (original 2.2) Water footprint per unit crop calculation. Therefore, the following information is added at the end of Section 2.3 (Lines 162–166). The relevant Table S6 has been placed in the supplementary material.

“In the simulation, different planting modes, namely rain-fed and three different irrigation techniques (furrow, micro, and sprinkler irrigation), were considered. The irrigation schedule of three irrigation techniques in the model was the Generation of Irrigation Schedule, namely the generation of an irrigation schedule by specifying a time and depth criterion for planning or evaluating a potential irrigation strategy. Table S6 shows the parameters of three irrigation techniques (Raes et al., 2017). We can adjust the simulated ET and Y according to the performance of the irrigation schedule.”

Table S6. Parameters of three irrigation techniques.

Irrigation technique	From day	Time criterion	Depth criterion	Water quality	Soil surface wetted
		Depleted RAW	Back to FC	Ecw	
		(%)	(+/- mm)	(dS m^{-1})	(%)
Furrow	1	50	10	1.5	80
Micro	1	20	10	0	40
Sprinkler	1	50	10	1.5	100

5. The most common abbreviation in water footprint assessment literature for water footprint is WF not WFP. I strongly suggest to stick to WF.

Response: Thank you very much for your valuable advice. We correct the abbreviation of water footprint in the manuscript to WF entirely.

Specific comments

6. The abstract should mention what method (model) has been used to estimate WFPs.

Response: Thank you very much for your suggestion. The following sentence is added to the abstract (Lines 19–21) according to your suggestion.

“The AquaCrop model with the outputs of six global climate models in Coupled Model Intercomparison Project Phase 5 (CMIP5) as its input data was used to simulate the WF of maize and wheat.”

7. “Wheat WFP will increase under RCP2.6 (by 12 % until the 2080s), while decrease by 12 % under RCP8.5 until the 2080s.” Please add a brief explanation for this opposite trend under RCP8.5 in the abstract.

Response: Thank you very much for your comment. The reason is that the CO_2 concentration in 2080s under RCP8.5 is higher, which leads to a higher increase in wheat yield and decrease in wheat WF. We add this reason to the abstract (Lines 24–25).

8. Please add in the abstract what benchmarks have been determined. You mention that "Furthermore, the spatial distributions of WFP benchmarks will not change as dramatically as those of WFP" but the WFP benchmarks themselves have not been mentioned earlier in the abstract.

Response: Thank you very much for your suggestion. The following information is added to the abstract (Lines 27–31) according to your suggestion.

"The WF benchmarks of maize and wheat in the humid zone are 13–32 % higher than those in the arid zone. The differences in WF benchmarks among various irrigation techniques are more significant in the arid zone, which can be as high as 57%, for 20th percentile WF benchmarks of sprinkler-irrigated and micro-irrigated wheat. Nevertheless, WF benchmarks will not respond to climate changes as dramatically as the WF in the same area, especially in the area with limited agricultural development."

9. "The present study demonstrated that … must be addressed and monitored". Stated too strongly. Did you really provide evidence that this must be done (in order to …)?

Response: We are very sorry for our unclear expression and use of incorrect word. We have modified this sentence in the abstract (Lines 31–33) to the following information according to your suggestion.

"The present study demonstrated that the visible different responses to climate change in terms of crop water consumption, water use efficiency, and WF benchmarks under different irrigation techniques cannot be ignored."

10. A general overview of the methodological steps at the start of the section is missing. You now jump directly into "Determining the baseline year", but it is not yet clear that/why you need to determine that (and why you use the Aridity Index for that).

Response: We deeply appreciate your valuable comment. We have added the Section 2.1 Research set-up, which provided a general overview of the methodological steps, at the beginning of Section 2 Method and data (Lines 109–119). The content is as follows.

"2.1 Research set-up

We studied the spatiotemporal responses of blue and green WF and corresponding WF benchmarks for two crops (maize and wheat) to future climate change under two climate change scenarios (RCP2.6 and RCP8.5) using four different planting modes (rain-fed and furrow-, micro-, and sprinkler-irrigated). First, we determined the baseline year. Second, we considered different planting modes to quantify WF and corresponding WF benchmarks of two crops in the baseline year and future year levels under two climate change scenarios. Finally, the spatiotemporal responses of crop WF and corresponding WF benchmarks to future climate change were analysed (Fig. 1)."

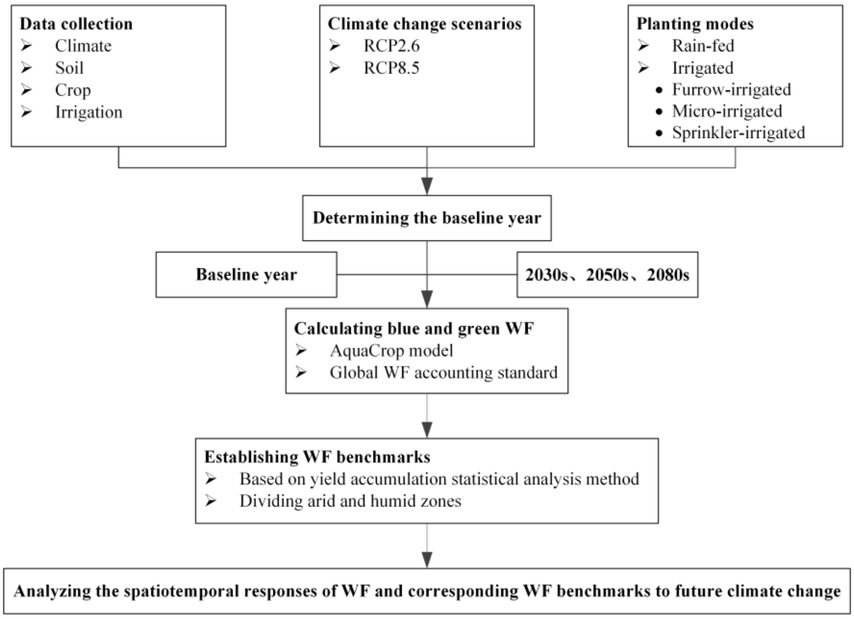

Figure 1. Flow chart for the study.

Meanwhile, the following information is added to Section 2.2 (original 2.1) Determining the baseline year (Lines 121–123) according to your suggestion.

“To ensure that the simulation results of future climate change scenarios are still reliable and meaningful, the baseline year was determined. Climate determines the annual variability of WF (Zhuo et al., 2014), and the baseline year should be determined when there is a relative balance between aridity and moisture. Hence, the aridity index (AI) was used here.”

11. Why do you take the maximum root depth (Zx) and Harvest Index (HI) from Allan et al. (1998)? These parameters are also available for maize and wheat in the default crop files that come with AquaCrop, like the rest of the parameters that you take from Raes et al. (2017).

Response: We are very sorry for our unclear expression and use of incorrect word. The reference manual of AquaCrop (Raes et al., 2017) does have default maximum root depth (Zx) and Harvest Index (HI). Since AquaCrop model itself is developed by Food and Agriculture Organization of the United Nations (FAO). To make the model simulation more reliable, we reset the Zx according to the FAO-56 recommendation (Allan et al., 1998). In addition, we further combined the literature research on maize and wheat in China to reset the HI_0 (Zhuo et al., 2016c). In this way, we make the crop parameters more in line with the actual situation in China. We modify the corresponding sentences in Section 2.5 (original 2.4) Data sources (Lines 186–188) to the following information according to your suggestion.

“To make the model simulation more in line with the actual situation in China, we reset the maximum root depth (Zx) according to the FAO-56 recommendation (Allan et al., 1998). In addition, we further combined the literature research on maize and wheat in China to reset the HI_0 (Zhuo et al., 2016c).”

12. Refrain from mentioning that in your study the AquaCrop model was coupled with GCMs. You did not couple these models. You used GCM outputs as input for AquaCrop. That is

something different than coupling models.

Response: We are very sorry for our unclear expression and deeply appreciate your valuable comment. We delete the relevant inappropriate expression in the last paragraph of Section 3.5 Discussion and modify the related sentence in Section 4 Conclusions (Lines 461–462).

"The AquaCrop model with the outputs of six GCMs in CMIP5 as its input data was used to simulate the WF of maize and wheat."

13. In the before last sentence of the conclusion you suddenly introduce other agricultural management practices that water-saving irrigation technology to reduce agricultural water use, such as mulching. The way it is phrased suggest that this is a conclusion from this study, which is not the case. Thus, you may want to rephrase this. Also, it is advised to add in the Introduction a description on the alternative options to reduce agricultural water use, after which you decide to focus this study on exploring the effects of water-saving irrigation technology only.

Response: Thank you very much for your valuable comment. We delete the relevant inappropriate expression in Conclusions according to your suggestion. Meanwhile, we add the consideration to Section 3.5 Discussion (Lines 415–433) on the choice of two WF benchmarking methods and different agricultural management practices in combination with your General comment 1. In the Introduction, we add the explanation on the reasons and feasibility of exploring the effects of different water-saving irrigation technologies (Lines 93–99), which is also referring to your valuable General comment 3.

Thank you again for your efforts and time on improving our study substantially.

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Allen, R. G., Pereira, L. S., Raes, D., and Smith, M.: Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56, 300, FAO, Rome, Italy, 1998.

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Raes, D., Steduto, P., Hsiao, T. C., and Fereres, E.: Reference manual, Chapter 2, AquaCrop model, Version 6.0, Food and Agriculture Organization of the United Nations, Rome, Italy, 2017.

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Referee #2

The paper is interesting for the wide area it involves and the relevance of the area for corn and wheat production, despite results and methods are not totally novel.

Response: We deeply appreciate your recognition of this study and valuable comment. Our research adopts the widely used method (Mekonnen and Hoekstra, 2011; Zhuo et al., 2016b, 2016c, 2019; Wang et al., 2019; Mialyk et al., 2022) to calculate the water footprint per unit crop (WF, the abbreviation of water footprint was changed from WFP to WF at Referee #1's suggestion). We totally agree with Referee#2 that there are still possible to improve the methods specifically of setting WF benchmarks if there are more adequate data available for such scale study. Such limitation is also pointed by Referee#1. Regarding the choice of method for setting crop WF benchmarks, we add relative discussion in the revision (Lines 415–433). Please kindly refer to our responses to Referee#1's comment 1.

Meanwhile, we want to highlight the innovations in the current research. As we mentioned in the Introduction (Lines 101–104), "Compared to existing literatures, the innovations of the current research are embodied in two points. The present study clarifies large-scale spatiotemporal responses of WF to future climate change scenarios under different irrigation techniques for the first time. This analysis is also the first to explore large-scale changes in WF benchmarks under future climate change scenarios." Although Wang et al. (2019) considered different irrigation techniques when calculating the large-scale WF of wheat, they focused on only one crop, wheat, and did not consider the impacts of future climate changes.

There are also unique and new conclusions. We find that micro irrigation and sprinkler irrigation result in the lowest increases in WF for maize and wheat, respectively, to future possible climate changes. Hence, these water-saving irrigation practices will effectively mitigate the negative impacts of climate changes. Moreover, we find that crop WF benchmarks will not change as dramatically as WF in the same area, especially in the area with limited agricultural development, which also proves the stability of WF benchmarks. We believe these conclusions also contribute to the improvement of the existing WF research field.

Specific comments:

It's not clear how irrigation techniques scenario are managed in the analysis. Are the actual techniques implemented when baseline year was determined? And what about future scenarios? Are techniques assumed considering the actual feasibility of the territory?

Response: We are very sorry for our unclear expression and deeply appreciate your valuable comment. We obtained the planted areas of each crop under each irrigation technique at provincial level from 2000 to 2014 from the China Statistical Yearbook (NBSC, 2021). In this way, the proportion of irrigated area under different irrigation techniques in the baseline year 2013 can be calculated. Then the irrigated and rain-fed areas of maize and wheat at a 5-arc minute grid resolution from MIRCA2000 dataset (Portmann et al., 2010) were divided into different parts under various irrigation techniques. Since we mainly focus on the impact of future climate change on WF and corresponding benchmarks, the change in land use is not considered. We assumed that the crop planted areas will not change in the future compared to baseline year 2013.

Furthermore, we realized that description of different irrigation techniques settings was missing in Section 2.3 (original 2.2, since we added the Section 2.1 Research set-up at Referee #1's suggestion) Water footprint per unit crop calculation. Therefore, the following information is added at the end of

Section 2.3 (Lines 162–166).

“In the simulation, different planting modes, namely rain-fed and three different irrigation techniques (furrow, micro, and sprinkler irrigation), were considered. The irrigation schedule of three irrigation techniques in the model was the Generation of Irrigation Schedule, namely the generation of an irrigation schedule by specifying a time and depth criterion for planning or evaluating a potential irrigation strategy. Table S6 shows the parameters of three irrigation techniques (Raes et al., 2017). We can adjust the simulated ET and Y according to the performance of the irrigation schedule.”

Table S6. Parameters of three irrigation techniques.

Irrigation technique	From day	Time criterion Depleted RAW (%)	Depth criterion Back to FC (+/- mm)	Water quality Ecw (dS m^{-1})	Soil surface wetted (%)
Furrow	1	50	10	1.5	80
Micro	1	20	10	0	40
Sprinkler	1	50	10	1.5	100

L. 148 “using temperature inputs and the Penman-Monteith method”. Penman-Monteith equation requires solar radiation, wind spped, relative humidity, and pressure in order to compute potential evapotranspiration (PET). Can you clarify how you computed PET?

Response: We deeply appreciate and agree with your valuable comment. We will apply the Penman-Monteith equation you mentioned to compute reference evapotranspiration (ET_0) if future climate data types are sufficient, including monthly maximum and minimum air temperature (T_{max} and T_{min}), actual vapour pressure (e_a), net radiation (R_n) and wind speed measured at 2 m (u_2). However, due to the limited future climate data obtained from the Climate Change, Agriculture and Food Security (CCAFS) database (Navarro-Racines et al., 2020; CCAFS, 2015), only monthly air temperature and precipitation data were available. Therefore, FAO Penman-Monteith method with missing data was used here to compute ET_0 (Allen et al., 1998). We modify the relevant sentence in Section 2.5 (original 2.4) Data sources (Lines 183–185) to be clearer.

“As the CCAFS database has no ET_0 data, we calculated ET_0 for each climate scenario using temperature inputs via the FAO Penman-Monteith method with missing data as described by Allen et al. (1998).”

There are corresponding procedures to estimate missing humidity, radiation and wind speed data in this method.

1. Estimating missing humidity data

Where humidity data are lacking or are of questionable quality, an estimate of actual vapour pressure (e_a, kPa) can be obtained by assuming that dewpoint temperature (T_{dew}, °C) is near minimum air temperature (T_{min}, °C). This statement implicitly assumes that at sunrise, when the air temperature is close to T_{min}, that the air is nearly saturated with water vapour and the relative humidity is nearly 100%. If T_{min} is used to represent T_{dew} then:

$$e_a=\mathrm{e}^0(T_{min})=0.611\exp\left[\frac{17.27T_{min}}{T_{min}+237.3}\right]\ , \tag{1}$$

2. Estimating missing radiation data

We can estimate R_n by combining elevation, latitude and longitude data and air temperature data for each grid. The net radiation (R_n, MJ m^{-2} day $^{-1}$) is the difference between the incoming net shortwave radiation (R_{ns}, MJ m^{-2} day $^{-1}$) and the outgoing net longwave radiation (R_{nl}, MJ m^{-2} day $^{-1}$):

$$R_n=R_{ns}-R_{nl}\ , \tag{2}$$

where R_{ns} and R_{nl} are calculated by Equations (3) and (4), respectively.

$$R_{ns}=(1-\alpha)R_s\ , \tag{3}$$

$$R_{nl}=\sigma\left[\frac{T_{max,\ K}^{4}+T_{min,\ K}^{4}}{2}\right]\left(0.34-0.14\sqrt{e_a}\right)\left[1.35\frac{R_s}{R_{so}}-0.35\right]\ , \tag{4}$$

where α is the albedo or canopy reflection coefficient, which is 0.23 for the hypothetical grass reference crop, R_s (MJ m^{-2} day $^{-1}$) is the incoming solar radiation (Equation 5), σ (4.903 10^{-9} MJ K^{-4} m^{-2} day^{-1}) is Stefan-Boltzmann constant, $T_{max,K}$ and $T_{min,K}$ (K=°C+273.6) are maximum and minimum absolute temperature during the 24-hour period, respectively, and R_{so} (MJ m^{-2} day $^{-1}$) is the clear-sky radiation (Equation 6).

Rs is estimated using Hargreaves' radiation formula based on the difference between the maximum and minimum air temperature:

$$R_s=K_{RS}\sqrt{(T_{max}-T_{min})R_a}\ , \tag{5}$$

where K_{RS} (°$C^{-0.5}$) is the adjustment coefficient from 0.16 to 0.19, which differs for 'interior' or 'coastal' regions. For 'interior' locations, where land mass dominates and air masses are not strongly influenced by a large water body, $K_{RS} \approx 0.16$. For 'coastal' locations, situated on or adjacent to the coast of a large land mass and where air masses are influenced by a nearby water body, $K_{RS} \approx 0.19$. And R_a (MJ m^{-2} day $^{-1}$) is the extraterrestrial radiation (Equation 7).

R_{so} is estimated according to the elevation for each grid:

$$R_{so}=\left(0.75+210^{-5}Z\right)R_a\ , \tag{6}$$

where Z (m) is the elevation above sea level.

R_a is estimated by Equation 7:

$$R_a=\frac{24(60)}{\pi}G_{sc}d_r[\omega_s\sin(\varphi)\sin(\delta)+\cos(\varphi)\cos(\delta)\sin(\omega_s)]\ , \tag{7}$$

where G_{sc} (0.0820 MJ m^{-2} min^{-1}) is the solar constant, d_r is the inverse relative distance Earth-Sun (Equation 8), ω_s (rad) is the sunset hour angle (Equation 10), φ (rad) is the latitude, and δ (rad) is the solar decimation (Equation 9).

$$d_r=1+0.033\cos\left(\frac{2\pi}{365}J\right) , \tag{8}$$

$$\delta=0.409\sin\left(\frac{2\pi}{365}J-1.39\right) , \tag{9}$$

$$\omega_s=\arccos[-\tan(\varphi)\tan(\delta)] , \tag{10}$$

where *J* is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).

3. Estimating missing wind speed data

Where no wind data are available within the region, a value of 2 m s^{-1} can be used as a temporary estimate for u_2. This value is the average over 2000 weather stations around the globe.

I am not an English native speaker but I think there's need to make the manuscript be checked for English grammar.

Response: We deeply appreciate your valuable advice and apologize for our improper use of English grammar. We asked for native English speaker through a language editing service to enhance the text. Please kindly refer to our response to the Editor's comments.

Thank you again for your efforts and time on improving our study.

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