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## Comment on hess-2021-388

Anonymous Referee #1

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Referee comment on "A conceptual framework for including irrigation supply chains in the water footprint concept: gross and net blue and green water footprints in agriculture in Pakistan" by Abdul Wahab Siyal et al., Hydrol. Earth Syst. Sci. Discuss.,  
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### General comments

The paper presents a framework to account the water footprint (WF) of an irrigation supply network next to the water footprint of growing the crops in the field, and applies this framework to the case of the Pakistani part of the Indus river basin, which hosts a large irrigation supply network. It concludes that the WF of the irrigation supply network is significant compared to the WF of growing the crops, which indicates that WF reduction in agriculture should not merely focus on the farm, but also on the water supply network.

I support the need to explicitly assess the WF of irrigation supply networks, which are often excluded from WF assessment studies. However, this paper suffers from a number of flaws which I outline under the specific comments below.

### Specific comments

1. The novelty of this paper is overstated. The claimed innovation of the paper is the development of a framework that includes irrigation supply networks in the WF concept. First of all, the Global Standard for Water Footprint Assessment (Hoekstra et al., 2011) explicitly considers the WF of these supply networks: see Figure 3.6 on page 43 of Hoekstra et al. (2011). Judging from lines 97-99, the authors are aware of this, but this is not reflected from bold statements in the paper, e.g. the first listed highlight and the second sentence of the abstract. The authors should be more modest and nuanced in their statements on the innovations of the paper. Maybe the authors rather meant to say that applications of and elaborations on how to account the WF of irrigation supply networks are sparse in literature. Although the focus of many WF studies on agriculture may have been on the WF of growing the crop in the field only, there are several studies that did account for the WF of the irrigation supply network as well. See the review by Feng et al.

(2021) [<https://doi.org/10.1016/j.ecolind.2020.106962>] – concretely, the RWB approach in Table 1 – which lists at least two studies that are not cited and discussed in this paper: Cao et al. (2014) [<https://doi.org/10.1007/s11269-014-0607-1>]; Sun et al. (2016) [<https://doi.org/10.1016/j.jclepro.2015.06.123>]. Since such previous studies already pointed towards the relevance of the WF of irrigation supply networks, it is not clear what new insights this paper brings.

2. Terminology is confusing and not in line with existing literature in the field.

2a. The paper introduces the terms gross and net WF, for both blue and green water. The net blue WF is equal to the blue WF of the process of growing a crop. The gross blue WF is equal to the blue WF of the process of growing a crop plus the WF of the irrigation supply network. It is not clear to me, why we would call this net and gross blue WFs. Both refer to gross (or total) water consumption, as opposed to 'net (or additional) water consumption', which is a term that is used in LCA studies and refers to the difference in the ET of a human-made system (e.g. a crop field) and the ET of natural vegetation. So, I would argue that in both cases – with or without considering the irrigation supply network in addition to the process of growing the crop – we have a gross WF, but the scope of the system differs. There is no need to introduce a new term like gross/net WF for this.

2b. I do see the relevance of distinguishing between beneficial and non-beneficial water consumption, as others have done (Jägermey et al., 2015; cited in the paper), but it is confusing to then label the beneficial part as 'net WF' viz. the WF of growing a crop (lines 272-273), since the WF of growing a crop itself contains beneficial (transpiration) and non-beneficial (evaporation from the soil and intercepted water) flows.

2c. On several occasions (e.g. lines 99-100; 312-314) it is mentioned that the blue WF or growing a crop based on the irrigation requirements method can be considered as "the minimum amount of blue water needed in the production chain of an agricultural blue WF". This is a confusing statement, because this method assumes that crop water requirements are met by irrigation (line 271), i.e. representing a full irrigation strategy. Although other irrigation strategies are possible (deficit, supplemental) that use less blue water since not all crop water requirement are met, intentionally.

2d. The term 'irrigation WF' is often used in this paper to refer to the blue WF of the irrigation supply network. This is confusing since other scholars in the field have used the term 'blue WF of irrigation' to refer to the consumptive use of irrigation water on the crop field next to the 'blue WF of capillary rise' which refers to the contribution of shallow groundwater to crop ET (Chukalla et al., 2015 [<https://doi.org/10.5194/hess-19-4877-2015>]; Zhuo et al., 2016 [<https://doi.org/10.1016/j.advwatres.2015.11.002>]).

3. The title, abstract and introduction of the paper mention that green WFs (related to weeds) are assessed, but the methods and data description is incomplete for this aspect

and results on green WFs are completely absent; the entire results section focuses on blue water. The authors suggest to add the green ET of weeds on the crop field to the WF of growing a crop. The question is to what degree this is already included in previous studies. Often the green WF of crops has been estimated with the approach of multiplying FAO Reference ET ( $ET_o$ ) with crop factors, and using this to estimate actual ET with a soil water balance model. This approach to estimate actual ET of a crop field may include the ET from weeds present below the crop canopy already to some degree. Furthermore, one may argue that irrigated agriculture is often rather intensive, meaning that measures are taken (use of herbicides) to minimize the presence of weeds on the crop fields, such that the additional ET caused by weeds is hardly relevant.

4. An irrigation supply network serves multiple farmers who grow different crops. How to attribute the WF of the irrigation supply network to these different users and uses? This is an interesting question that is not addressed in this paper, since it assesses the WF of agriculture in the study area as a whole.

5. Equation 7 needs more explanation to be understood. For example, it is not clear why you multiply the three elements in the equation. It seems to me there might be some double-counting through this multiplication, since  $L_{ii}$  is calculated based on  $L_i$  (Eq 9) and  $L_{ii}$  based on both  $L_i$  and  $L_{ii}$  (Eq 10).

6. Equations 11 and 12 define the Gross Blue WF which was already defined in Eq 3. How do these relate?

7. Equation 13. I was surprised to see that you calculate NetBlueWF as a fraction of the gross blue WF. Why didn't you calculate the WF of growing a crop using the bottom-up approach ( $ET_o$ ,  $K_c$  factors, etc)? At least that would be an interesting verification of the result of Eq 13.

8. Equation 14. You say that you adopted this equation from Schyns & Hoekstra (2014), but they defined  $K$  totally different as it appears from their paper, based on conveyance and field application efficiency and a fraction of losses in the irrigation canal network that evaporates. How does their definition relate to yours?

9. You conclude that the water losses from storage reservoirs are negligible. That is a remarkable outcome considering that Schyns & Hoekstra (2014) conclude that "evaporation from storage reservoirs is the second largest form of blue water consumption in Morocco, after irrigated crop production". Also Hogeboom et al. (2018) show that the WF of reservoirs (in total and the part attributed to irrigation) are significant compared to the WF of irrigation on the crop field. How do you interpret and explain your outcome?

10. Looking at Figure 5 I wonder: How do losses in one command area relate to other

command areas considering they are interconnected via the supply network (Figure 1), such that crops produced in area A may have a WF in areas B, C, D, etc.?

11. The first point of the Discussion again stresses that this study shows that previous studies underestimated the WF of crops (b/c they explicitly focused only on the WF of growing the crop in the field). Such a claim should be substantiated by a quantitative comparison of the outcomes of this study and several previous studies (incl. those mentioned under point 1 of this commentary), which is not present.

12. Lines 587-592: You conclude that the WF of the supply network is very large compared to the WF on the farm, such that the focus should shift from on-farm WF reduction measures to measures to reduce the WF of the supply network. Also, you point out the latter involves other actors (policy makers) than the farmers. I would argue that this is a good reason to separately assess the WF of the irrigation supply network and the WF of growing the crops on farm, rather than trying to merge them in one indicator (the gross blue WF in this paper). In case you do the latter, you attribute part of the WF of the supply network (which you actually don't do explicitly in this paper, as mentioned under point 4 in this commentary) to the farmer, while this part of the WF is outside the farmer's control. Side note: You can argue whether this is actually out of the farmer's control, since the group of farmers in a command area can take collective action to ask for measures to improve the supply network to combat water losses.

### **Technical corrections**

L78-79: The grey WF refers to the volume of freshwater to assimilate pollutants (not polluted water).

L150-152: First sentence mentions that irrigation supply networks are included next to the WF of growing the crop and green water as well. Second sentence states that the focus is on blue crop water use. This is contradictory.

Figure 2: Can be improved. Consistently show water flows as arrows and water stocks as boxes. Currently, this is not consistent (e.g. return flows, precipitation and seepage as a box). Precipitation and rainfall appear as separate boxes, why? Same for ET and ET+E. Why ET+E? You probably mean ET from land + E from open water?

L340: LostReturnflow is defined here differently than in line 298.

L484: It is not clear how GrossBlueWFgroundwater has been calculated. The same as for surface water it reads. Yet that seems odd. Does the GrossBlueWFgroundwater depend on

total withdrawals from groundwater minus the SFA fraction, which related to groundwater recharge from seepage from surface water infrastructure?

L634-635: I suppose this is not true when surface water is transported over large distances (as opposed to groundwater which is often pumped and used the same site), which also costs energy.