Authors' response to Interactive comments on "Trade-offs between crop-related (physical and virtual) water flows and the associated economic benefits and values: a case study of the Yellow River Basin"

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Response to Referee #3:

Dear Referee #3,

Thank you for your valuable comments and suggestions on our manuscript. We have provided our responses directly below the comments：

The paper presents an approach to account for economic water productivity. However, the concept of the manuscript is not clearly developed, and at it is not entirely clear what the objective of the manuscript is. The novelty is the approach to divide green and blue water productivity, but it seems to use a very simplified approach. As a result, the authors conclude that green water productivity is higher, which is a direct result of the definition of the Net benefit per m3 of blue and green water (eq. 4 and 5). The result would be the same, if water would be free, and if there is irrigation costs, it is fully attributed to blue water. However, the motivation for this model is not presented in the paper nor sufficiently discussed. If cost of irrigation is only attributed to blue water (although green water productivity increases with irrigation too), then it would seem logical that the costs of green water (i.e. the land use where precipitation is definitely part of the land price) should be allocated to the green water (at least a share) and less to the blue water. In general, the approach seems to be a bit ad-hoc and not investigating procedures from other disciplines on how to allocate production costs and parameters. Calculating shadow prices and other approaches should be compared and discussed.

Response: The objective of the current study is to investigate the physical and virtual water flows related to crop production and trade, as well as the economic benefits of crop production and trade, taking the Yellow River Basin as a study case. Regarding the assessment of economic benefits of water used for crop production, we account for the green water (the rainfall) in addition to the blue water, which is innovative since previous studies have always focused on the economic value of blue water alone. We do it by dividing the economic values generated by green and blue water according to their corresponding weights in the water footprint of crop production (Eq. 4 and 5). We assume that every drop of water consumption, either green or blue, has the same contribution to forming the final products. The results of Eq. 4 and 5 will not be the same, given that there is irrigation cost accounted for blue water and that green/blue water consumption ratios are not necessarily equal to green/blue water supply ratios.

We agree with the comments from both Referees #2 and #3 that we could better consider the marginal effect of irrigation water. It means that the contribution of blue water in the crop production equals the actual crop production ($P_{ir}[i]$, t/y) minus the crop production under rainfed condition ($\widetilde{P_{rf}[i]}$, t/y) at the same field. Then the approach can be modified from the current Eqs. 4 and 5 to equations as followed:

$$NB_{b,ir}[i] = \frac{(P_{ir}[i] - \widetilde{P_{rf}[i]}) \times (V[i] - FC[i]) - IRS[i] \times p_{irr}}{IRS[i]} \quad (4)$$

$$NB_{g,ir}[i] = \frac{\widetilde{P_{rf}[i]} \times (V[i] - FC[i]) - IRS[i] \times p_{irr}}{PR[i]} \quad (5)$$

As strongly suggested by Referees, we will estimate the net benefits of green and blue water used in irrigated crop fields accounting for irrigation marginal effects. In the discussion in the revised paper, we will also estimate the shadow price of irrigation water following the method by Ziolkowska (2015) in order to make current estimations be comparable.

The modeling of the case study region is missing some details. In general, the model results and input files should be made available to allow reproduction of the results, otherwise the study cannot be properly assessed. One question relates to the definition of blue water: in many occasions I understand form the description that water withdrawals are used. It might be a miscommunication, but it must be clarified. For instance, with irrigation, losses in flood irrigation are only to a share consumption, since it partially percolates back to ground water.

Response: We will add a supplementary file including required input and output data for reproduction of the results. Regarding the definition of blue water, there are different terms. The blue water abstraction refers the blue water withdrawal (from groundwater or surface water). The blue water supply to the field is the irrigation water applied at the field (and is the volume of irrigation water the farmers pay for). The blue water footprint refers to the actual consumption of blue water (the water evaporated), either during transport to the field, or on the field. To avoid any miscommunication, we will clarify the terminologies on blue water in the revised paper.

Also the role of precipitation as explained below equation 1 should be revisited: Precipitation over the cropping field is set equal to green water, while in general only effective precipitation is available. However, RF is in equation, but it should not only be allocated to BW (which later on seems not to be done).

Response: We apologize for the unclear writing, similar to the last comment. We distinguish between precipitation and the evapotranspiration of precipitation from the field. The latter is called the green water footprint. In equation 1 we will replace RF by the hydrologic terms it refers to (surface runoff + percolation). Both surface runoff and percolation are partly from precipitation and partly from irrigation water.

The crop model is not described in detail and it seems that the yields calculated need to have assumptions on fertilizer and management aspects, which are not described.

Response: The details on crop model can be found in Zhuo et al. (2016a), as mentioned in Line1-2, Page6. In the AquaCrop, the daily crop transpiration ($Tr_{[t]}$, mm) is used to derive the daily gain in above-ground biomass (B) via the normalized biomass water productivity of the crop (WP*, kg m^{-3}):

$$B = WP^* \times \sum \frac{Tr_{[t]}}{ET_{0[t]}} \qquad (R1)$$

WP* is normalized for the carbon dioxide (CO_2) concentration of the bulk atmosphere, the evaporative demand of the atmosphere (ET_0) and crop classes (C3 or C4 crops). The harvestable portion (the crop yield Y, t ha^{-1}) of B at the end of the growing period is determined as product of B and the harvest index (HI, %):

$$Y = HI \times B \qquad (R2)$$

HI is adjusted to water and temperature stress depending on the timing and extent of the stress by an adjustment factor (f_{HI}) from the reference harvest index (HI_0):

$$HI = f_{HI} \times HI_0 \qquad (R3)$$

In the modelling, the effects of water stress on yield simulation were considered. Then the simulated Y per crop per year per grid cell was calibrated at provincial level, by scaling the model outputs in order to fit provincial crop yield statistics.

We will add some description on the crop modelling and crop yield calibration in the proper places in the revised paper.

Below eq3: Are the data from YRCC water consumption or supply or withdrawal?

Response: The data from YRCC is the water supply, equals to the water withdrawal.

Eq 6 is obsolete the Eq.5 results the same

Response: The results of Eq 5 and 6 are not the same, given that the green water productivity of a crop is different among irrigated and rainfed fields (Mekonnen and Hoekstra, 2011).

The whole trade analysis is highly simplified. Prices in locations don't reflect what exporters get and thus a net benefit is not necessarily occurring. There is taxes transport costs and more behind trade. Also, how are the water demands in other places calculated exactly? Are they consistent with the YRB results? Moreover distribution within China and trade among provinces might be based on published MRIO data rather then based on livestock numbers etc..

Response: The net benefits of virtual water flows in the current study is roughly based on the prices in the exporting places of the considered crop products. There is the underlying assumption that the inter-provincial trade values are defined by the price in the local markets of the exporting province. The goal of the trade analysis is to show there are unbalances between the water productivity and economic productivity in the cropping patterns and trade structures of the considered provinces. We admit that it is one of the limitations of the current study that we did not consider other costs in transports and relative services in the trade analysis. We will add this disclaimer in the revised Discussion section.

The crop trade balances per province were estimated consistent to the results in Zhuo et al. (2016b). The values on WFs of crops other than the YRB are from Zhuo et al. (2016b) using the same methodology on WF accounting. Therefore, the values are consistent with the YRB results. The trade of provinces, i.e. the net import of a crop in a province was estimated based on the consumption minus the local production of the province, based on the FAO food balance sheet. The methodology has been accepted as valid for virtual water trade analysis with the condition of no data (Ma et al., 2006). As compared to the MRIO approaches (the top-down approach), the current methodology (the bottom-up approach) is able to measure the trade balance of specific agricultural products (Hoekstra et al., 2011, Feng et al., 2012).

The work is based on the WFN manual (2011) but only does accounting and not water scarcity assessment (required as part of the guidelines as an operational sustainability assessment). This would the analysis also make in line with the ISO standard on WF and other studies assessing trade and water scarcity.

Response: The water scarcity analysis based on WF accounting for the YRB has been analyzed and published by the authors (Zhuo et al., 2016a, 2019). We agree with Referee#3 that the current results should be discussed considering the relationships among the water flows, net benefits of water and local water scarcity levels. Also, comparison of current results to available similar studies should be made. We will add relative discussions in the revised paper.

Finally, clear scientific conclusions based on the work presented are not established. The main conclusion that GW productivity is higher than BW is based on the assumptions (eq. 4 and 5). Also the whole socioeconomic situation behind agricultural production and trade is not discussed in detail. Especially the scenarios are requiring additional discussion of uncertainties of all the input parameters to put the results in context.

Response: There are two main contributions of this study. Firstly, we show the importance and provide an approach to quantify and divide the economic benefits of green and blue water used in crop production. Although the proposed methodology of estimating the net benefits of green and blue water based on WF accounting can be modified based on Referees' comments, as we will do. The net benefits of water used in agriculture are shown varied among different places as well as different colors of the water, with varied cropping patterns. Secondly, the results give the interesting result that the YRB has net import of virtual water, but still has a positive net economic benefit from crop trade in a wet year.

The reliability of the main conclusion about the higher GW economic productivity than BW will be further discussed by comparing to the results with the suggested methodology based on marginal effect as well as the shadow price accounting in the revised paper.

We will add information on socioeconomic situation behind the agricultural production and trade in the YRB in proper places in the revised manuscript.

We agree that the uncertainties behind the scenario analysis should and will be discussed in the revised paper.

The manuscript contains several typos and language should be improved to be more concise and avoid repetition.

Response: We will carefully check through the text and correct any typos and language problems like repetition in the revision.

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