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Discussions

Interactive comment on "Mapping irrigation potential from renewable groundwater in Africa – a quantitative hydrological approach" *by* Y. Altchenko and K. G. Villholth

Anonymous Referee #1

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The paper describes an analysis of the cropland that may potentially be irrigated with the groundwater resources available in Africa. The study is well written, reads interesting, the content is of general interest and the topic fits certainly very well to the scope of the journal. However, I think that improvements are required before the manuscript can be recommended for publication in HESS. My major points of concern are:

1) Irrigation potential is computed as the ratio between groundwater recharge (reduced for water requirements in other sectors or for the environment) and irrigation water requirement (Equation 1). Consequently, irrigation potential is largest in very humid regions where groundwater recharge is high and irrigation water requirement is low.

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However, irrigation is a measure of land use intensification and used to increase crop yield by reducing crop drought stress (in arid regions) or by reducing weed pressure by flooding (in rice paddies). Therefore the benefit of irrigation is largest in arid regions where the lowest potential is calculated according to equation 1. When comparing the current extent of groundwater irrigation in Africa with the potential computed in this study (Figure 7) it also becomes clear that most of the current groundwater based irrigation is in areas of low potential while very little irrigation is in regions of high potential according to equation 1. I can understand the viewpoint of hydrologists with the focus on resource availability but I also think that it is misleading to postulate a potential for irrigation in regions where irrigation is actually not needed or where the benefit for the farmers is low. Therefore I suggest to rephrase title and objectives of the study. What is investigated is basically the crop area in Africa that can be irrigated with local renewable groundwater resources. However, I highly recommend avoiding the use of the term irrigation potential for it.

2) It seems that the irrigation water requirement calculated in this study and shown on Figure 4 is much too high. For example, irrigation water requirement in the Congo or Gabon is about 1000 mm per year (Figure 4). In these tropical regions annual precipitation is up to 2000 mm per year or even more so that irrigation water requirement should be very low. Actually it looks more like that Figure 4 is showing the total crop water requirement from rainfall and irrigation (as shown in the supplementary information) but not the net irrigation water demand. It also seems that the area that can be irrigated with the available groundwater resources (Figure 6) is too low in these humid regions. Therefore it needs to be checked carefully whether the calculation procedure is correct.

3) The calculation of groundwater availability for irrigation neglects artificial recharge generated by irrigation with surface water resources. This is one of the reasons why the area currently irrigated with groundwater (in Northern Africa and South Africa) is not detected (Figure 7). Another reason is the scale used for the calculation of groundwa-

ter availability (resolution of 0.5 degree). In general, groundwater availability should be calculated for each single aquifer and it should also account for an exchange between groundwater and surface water resources. There are high yielding shallow aquifers along most of the large rivers in Africa and water extractions from groundwater would be compensated by groundwater flow from the rivers or wetlands connected to the river. In Western Africa, but also in other regions, most of the groundwater use for irrigation is of this type and therefore also not reflected on the map shown in Figure 7. The water resource described in this example is mainly created in more humid upstream areas, transported as surface water (river) to arid downstream areas, converted to groundwater by infiltration to shallow aquifers and extracted by wells in the alluvial plains. These examples show that neglecting these interactions between surface water resources and groundwater resources is critical. Accounting for these interactions would certainly change the spatial patterns of area irrigable with groundwater a lot. Therefore I see two options for modification of the study: i) Accounting for interactions between surface water resources and groundwater resources is certainly the best option but this would require major modifications in study setup, methodology and input data. ii) A second option is a change of the study objectives towards analyzing the extent of cropland that could be irrigated with groundwater created from local natural recharge. Local is then defined by the resolution of the data set (0.5 degree $\sim$ 50 km). Then it needs to be mentioned that the study is not accounting for the potential caused by lateral flows of groundwater and surface water between grid cells and consequences for the study results need to be discussed more in detail.

Specific comments:

1) Page 6066, line 21, page 6067, line 19: Please use a consistent format for numbers (either million hectares or 10ˆ6 hectares).

2) Page 6069, line 16: Strange units are used for water resources and water use (L3 T-1). Should be m3 yr-1, right?

3) Equations 1-3: It is very important to mention for which time steps these balances or ratios are calculated. In particular for equation 3 the results will strongly depend on the choice of the time step because green water and crop water demand show strong seasonality.

4) Page 6071, lines 17-18. "For the green water availability, the sum of the simulated actual transpiration of the two soil layers under non-irrigation conditions was used." => Water flows from the soil to the atmosphere are typically denoted as evaporation while flows from the plant to the atmosphere as transpiration. Please clarify.

5) Page 6072, lines 5-8. "Six major irrigated crop groups, accounting for an average of 84% of the total harvested cropland in 2000 (165.7×106 ha) over the continent, were considered (Table 1). These include: cereals, oils, roots, pulses, vegetables and sugar crops (sugarcane mostly in Africa)." => The crop distribution considered in this study mainly reflects patterns and extent of rainfed crops. However, irrigated crops differ completely from the rainfed crops grown so far in most regions of Sub-Saharan Africa (Portmann et al., 2010). In addition, irrigated crops are often grown in the dry season while rainfed crops are often sown at the beginning of the rainy season resulting in very different (irrigation) water requirements. This should be mentioned and discussed. Please change "oils" to "oil crops".

6) Page 6072, line 25 – page 6073, line 2: "The monthly crop water demand for each crop is determined by disaggregating total (for one cropping season) crop water demand for that crop and knowledge of its crop calendar (Supplement). The seasonal crop water demand, growing periods and associated single crop coefficients (Kc) for the various crops are extracted from the literature (FAO, 1992, 1986)." It is highly appreciated that the calculated crop water demand is listed in a supplementary table. However, the methods used to calculate crop water demand and irrigation water demand need to be described more in detail (maybe as part of the supplement). From the description it is not clear whether the monthly crop water demand is proportional to the monthly kc or whether it also accounts for differences in weather (temperature). It is

also not clear whether "Green Water" (Equation 3) is similar to precipitation or whether precipitation is reduced for surface runoff, percolation and interception.

7) Page 6085 (Table 2): The irrigation efficiencies refer to irrigation with off-farm surface water and are therefore too low for groundwater irrigation, which is mainly based on water extraction from on-farm wells. When groundwater is extracted from shallow aquifers the whole term does not really make sense because percolation is artificial recharge and therefore the water storage is not affected => efficiency should then be close to 100%.

8) Page 6086 (Table 3): Domestic and industrial water uses are reported per cap. For the spatial assignment the source of population density needs to be reported.

9) Page 6089, Table A1: The results presented in this table would be more interesting when separating the calculated irrigable areas to different levels of aridity (e.g. ratio between irrigation water demand and total crop water requirement). For example, the huge "potential" calculated for Congo DPR is not really a potential because irrigation is not needed there (with the exception of rice cultivation). More interesting is to see whether there is irrigable area in more arid regions where irrigation is really beneficial.

10) Figure 2: Again, please change "oils" to "oil crops"

11) Figure 4: Does the figure really show net irrigation water demand? It looks more like the total crop water demand (irrigation + green water) what is shown here.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 6065, 2014.