

August 8, 2013

Dear Dr. Gerten and Reviewers,

The authors would like to thank you for your time spent in reviewing our manuscript "Virtual water trade and development in Africa [HESS-2013-208]" submitted to *Hydrology and Earth System Sciences* for possible publication as part of the Special Issue titled "Predictions under change". The Reviewers have raised a number of important points that have provided us with the opportunity to improve upon the original submission.

We have addressed the comments of the Reviewers and incorporated revisions to the manuscript where appropriate. Our responses to the specific Reviewer comments are provided below. We have included Reviewer comments in regular font and our replies in bold font, in order to ensure that the document is self-contained.

Sincerely,

Megan Konar
(On behalf of all authors)

Reviewer #1

General comments

The dp by Konar and Caylor is an ambitious and very interesting attempt to provide new knowledge to African trade, agriculture and water resources management. It certainly deserves publication given its novel approach. However, the paper lacks a coherent structure. It is almost self-explanatory due to the several mega-topics the authors seek to address. Although I disagree with a number of claims or find them at least questionable, the general message is very important to be published. The authors should be made aware this paper is only a primer for future research. It by no means addresses the many different fields in a satisfactory manner. However, this is not surprising due to the high ambitions of the authors.

We thank Reviewer #1 for his/her appreciation of our paper. Indeed, we hope it will serve as a primer for future work. We address specific comments below.

Specific comments:

Page 7293 Lines 15-18

The claim of 'open economies' needs further justification. Is there any agricultural sector in the world that is an 'open economy'. The authors need to at least acknowledge that agriculture is subject to government subsidies and mention their importance. There is a major difference between agricultural trade and let's say mobile phone trade. The latter

market is fairly open, the former is not. References: Wesley Peterson (2009) A billion dollars a day; Paarlberg (2010) Food politics

Thank you for this comment. We have updated this paragraph to acknowledge the high levels of distortion in agricultural markets, as you suggest. Thank you for pointing out these references to which we were previously unaware, but now cite accordingly.

Page 7297 Lines 1-2

This explanation on Hanasaki is too thin. I would at least like to know more than "state-of-the-art hydrological model". It requires more explanation.

Thank you for this suggestion. We have re-written this section to provide more detail on the H08 model.

Page 7297 Lines 7-12

The crop choice is not justified. Why not sorghum? Why wheat, which gives Southern Africa an advantage. How would the numbers look like if sheep trade was taken into consideration. In north-east Africa, sheep is a major source of revenue in livestock trade, in particular with the Gulf. It is also important to stress that the Sahel zone and North Africa have different cultural traditions where pork is rarely consumed or traded. Any analysis that excludes sheep would not reflect trade in the Islamic part of Africa.

Thank you for bringing this important point to our attention. We now indicate that the commodity choice may impact our results in lines 284-288 and 516-518.

Page 7300 Lines 15-20

Southern Africa has received more FDI in agriculture than other parts of the continent. It should at least be mentioned. There is also a higher farming expertise for large-scale production. See Fred Pearce on the Guardian website.

We have added this information to lines 274-276 and now cite Fred Pearce's book.

Page 7300 Lines 21-22

I dislike the term "they" when referring to a continent. Consider revising it. It also never becomes clear to what extent the authors distinguish between NA and SSA. Each region is quite different. At least, acknowledge the vastness of Africa as a continent.

Thank you. We have changed "they" to "countries in Africa". We have added in lines 514-516 to acknowledge that our broad-scale analysis does not incorporate the stark regional differences of this vast continent.

Page 7306 Lines 4-5

I would like to know how the authors have calculated Egypt only receives 21% from external sources. Isn't Egypt the most downstream riparian of the Nile. Or do the authors assume the Aswan dam has enough storage that Egypt is in fact less dependent on Nile

inflows than the Egyptian government has claimed after Ethiopia announced its plans to construct the Renaissance Dam. This sentence needs clarification. A lot of clarification.

We apologize for this confusion. Here we determine the percent of water that a country receives from external sources as the proportion of its agricultural water footprint from external sources. This data comes from Column 15 of Appendix IV of Hoekstra and Chapagain, 2008. The external water footprint of a country is defined to be “...the annual volume of water resources used in other countries to produce goods and services consumed by the inhabitants of the country concerned” (p 54, Hoekstra and Chapagain, 2008).

Thus, Egypt may use vast quantities of Nile inflow to produce agricultural products without having a large external water footprint. The important point here is determining where the commodity is consumed. If crops are produced in Egypt, but are then exported to other countries, the water used in their production will not count in Egypt’s water footprint, but will count towards the water footprint of the importing nation. For example, if the USA imports cotton from Egypt, then the water used in the cotton production in Egypt will count towards the external water footprint of the USA, not towards that of Egypt. We have re-written lines 133-146 and 413-420 to clarify this important point.

Page 7310 somewhere at the end

Please acknowledge this topic needs further research. The crop choice placed a bias on Southern African countries, who are better equipped for trade than other regions. The North African countries trade different goods. Sorghum is the traditional crop of Sudan; sheep the meat of choice in the Islamic part of Africa. Overall the message is very important but it needs to either clarified that NA wasn’t subject of this study or the crop and livestock choice favoured SA. The terminology ‘Africa’ is very ambivalent as outlined above. It’s a very complex topic.

Thank you for raising this important point. We have added lines 514-518 to indicate that Africa is not a homogenous region and that our crop choice biased some of our results.

Reviewer #2

This paper presents several interesting findings related to virtual water trade in Africa, e.g. the infrastructure sharing across nations, and the positive contribution of virtual water trade to human welfare. However, I also have several concerns on the data inconsistency, statistical analysis, and the presentation of many methods in the “Results and discussion” section. I suggest publishing the paper after major revision. The general comments are shown below:

We thank Reviewer #2 for his/her appreciation of our work. We have tried to address concerns on data consistency and statistics. We have moved as much of the methods into the appropriate section as possible.

(1) In the “Results and discussion” section, the authors describe detailed methods for the assessments. All the method description should be moved to the “Methods” section, and should not stay in the “Results and discussion” section. This comment applies to Section 3.1-3.4.

Thank you for this comment. We have tried to move as much information regarding methods to the appropriate “Methods” section as possible. However, we choose to keep some descriptions of how we combine various data sources in the “Results and discussion” section. We prefer to motivate and explain the relationships presented as we present the relevant graphs in the “Results and discussion” section. We believe this aids in understanding results.

(2) There is a lack of consistency in the data sources used in the paper. First, the author uses yearly VWC information from the H08 model for 1986-2001, but from calculation based on Eq. 1 for 2002-2008. Here it is suggested that the author should use a consistent method e.g. all calculations are based on the H08 model. The reason is that ET fluctuates from year to year. If you only use ET in 2001 for the calculation (Eq. 1), large errors will occur for the VWC during 2002-2008. Second, for Eq. 6, VWE and VWI is calculated mainly based on the H08 model and trade data on an annual basis, but ET_c is from Hoekstra and Chapagain (2008), who provide the average data for a certain period. Hence, VWE/VWI and ET_c are used not consistently in terms of the temporal scale. It is strongly suggested that authors use consistent data in terms of time, and data sources. Otherwise, the analysis is not convincing.

Thank you for raising this important point. We use a variety of different data sources throughout the analysis. However, we do use consistent data within each equation and graph. In Equation 2 (formerly Equation 6), we obtain all of the variables from Hoekstra and Chapagain, 2008 (i.e. data on gross virtual water exports, gross virtual water imports, and total evapotranspiration). We have added lines 150-153 and 174-175 to clarify this important point.

Ideally, all of the data required for our analysis would be contained in one source. However, this is not the case. We require annual estimates of bilateral virtual water trade flows, which we obtain by combining yearly FAO trade and yield data, with H08 estimates of yearly ET. For other questions, we require data on internal and external water footprints and total domestic evapotranspiration. This data is available from Hoekstra and Chapagain, 2008. When we use data from Hoekstra and Chapagain,

2008 we also choose to use their data on gross virtual water flows, in order to be consistent in terms of both temporal scale and underlying crop commodities considered.

We agree that it would be best if estimates of yearly ET after 2002 were available from the H08 model. Unfortunately, WATCH climate forcing data ends in 2001, making these estimates unavailable at this time. For this reason, we change only the yield components of VWC from 2002-2008, following other studies in the literatures. We have added lines 217-218 to acknowledge this shortcoming.

(3) For many Figures, e.g. Fig. 2, Fig. 3, Fig. 4, Fig. 6, the R2 and significance level are expected. In addition, for Fig. 5, statistical analysis is needed to show how significant is the external water consumption in small dam capacity group higher than that in large dam capacity group.

Thank you for this suggestion. We have included statistical analysis for the Figures as suggested. Please find all estimated regression equations and R2 values listed in the relevant Results and Discussion sub-section. Several of the relationships presented in this paper are provocative, but are not statistically significant. We keep these relationships in the paper, because our goal is to present empirical evidence for some of the relationships previously described only in theoretical terms, particularly when they display opposite trends.

Our statistical analysis of Figure 5 indicates that the means are not statistically different, which is evident from the overlapping distributions of the box-whisker plots, as well as unlikely due to the small number of countries in the large dam pool. We estimated the regression equation $Y_i = \alpha_{\text{small}} + \alpha_{(\text{large-small})} * 1_{(X_i=\text{large})}$, where $1_{(X_i=\text{large})}$ is an indicator variable which is equal to 1 whenever the observation X_i is in the large dam group. Here, $\alpha_{(\text{big-small})}$ corresponds to the difference between the two groups and is estimated at -7.15, but is not statistically significant. However, we keep this graph, since the differences are meaningful in magnitude and interesting in terms of the tails/outliers in the distributions. Thus, despite the fact that the means do not differ in a statistically significant manner, we keep this graph because it is thought provoking.

(4) There are a lot of repetitions when the figures are explained. For example, authors describe red horizontal line, red star etc in detail in the Figure Legend. Then the description is repeated in text (i.e. Page 7305, Line 17-21). Repetition should be avoided if possible. This comment applies to other graphs in the manuscript.

Thank you. We have removed this paragraph and reduced repetition elsewhere.

(5) The authors point out outliers. For example, Mauritius and Botswana are outliers for small dam storage capacity group. An in-depth analysis is expected to know why they stand out to be outliers. This comment also applies to other places in the paper.

Although in-depth analyses for particular countries remains beyond the scope of this continent-scale work, we have added some explanation for why Mauritius and Botswana may be outliers to lines 402-412.

(6) There are many places where authors use “African trade”. Do you mean the internal African trade, or the total trade that also includes international trade with other continent? For example, Page 7308, Line 5-6, the authors mention “Internal African savings are 2.5 times higher than total African trade”. Another example is Page 7301, Line 1-2: “internal African trade is larger than African trade with the ROW”? (7)

We apologize for this confusion. The first instance that you mention refers only to internal African trade. The second instance that you mention does include international trade, since we state “...African trade with the ROW”, where ROW indicates rest of the world. We have clarified the first statement in the revised paper.

(7) Page 7294, Line 8-14: Two comments here. First, a citation is needed for the IPCC report. Second, there have been several doubts to the findings for the impacts of climate change on agricultural yield in Africa from IPCC (e.g. decrease by 50%). It is argued that IPCC report does not provide sufficient evidence or literature support for such findings. In a recent article, Liu et al., 2013 found that due to climate change, crop yield in Africa will first increase in the near future, but decrease in the far future. It is suggested that authors should not only cite the IPCC report results but also cite new findings in recent literature here.

Reference: Liu J., Folberth C., Yang H., Röckström J., Abbaspour K., et al. (2013) A Global and Spatially Explicit Assessment of Climate Change Impacts on Crop Production and Consumptive Water Use. PLoS ONE 8 (2): e57750.

Thank you for raising this point. We now cite the original IPCC report and have added reference to Liu et al 2013 as suggested, as well as Schlenker and Lobell 2010.

Specific comments:

Page 7293, Line 26: The article below reviews China’s water availability and water scarcity, and could be cited here: Liu J., Zang C., Tian S., Liu J., Yang H., Jia S., You L., Liu B., Zhang M., 2013. Water conservancy projects in China: achievements, challenges and way forward. Global Environmental Change 23 (3): 633-643.

Thank you. We have done so.

Page 7294, Line 1: Typo error. Change :FAO, 2009) to (FAO, 2009)

Thank you. We have done so.

Page 7297, Line 9-10: It is not clear how the VWC of livestock products is calculated. Please clarify!

Thank you. We have added detail on the calculation of livestock VWC to this section.

Page 7298, Line 8-10: how representative are the 50 commodities for Africa?

Thank you for raising this point. We have added lines 284-288 and 516-518 to indicate that our commodity choice may bias our results, likely emphasizing trade in Southern Africa.

Page 7302, Line 12-13 “future values of VWI and future values of the variables of interest”,

did you use future values of VWI in this paper?

We apologize for this confusion. Here “future” does not refer to projections, but to a 10 year time-lagged global analysis of trends. We have changed our wording to be more clear.

Page 7303, Line 9, “in the literature”, which literature? Page 7306, Line 14: “thos”?

Thank you. We have added a reference and fixed the typo.

Figure 7: The country names (probably the most important countries) should be marked in A and B.

Thank you for this suggestion. We have included the most important country names as suggested.