REVIEWER 2:

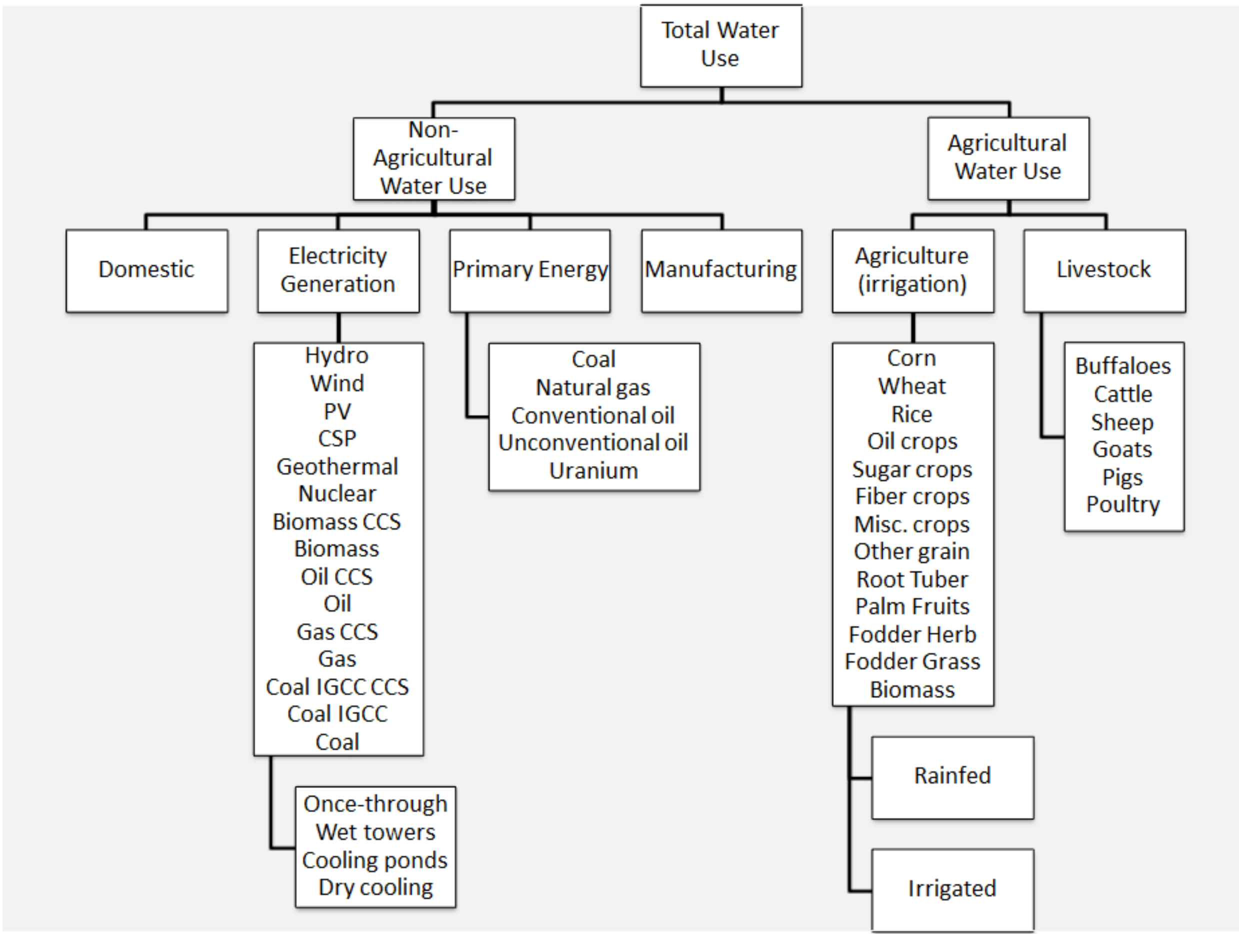
The authors combined an energy-economic model GCAM and a group of models on hydrology and water use including a water balance model GWAM and global water demands models for six sectors. In this paper, the authors mainly introduced the formulation of GWAM and the results of water scarcity assessment using a well known index devised by Raskin et al. (1997). They reported that in some parts of the world, water scarcity considerably increases in the middle and the end of 21st century under a SRES A1Fi compatible scenario. They also briefly discussed the water use projection under the scenario but the details are described elsewhere (Hejazi et al., 2013, Technol. Forecast. Soc., Submitted).

Integration of energy-economic models and hydrological models with details on water use and management is crucial to analyze the impact and policy of global climate change. The authors have devoted themselves to this challenging task and achieved the integration to a certain extent. The manuscript is basically well prepared. Nevertheless their success, I have to take a critical position to this work as a research article of HESS, one of most important journals in the field of hydrology, because of the reasons shown below. In short, this paper should be a supplemental material of the accompanying paper by the same authors.

We agree with the reviewer that the paper borrows from the literature and we are certainly open to the option of merging the two papers in a single one. However, we still believe that having two separate papers is the better option for multiple reasons.

1- The major contribution of this paper is in the integration of all these components in one of the leading integrated assessment models (GCAM) - a novel and an important step to the progression of IAM community of models (commonly used in the IPCC process) to adopt an adequate representation of the water system. This paper highlights the importance of including water systems (Fig 1 in the paper) in integrated assessment of global change to facilitate a new class of IAMs that can capture the implications on water scarcity conditions in the context of future energy use, agriculture and land use, and climate change. This capability can provide greater insight into the implications of climate policies on the dynamics of natural Earth systems and help to identify important technological investment and adaptation measures. This is also important since GCAM is a community model with open source and having a paper entirely focused on the addition of the water system carries tremendous scientific value to the GCAM and IAM community at large.

2- We agree that the hydrology component borrows from the existing literature, the water demand modules are described elsewhere (e.g., Hejazi et al., 2013), and the downscaling work in GCAM is new but is also using existing techniques published elsewhere. However, the level of detail the model offers especially on the energy sector exceeds most of the previous studies (see figure below – taken from Hejazi et al., 2013). We also dive deeper to study the cumulative distribution of people facing different levels of water scarcity than most previous studies. The fact that the GCAM results (from an IAM framework) fall within the range of previous efforts is still useful and comes as a confirmation of previous findings.



3- The companion paper is specifically focused on the effects of climate mitigation policies, policy regimes, and target stringencies on the calculations of water scarcity and number of people facing water stress conditions. This first paper serves a different purpose and delivers other key messages related to endogenous incorporation of water supply, demand, and spatial downscaling in one of the leading IAMs, understanding the role of a do-nothing scenario (no mitigation) and high population growth, understanding the role of spatial scale by comparing the grid and basin scale results, and investigating how the global and regional populations will face different levels of scarcity in future decades. Thus, reformatting the paper as supplementary material for the second, or combining the two papers would cause us to lose a set of important insights.

M. Hejazi, et al., Long-term global water projections using six socioeconomic scenarios in an integrated assessment modeling framework, Technol. Forecast. Soc. Change (2013), http://dx.doi.org/10.1016/j.techfore.2013.05.006

Specific comments

The manuscript consists of six sections.

Introduction: The authors reviewed earlier works on land surface models and global water balance models, but it is too superficial and unfocused in the current form. A lot of important papers are missing, particularly the development of land surface models (page 3330, line 6-21). If I understand correctly, the key strength and uniqueness of the authors work is integration of energy-economic models and hydrological models. I'm wondering why the authors didn't focus on the history of this effort, for example Hayashi et al. (2013) and many others.

We have added the suggested reference – which only became available after the paper was originally submitted. We believe the introduction is quite comprehensive and we have tried to maintain a balance of covering all the key elements of this research (global hydrologic models, LSMs, water demands, water scarcity, etc.). There are close to 90 citations already included in the paper.

GCAM: No specific comments on this section, because it only briefly overviews the GCAM model.

GWAM: The authors introduced their water balance model here, which is one of the main content of this paper. However, the author's water balance model is too simple to be discussed in detail in main text. The model is founded on the most basic water balance equation (dS/dT=P-E-R) and well established classical formulations. I think the authors can move a large part of this section to supplemental material because the most of the techniques are devised elsewhere. In the following part, the results of model evaluation is shown but it is less informative. For example, Figure 7 shows that in some of the basins, the error reaches 1000% (there is a plot showing that the observation is around 80 km3/yr while simulation is around 800 km3/yr). I understand it very well that the current global hydrological models subject to produce large errors in arid basins, but at least the authors should carefully discuss in which regions the model are more/less reliable, because this is crucially important to interpret the results.

We discussed the skill the model and showed that it performed similar to other models (see figures 4-7, and tables 1-3). Also please see our response to first comment by the reviewer.

GWDM: The authors introduce their global water demand model (GWDM) and some of the results of water demand projection, but again I need to be critical here. First, GWDM consists of six major sub-models (irrigation, livestock, domestic, electricity production, primary energy production, and manufacturing), but details are described in elsewhere. The only original content seems a description on how they spatially interpolated their projection from regions to grid cells. But it is a quite simplistic technique (i.e. weighting by population density, etc.) which has been widely used for a decade (Vorosmarty et al., 2000, Alcamo et al., 2003). Because the most of the contents are shown in elsewhere, I got an impression that the whole section is less scientifically important.

Please see our response to first comment by the reviewer.

Water scarcity: The authors conducted a global water scarcity assessment using a conventional water scarcity index of Raskin (1997) under a global scenario of SRES A1Fi. A grid-based calculation of the index first appeared in Vorosmarty et al. (2000) and hundreds of similar reports have been published since then. I hardly believe the necessity to repeat such an exercise here in HESS. The authors may claim that the results are consistent with energy-economic factors. Then, the authors should emphasize the difference and advantage of their results compared to those of conventional stand alone hydrological models.

Please see our response to first comment by the reviewer for discussion on how the adopted approach is advantageous.

Discussion and conclusions: As mentioned above, the key contents are less novel and original, the discussion and conclusions are basically conventional.
In summary, although it is well written as a scientific report, the manuscript contains not enough novel and original contents as an independent research article. I believe the accompanying paper includes many new challenges, I recommend that two papers should be merged. A substantial amount of the contents of this manuscript should be placed in supplemental material because they are originally published elsewhere as discussed above.

Please see our response to first comment by the reviewer.

Technical comments

Page 3330, line 24, "WaterGAP/WEHY": What is WEHY?

Omitted.

Page 3330, line 26, "Gertena et al." reads "Gerten et al."

Changed, thanks.

Page 3330, line 27: "Wide'n-Nilsson" reads "Widén Nilsson".

Changed all occurrences, thanks.

Page 3330, line 28: "H07/H08 (Hanasaki et al., 2006, 2007)" reads "H08 (Hanasaki et al., 2008)", since H08 is short for "the model described in Hanasaki et al. (2008)".

Thanks for pointing out this to our attention. We have changed it to "Hanasaki et al., 2008a,b" and we corrected the list of references.

Page 3330, line 28: "Weiland et al." reads "Sperna Weiland et al."

Changed, thanks.

Page 3341, line 3, "Figure 9 shows…": According to the GCAM, irrigation water demands grows throughout the 21st century. However, some of earlier works showed pessimistic view in increase of irrigation water (e.g. Alcamo et al., 2003; Rosegrant et al. 2009). Because the projection of irrigation water demand critically affects the results of the study (including the accompanying paper), the authors need to explain here in detail how irrigation demand is modeled in GCAM.

The method is already documented in two previous publications:

> Hejazi, M., Edmonds, J., Clarke, L., Kyle, P., Chaturvedi, V., Davies, E., Wise, M., Patel, P., Eom, J., and Calvin, K.: Long-term global water use projections using six socioeconomic scenarios in an integrated assessment modeling framework, Technological Forecasting and Social Change, 2013b (in press).
>
> Chaturvedi, V., Hejazi, M., Edmonds, J., Clarke, L., Kyle, P., Davies, E., and Wise, M.: Climate mitigation policy implications for global irrigation water demand, Mitigation and Adaptation Strategies for Global Change, doi: 10.1007/s11027-013-9497-4, In press.

Page 3344, line 23: "cumulative probability density function" reads "cumulative distribution function".

Changed all occurrences, thanks.

Page 3346, line 3 "Thus, both water demand and supply are driven from the same set of assumptions about population and income growth, technological change, and emission scenario": In my understanding, all earlier assessments under SRES and CMIP3 meet this condition. I'm not convinced that it is the advantage of this study.

Most previous modeling efforts have focused on specific components of the human-earth system and assumed the behavior of remaining components by applying projected trends, output of other models, or reanalysis data. For example, Arnell et al. (2011) used the IMAGE model and Shen et al.'s (2008) water withdrawals to assess the effect of climate mitigation on water scarcity – but such one-way sneaker-net coupling of models does not lend itself to easily propagating water scarcity information back to the IAM framework.

Page 3346, line 26 "Indi's" read "India's"

Corrected, thanks.

Page 3347, line 3 "These high water scarcity values indicate that the scenario is likely infeasible from water perspective, since such high water stress would typically lead to the adoption of water conservation technologies with implications for other human choices": Does GCAM include this feedback mechanism? If so emphasize it more in text.

This will be addressed in future research. This is where we are heading with the model development in the near future.

Page 3348, line 13, "Wada et al.": Add the year of publication.

Added, thanks.

Page 3348, Appendix: The description of Hargreaves method is quite easily found in the textbook of hydrology, and the whole section can be omitted.

We have omitted this section from the paper.

Figure 3: Because all information is in text, this figure can be omitted.

We have omitted this figure from the paper.

Figure 10-14: These figures are not very informative, because neither the models nor the results are discussed in detail.

We have dropped figures 10-14 and updated the numbering of all the following figures.

References

Hayashi, A., Akimoto, K., Tomoda, T., and Kii, M.: Global evaluation of the effects of agriculture and water management adaptations on the water-stressed population, Mitig Adapt Strateg Glob Change, 18, 591-618, 10.1007/s11027-012-9377-3, 2013.

Rosegrant, M., Fernandez, M., and Shinha, A.: Looking into the future for agriculture and AKST, in: Agriculture at a crossroads, edited by: McIntyre, B. D., Herren, H. R., Wakhungu, J., and Watson, R. T., Island Press, Washington, D.C., 2009.