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Interactive comment on "A site-specific agricultural water requirement and footprint estimator (SPARE:WATER 1.0) for irrigation agriculture" *by* S. Multsch et al.

Anonymous Referee #2

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Review of "A site-specific agricultural water requirement and footprint estimator (SPARE:WATER 1.0) for irrigation agriculture" by S. Multsch, Y. A. Al-Rumaikhani, H.-G. Frede, and L. Breuer

In the paper "A site-specific agricultural water requirement and footprint estimator (SPARE:WATER 1.0) for irrigation agriculture" S. Multsch, Y. A. Al-Rumaikhani, H.-G. Frede, and L. Breuer introduce a newly developed software tool to inform agricultural water management decision making. The motivation comes from the need to assess consumptive water use at farm or regional scale using local data and to provide a means to determine sustainable management strategies. The authors provide a de-

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tailed description of the underlying model structure of the software tool. The software itself seems to be useful in practice due to its seemingly ease of use (mind the issues related to collection and preparation of the required input data). The paper also includes an application of the developed software for Saudi Arabia. It is very positive that the software is being made publicly available by the authors, as certainly more tests are required to determine its general applicability. The scientific community and practitioners now have the change to test this model and provide feedback.

General comments In general the paper is well written and the structure allows to follow the development well. What I did not find was a notion of the spatial grid resolution. This will depend on the input data available, as crop production is not modeled. Hence a smaller scale, local assessment is always dependent on the availability of data at high spatial resolution. This may make investigations at small scale impossible, as often local data are not available.

The authors state to have extended/improved the concept of Hoekstra et al. (2011) by at least incorporating irrigation efficiency and different irrigation methods and a new grey water footprint. It is difficult to understand as to why this is an extension of the method. Different irrigation efficiencies and methods can of course be included in the water footprint assessment. The fact that the selected studies that the authors cite have not done this does not mean that it is not feasible. The new definition of the grey water footprint by the authors leads to having to also evaluate how much water percolates (and hence returns to the same catchment where it has been withdrawn) and how much is needed to dilute the salt. This remark is not alluding to a specific case (the authors looked at conditions in Saudi Arabia only, p. 664), but it is an issue of general applicability of the tool. The authors are asked to take a look at the work by Chapagain and Hoekstra (2011), which alludes to percolation, and reflect on this work in light of their own work beyond the brief remark on p. 667. In Multsch et al. no irrigation methods have been tested (e.g. drip irrigation, sprinkler irrigation, etc.), it is only mentioned that the efficiency has been set to resemble surface and sprinkler

GMDD

6, C148–C155, 2013

irrigation (p. 665). It is also not clear as to how those different methods have been implemented (see text on p. 649, line 25). With respect to irrigation efficiency it is advised to be critical about the data provided and included for the calculations. There is are a number of publications that debate this issue (e.g. Jensen, 2007; Perry, 2007; Lankford, 2012).

The model proposed is in a great many of aspects CropWat of FAO with additions. It is not clear why AquaCrop of FAO has not been mentioned nor discussed, as it is intended to cope with some of the aspects that have been implemented by the authors and relates to the spatial scale that is investigated here, other than the references mentioned. SPARE:WATER 1.0 has, at this point, precisely the functionalities required for the shown test case of Saudi Arabia, which is a very peculiar case. AquaCrop has more functionality, in particular it is clear in terms of irrigation practices.

In SPARE:WATER 1.0 salt has been included, but fertilizer, pesticides, herbicides and other pollutants have not been considered. In general they will need to be included. Is this feasible? The authors state on p. 664 that "the grey water footprint component need not be considered in Saudi Arabian agriculture". This statement is flawed. If salt needs to be diluted to not degrade soil quality, then for the same reason pollutants also need to be diluted. The authors are asked to reflect on this.

The wording used when it comes to "water footprint related" issues must be revised in several places. Please use the same nomenclature throughout, as otherwise even more confusion arises than there already is (examples: p. 646, line 6: spatial decision support system; p. 646, line 23: withdrawn instead of consumed; p. 663, line 6: the Water Footprint of Nations (WFPN) model: I would think that this is a name that has been created by the authors, i.e. not in the original work cited. Even worse, water footprint assessment is not a model and this should be rectified; p. 666, line 6: WF assessment ;p. 667, line 4: explicit spatial water footprint system).

I disagree with the authors' statement that a monthly time step is sufficient for analyses

GMDD

6, C148–C155, 2013

in the agricultural sector (p. 668). But this is scope of future work, which the authors acknowledge in the conclusions/outlook section.

The text has a focus on the agricultural sector. Water Footprint Assessment goes far beyond this. SPARE:WATER does of course not, it is not intended to at present. It is a tool that carries out a methodology. But the authors would be advised to not present water footprint assessment as a means to investigate agriculture only.

It is unfortunate that no recommendations are drawn from the results obtained with the decision support system SPARE:WATER to aid in the development of sustainable water management in Saudi Arabia, as this should be the main goal of a DSS. In particular since the authors state that over-exploitation of (fossil) groundwater resources is the norm, rather than the exception in their test case. The focus of the paper is more on the competition with results obtained by others. In a next paper by the authors the usefulness for decision making will hopefully become a focus.

References: Chapagain, A.K. and Hoekstra, A.Y. (2011) The blue, green and grey water footprint of rice from production and consumption perspectives, Ecological Economics, 70(4): 749-758.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2011) The water footprint assessment manual: Setting the global standard, Earthscan, London, UK.

Jensen, M. E. (2007). "Beyond irrigation efficiency." Irrigation Science 25(3): 233-245.

Lankford, B. (2012). "Fictions, fractions, factorials and fractures; on the framing of irrigation efficiency." Agricultural Water Management 108: 27-38.

Perry, C. (2007). "Efficient irrigation; inefficient communication; flawed recommendations." Irrigation and Drainage 56(4): 367-378.

Technical content The work is certainly relevant. An important research question has been approached. The research methodology is sufficiently (if not overly – I wonder if some of the simple equations could be removed and some in particular CropWat

GMDD

6, C148–C155, 2013

descriptions and equations be moved to an Appendix, so that it does not read like a user manual) described. The authors should reconsider what their work in fact is: a new development or a software development to support decision making based on existing methodologies. Important questions remain:

It is stated that different irrigation methods can be modeled. How? Why has pollution not been included? Why is AquaCrop not mentioned, even though it is closely related and widely used software?

The application is significant, as the results for Saudi Arabia can certainly be used for decision making.

Writing and Presentation The writing is it clear, concise and in good English. The development of the argument can be followed. One style correction that should be considered throughout the text: what comes next does not have to be "announced" (next we present...; or ..in Equ (x)...and the equation follows right thereafter).

Title: The title implies that rainfed agriculture cannot be analyzed. Is such an application not intended? That would be unfortunate in light of the importance of rainfed agriculture and the measures that must be taken to make rainfed agriculture more efficient in order to feed a growing world population.

Abstract: The abstract does indicate the purpose of the work, it describes what was done, what was found and elaborates on the significance of the results.

Conclusions: The conclusions provide a brief overview of the most important results and give a short interpretation of the results. Also, an outlook is given.

Figures: The figures are justified, of good quality and adequate lettering. Appropriate legends are provided.

References section: The references provided are formatted properly. All the information required is given. A few typos have been spotted, which will be listed under the specific comment section.

GMDD

6, C148–C155, 2013

Specific comments p. 664, line 5: “Most of current water footprint assessments focus on global to continental scale.” This is an uninformed statement. Apart from publicly available literature on smaller scale assessments there is a large number of unpublished assessments (for a business, one production site, a sector, an individual, a product, . . .).

Please consider rewording this statement. Also, the list of publications given on p. 647, line 11 onwards is disturbing, as it is used to show that "...all these applications focused on large scales with an emphasis on nations". This gives the impression that nothing else has ever achieved using the water footprint assessment methodology.

p. 647: a large body of literature exists in which the CropWat model...and then three sources are listed. Three is not a large number. And this statement holds true, then the model presented by the authors is also "just CropWat with a twist".

Please consider the scientific publication of Hoekstra and Mekonnen (2012). In the text reference is made to Mekonnen and Hoekstra (2010), which is a data source.

It is stated that Mekonnen and Hoekstra (2010) use CropWat (p. 647). After visiting this publication I found the following description given therein: "The green, blue and grey water footprints of crop production were estimated following the calculation framework of Hoekstra et al. (2009). The computations of crop evapotranspiration and yield, required for the estimation of the green and blue water footprint in crop production, have been done following the method and assumptions provided by Allen et al. (1998) for the case of crop growth under non-optimal conditions. The grid based dynamic water balance model used in this study computes a daily soil water balance and calculates crop water requirements, actual crop water use (both green and blue) and actual yields. The model is applied at a global scale using a resolution of 5 by 5 arc minute (Mekonnen and Hoekstra, 2010). We estimated the water footprint of 146 primary crops (as listed in Appendix I) and more than two hundred derived products. The grid based water balance model was used to estimate the crop water use for 126 primary crops; for the

GMDD
6, C148–C155, 2013

other 20 crops, which are grown in only few countries, the CROPWAT 8.0 model was used." (cited from Mekonnen and Hoekstra, 2010) Hence it seems that the statement made by Multsch et al. regarding CropWat is only partially true.

It is suggested to restructure part 2 of the paper. Consider renaming section 2 in "Method and Data", erase the section "Equations" and then move the third level sub-sections one level up.

One caveat that came up when reading p. 653, which stands in sharp contrast to the level of detail the authors are aiming for with their work. It is stated that " the model accounts for the runoff losses (RO) as a constant ratio of 20% of precipitation (P). Why precisely 20% and not another percentage?

Section 2.2.4 Site specific leaching requirement: How does this relate to the leaching and runoff fractions in section 3.3.3 of the water footprint assessment manual (Hoekstra et al., 2011)?

I would suggest to rename section 3 into "Application to crop production in Saudi Arabia". Proof of concept sounds like a mathematical proof after a derivation.

p. 647, line 8: what is a unit water?

p. 648, line 23: the definition of grey wf is not correct. Please refer to the water footprint assessment manual.

Typos: p. 648, line 6: remove "to" after "regarding"

p. 653, line3: crop coefficient, not coefficients

p. 656, line 5: input parameters, not parameter

p. 657, line 5: a text file, not a text files

p. 669, line 11: crop ET and Kc, not et and kc

p. 669, line 20: use lower case letters, the same on p. 670 in lines 20, 21, 24

GMDD

6, C148–C155, 2013

p. 671, line 4: the reference is not complete, it is given above

p. 671, line 18: there is a backslash that needs to be removed same page, line 22: please check with the journals' policy, but links to pdf should most likely not be made

Figure 8: I would imagine that it is easier to compare if the axes (x,y) have the same maximum value. Now they have 6000 and 8000.

References:

Hoekstra, A.Y. and Mekonnen, M.M. (2012) The water footprint of humanity, Proceedings of the National Academy of Sciences, 109(9): 3232–3237.

Mekonnen, M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No.47, UNESCO-IHE.

Overall Recommendation: Considering the above listed strengths and weaknesses of the contribution it is recommended that the paper may be accept after revisions.

Interactive comment on Geosci. Model Dev. Discuss., 6, 645, 2013.