Interactive comment on "Grey water footprint reduction in irrigated crop production: effect of nitrogen application rate, nitrogen form, tillage practice and irrigation strategy" by Abebe D. Chukalla et al.

Reply to Anonymous Referee #1

We thank Referee #1 for the comments; below we give the reply.

Comment

The authors make an assessment of the grey and total water footprints of irrigated maize grown in Badajoz, Spain. They use the APEX model to study the effects of 56 management packages to determine the options giving the highest yields and the lowest grey and total water footprints.

I think the subject is interesting for its application to agricultural managements, (after still may improvements) possibly ending in recommendations to agricultural stakeholders in order to decrease water consumption, improve water quality and increase crop yield. The authors have made a full exploration of results based on the results given by the APEX model.
However, as it is now, the manuscript has more drawbacks than qualities. The problems are the following:

1. Presentation: The language at the beginning is of considerably low quality. Although it improves along the manuscript, the sloppy writing of the introduction, methods and beginning of results puts off the reader. I would recommend improving sentence structure, grammar, term usage, etc, with a professional service. I mention at the end some examples.

Reply:

We will improve the language of the manuscript at the beginning, with a focus to the introduction section, we will also incorporate the corrections that the referee mentioned as examples.

Comment

2. Site description, Methods. Incredibly the only information of the study site is packed in three words, Spain, maize and Badajoz. Where is this? What are the hydroclimatic characteristics (precipitation, temperature, PET, relative humidity, soil moisture content, water stress), any map? size of the plot, water source, time period of study, elevation, etc. This contrasts with the huge explanation on the parametrization of the APEX model.

Reply:

We agree with reviewer's comment that we did not give enough description of the study area. In fact in our study we want to show the potential for grey WF reduction in a water-scarce area by experimenting the effect of different field-management packages on the grey water footprint of growing crops. As example we used a real agro-hydrologic system in arid environment in water scarce region, which is Badajoz in Spain that is situated in water scarce Guadiana river basin. We will add the following relevant description of the case study area in the data section and in the appendix of the revised version of the manuscript.

The model experiments was carried out for semi-arid climate at Badajoz in Spain (38.88^o N, -6.83^o E; 185 m above mean sea level). The study area is situated in Guadiana river base, which faces water scarcity during part of the year particularly in summer when water is needed for irrigation (Hoekstra et al., 2012). We run APEX for 20 years (1993-2012) using daily climatic data that includes precipitation, minimum temperature and maximum temperature extracted from the European Climate Assessment and Dataset (Klein Tank et al., 2002). We also used monthly average climatic data such as solar radiation, relative humidity and wind speed from the FAO CLIMAWAT database (Smith, 1993). Daily reference evapotranspiration is calculated using the Penman-Montheith equation, as implemented in APEX (Williams et al., 2008). The average monthly climatic data are tabulated in Appendix A-4.

Table A.4. The average monthly climatic data of Badajoz in Spain (38.88^{o} N, -6.83^{o} E; 185 m above 272 mean sea level), this table will be added in the appendix section of the manuscript.

Climatic variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature max, ^{0}C	14.1	16.5	20.4	22.2	26.1	31.9	34.9	34.7	30.0	24.4	18.0	14.3
Temperature min, ^{0}C	3.6	4.2	6.7	9.0	12.2	15.8	17.3	17.6	15.2	11.9	7.3	4.9
Precipitation, mm	50.2	39.5	30.9	41.1	41.9	10.8	2.3	4.2	25.1	64.4	65.2	64.0
Solar radiation, MJ/M^{2}	7.4	10.5	12.9	19	21.9	25.7	26.9	23.9	17.8	12.3	8.1	6.4
Relative humidity, %	83	71	63	56	45	42	37	35	46	64	76	80
Wind Speed, m/s	1.7	1.9	2.09	2.09	2.2	2.3	2.4	2.2	1.81	1.6	1.7	1.7
ET0, mm (penman monteth in APEX)	33.2	57.1	108.8	145.3	196.6	224.2	250.9	218.2	139.7	83.7	43.3	29.3

The physical and chemical characteristics of the loam soil, and nutrient content in the soil (nitrogen, phosphorus, carbon) are extracted from the 1×1 km^{2} resolution European Soil Database (Hannam et al., 2009).

Soil moisture content is initialised using the standard procedure in APEX, which is based on average annual rainfall within the period considered (1993-2012). We adjust initial organic-N content for each simulation so that the N build-up in the soil over the 20-year period is zero. We apply the graphical time-series inspection method (Robinson, 2002) to determine the warm-up period, i.e. the period in which simulation results are still affected by the model initialization. We find that we best exclude the first five years of the simulation, thus we show results for the period 1998-2012.

Comment

3. I know that water foot printing models/ET estimate models on land cover climatic information are not generally calibrated or validated hydrologically. Such appears to be the case of APEX. Although this drawback is well known, the authors do not justify why they are omitting any effort to do so. At least some effort should be done in the manuscript to perform a hydrologic (and/or nutrient load) calibration/validation of APEX in this region, or at least mention and justify why this is impossible to do. Worst case, a good sensitivity analysis of the main parameters regulating the water and N fluxes and/or exhaustive literature review of similar studies shedding some light on the initial parametrization of the model should be included.

Reply:

We thank the referee for understanding the data limitation for calibrating and validating the APEX model, which is more true when the experiment is by changing large field-management practices. We put effort to validate our simulation results with earlier studies for N-response curve. As we explained in the manuscript L.467-477, the shape of the N-response curves of our study is comparable with the N-response curve constructed for crops, including maize, for the EU based on field measurements (Godard et al., 2008). Our N-response is also consistent with the results presented by Berenguer et al. (2009), who carried out field experiments for maize for similar conditions in Spain.

In fact it would have been better to calibrate and validate the model for water- and nutrient fluxes; in the revised manuscript we will add a justification why we could not calibrate or validate the hydrologic and nutrient fluxes, also the need of doing it in the subsequent studies.

Comment
4. Does the APEX give an opportunity to choose the PET model? Is Penman-Monteith adequate for this region? Recent studies have found that this model over predicts PET [Milly and Dunne, 2016]. What parameters did you put into Penman Monteith if you didn't have any data?
Milly, P. C. D., and K. A. Dunne (2016), Potential evapotranspiration and continental drying, Nat. Clim. Change, 6(10), 946–949, doi:10.1038/nclimate3046.

Reply:
APEX gives five options to estimate PET: Penman-Monteith, Penman, Priestley Taylor, Hargreaves, and Baier Robertson. In our study we applied Penman Monteith, which is the default method in the model. We have all the required input data to apply Penman Monteith. Though Penman Monteith is commonly used for PET estimation, we find the study by Milly and Dunne (2016) to be relevant; and in the revised version we will add their disclaim on the Penman-Monteith method 'the method over estimate PET as it does not consider the stomatal conductance reductions, which is commonly induced by increasing atmospheric CO_2 concentrations)'.

Comment
4. Based on points 2, 3 and 4, how can you tell which of Tier 1 and Tier 3-APEX is better if you really don't know how accurate are both options due to the lack of observations and real data or calibration or validation? As you state in 489, "the precise values presented here should be taken with caution" and "the outcomes are subject to uncertainties inherent to any modelling effort". This makes me wonder on the real point of reading the manuscript.

Reply:
We argue that the comparison of Tier-1 and Tier-3 in the study is still valid as the change in the field-management packages was experimented for the same, default, model parameters. In addition the alpha and beta calculated based on tier-1 level, which is less accurate but easy to estimate the load to freshwater (Franke et al., 2013), does not respond as expected to the changes in the field-management options.

We simulate our experiment using the default parameter in APEX, without calibrating it; and we validate the result based on the N-response curve. We still acknowledge validating of APEX for the water and nutrient fluxes would have increased our confidence to the simulated results, and we will reflect on this in the revised version of the manuscript, also the need of doing it in the subsequent studies.

Other issues: (the following comments will be incorporated in the revised article)

L. 36-37. First sentence is the worst of all the manuscript. Check language

L. 42 - three quarters of what?

> The grey WF from global crop production makes three quarters of the total N-related grey WF in the world (Mekonnen and Hoekstra, 2015).

L. 66- tillage pan formation?

> Tillage-pan formation is a formation of compacted soil layer caused by repeated ploughing using heavy weight tillage machineries (Podder et al., 2012).

L. 66- no-tillage develops mulch cover?

> By practicing no-tillage the crop residue remains untouched as soil cover, which serves as mulch.

L. 49- Application rate, form of N applied are not practices.

Agricultural management practices that influence the grey WF include the N-application rate, the form of N-applied (particularly inorganic-N versus manure or organic-N), and the tillage and irrigation practice.

L. 50-52 This does not make sense

A low N-application rate will hamper cop growth and reduce crop yield (Raun et al., 2002). In addition, the low N-application rate will have small water-pollution per hectare, but will have large pollution relative to the amount of crops produced.

L. 75-79 and and and or or or

L. 96 what is a systematic model-based assessment?

It is an assessment using model in systematic way, which is methodical or a well ordered and efficient way.

L. 103 is this really more advanced? in what way?

In this paper the APEX model, process based water- and nitrogen balance and crop growth model, was applied to estimate the grey WF of crop production by tracking the pollutant load to surface water and groundwater with a daily time step. In the previous studies, the pollutant load to surface water and groundwater were estimated based on an annual mass balance approach (Mekonnen and Hoekstra, 2015;Liu et al., 2012). The earlier studies ignore soil organic matter build-up and decomposition, and nitrogen transformations such as mineralization, immobilization and nitrification, which all affect the N uptake and N load to freshwater.

L. 103-104 mention the tiers in this sentence first.

Franke et al. (2013) distinguish three tiers, which are ordered 1 to 3 in the increase of accuracy and decrease of feasibility (and data requirement) to estimate the load to freshwater.

L. 109 approach applying an approach

The more advanced tier-2 for estimating grey WFs from diffuse pollution is based on an N balance approach, applying a simplified model approach (see for example Mekonnen and Hoekstra (2015), and Liu et al. (2012)).

L. 99-101 Bad English

Will be replaced by 'We simulate irrigated-maize growth for twenty-years (1993-2012) at Badajoz in Spain on loam soil in a semi-arid environment'.

L. 114. I don't think you can determine the added value as it is now.

L. 127 "are" partitioned

L. 130 Quick and slow component?

Lateral flow is divided in to two: quick lateral flow joins to the surface runoff quickly; slow later flow components flows as subsurface lateral flow horizontally.

L. 126-136 It sounds to me as you are just putting in words the ticks/options and numbers that you are entering in the fields of the model.

L. 138-145 This is not necessary. Figure 1 has some strange arrows going nowhere. What is a unit of heat accumulation?

The unit of heat accumulation is growing degree days (GDD).

L. 201 or to surface water through runoff?

or to surface water with runoff

L. 192-195 Isn't this the main objective of the article?

L.192-195 is not the main objective. The main objective of this study is to explore the effect of nitrogen application rate, nitrogen form, tillage practice and irrigation strategy on the nitrogen load to groundwater and surface water, crop yield and the grey water footprint of crop production by a systematic model-based assessment.

L. 204 Is alpha< or > than beta?

Alpha is less than beta

L. 212 Eqs. 2 and 3?

At the tier-1 level, α and β can be estimated using equation 4 and 5 following the guidelines of Franke et al. (2013).

L. 219 what?

where s_i is score for the leaching runoff potential for environmental or management factor i, and w_i is the weight of that factor.

L. 229 full irrigation?

L. 236 derogation? and check units

derogation means an exemption from or relaxation of a rule or law. The unit will be corrected to 250 kg N ha^{-1} y^{-1}.

L. 287 why is it important to be zero?

N build-up is made zero to avoid N depletion and N surplus in the soil.

L. 338-352 Isn't this a discussion? Fig. 4 The definition of the three region seems a little bit arbitrary? Why do you put some much emphasis in Region 1 if it is almost the same for all packages? Considering the uncertainty of the analysis I would assume the are really no differences. Figure 6. Nothing makes sense in this figure. Check axis and data on grey and consumptive WF. Or is the difference in magnitude due to green water consumption? Is GW consumption so big in Spain? I don't think so. Everything here needs explanation. .....

L 338-352 is meant to explain the result based on the underlining drivers and the processes.

The definition of the three region in Fig. 4 is not arbitrary. The three regions has unique management package that gives the smallest grey WF, the grey WF in region-I is the smallest with Ma-CT-DI (Manure-conventional tillage and deficit irrigation), the grey WF in region-II is the smallest with Ma-CT-FI, and in region-III with Ma-NT-FI.

Region-I is shown magnified to add visibility that the grey WF is the smallest for all management packages at N-application rate equal to 50 kg N ha^{-1} y^{-1}.

Figure 6 shows the potential change to the grey WF and consumptive WF, if the reference management package is replaced with a management package reduces the total WF.

Figure 6 will be explained in the revised version.

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