Interactive comment on “Marginal cost curves for water footprint reduction in irrigated agriculture: guiding a cost-effective reduction of crop water consumption to a benchmark or permit level” by Abebe D. Chukalla et al.

Reply to Anonymous Referee #2

We thank Referee #2 for the comments; below we give the reply to the comments.

Comment

The manuscript is very interesting and focuses on a very important topic: WF reduction studied with the application of MCC for analysing the economic side of strategies improvement for water use reduction. The study is well balanced and clearly written, therefore I suggest accepting it after solving few comments.

Specific comments:

In the introduction literature is lacking, more details should be given on MCC, on possible studies that tried to perform something similar, and better explaining the advantages and innovation of introducing such an assessment (e.g., pay more attention on lines 67-70). In addition, the references reported are written often together (line 64: 4 references in the brackets) and explaining their single specific role as reference would be helpful.

Reply: We agree to the reviewer’s comment on the importance of introducing the cost side of analysing WF reduction, and to the comments on explaining the MCC with additional literature. The following explanations will be incorporated in the revised version of the paper.

The MCC for WF reduction ranks WF reduction measures according to their cost-effectiveness (WF reduction achieved per USD) and shows the most cost-effective set of measures for a certain WF reduction target. The MCC has been applied extensively for carbon footprint reduction in various studies, focusing on various sectors and regions. Enkvist et al. (2007) show cost curves for reducing greenhouse gas emissions of different regions globally. Lewis and Gomer (2008) develop an MCC for reducing greenhouse gas emissions of all sectors in Australia, and (MacLeod et al., 2010) develop an MCC for the agricultural sector in the UK. A detailed method to derive MCCs for the most economically efficient reductions in greenhouse gas emissions in the agricultural sector is presented by (Bockel et al., 2012). The weaknesses and strengths intrinsic to different methods of deriving MCCs of greenhouse gas reduction are reviewed in different papers (Kesicki, 2010;Kesicki and Strachan, 2011;Kesicki and Ekins, 2012). The application of MCCs in the water sector is just starting. Tata-Group (2013) developed MCCs for WF reduction in some factories. Addams et al. (2009) apply MCCs for closing the gap between water supply and demand in irrigated agriculture. Khan et al. (2009) discuss two possible pathways to reduce the environmental footprints of water and energy inputs in food production: improving water productivity and energy use efficiency. This work however does not explicitly specify the measures and their cost effectiveness, which would inform the unit cost of improving water and energy use efficiency. In the current study, we apply MCCs for WF reduction and show the cost effectiveness of measures as well as the most cost efficient pathway to reduce water consumption to a certain WF reduction target, e.g. towards a given WF permit or to a certain WF benchmark.

Comment

Lines 208-213: what are the average yields for the crops? Maize is considered cultivated in Italy only, or also in Spain for example? What about the other crops? With this point in mind, are the Figures 4-5 referred to maize production in one single country or in more? Understanding the country would make possible to connect these results with the values reported in the Appendix.

Reply:

In lines 208 -2013 we state that the WF of crop production is expressed in two ways: WF per tonne of crop production (expressed in m^3 per tonne of crop), or WF per unit area (expressed in m^3 per hectare per season). Maize, tomato and potato are cultivated in Italy, Spain, Israel and UK. In a previous paper we show the water footprint of each crop for each country (Chukalla et al., 2015). Figures 4-5 in the current paper illustrate the average WF (m^3 per tonne) for maize over different cases (four countries, three hydrologic years and three soil types). The whiskers around the WF estimates in Figure 4 show the range of outcomes for the different cases. The WF and cost values reported in Appendix G are also average over the cases and the countries respectively. In the current paper, we consider the average WF estimates, which means that the MCCs are not case specific; this does not affect the goal of the study, which is to introduce the methodological development of an MCC and show its application by giving a hypothetical example.

Comment

Line 250-251: not considering energy for transport and pumping is a very important simplification and surely affects the results. Please motivate your choice.

Reply:

We agree with the referee's comment. The energy costs to bring water from a source to the field (and the water losses during transport) are worth to include, but these are case specific and beyond the scope of the current study. We constrained the study to costs at field level. This does not affect the conclusions from the study as we will explain. The overall annual cost per measure increases if we add the cost of energy to bring irrigation water from a source to a field to the annual cost of a measure at field level. The cost increase will depend on the measure (Figure 1): the cost increase is highest for furrow irrigation, followed by sprinkler and drip or subsurface drip irrigation; furthermore, the cost increase is more with full irrigation than with deficit irrigation; and finally, the cost increase is most with no-mulching followed by organic and synthetic mulching). One can see that the additional cost related to energy for transporting the water to the field decreases in the direction of decreasing WF. Thus, this does not affect the order of measures ranked based on their cost effectiveness in reducing WF.

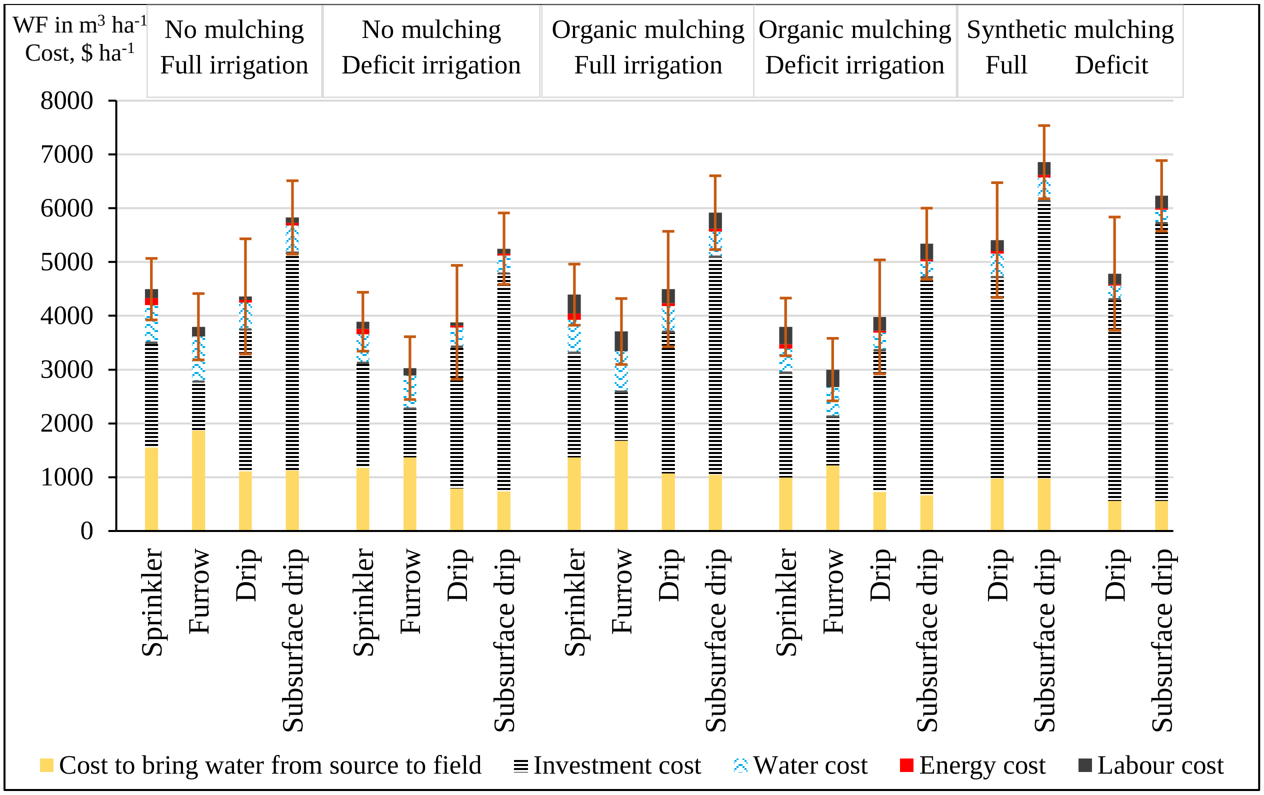

Figure 1: Average WF per area ($m^3\ ha^{-1}$) for maize production and average annual costs associated with 20 management packages. The whiskers around WF estimates indicate the range of outcomes for the different cases (different environments, soils and hydrologic years). The whiskers around cost estimates indicate uncertainties in the costs. WF estimates are split up in blue and green components; costs are split up in investment, water, energy and labour costs. The energy cost to bring irrigation water from a source to a field is calculated by multiplying the volume of irrigation water by a cost of energy, assumed 0.2 $ per m^3.

Comment

Finally, a discussion paragraph is missing, which would be helpful for better discussing literature, the benefits of this new method applied to WF and the possible limits met by authors.

Reply:

In the revised paper we will add the following discussion points: (a) discussion of the challenge of developing MCCs for each specific case, requiring a modelling effort for each specific case, (b) discussion of uncertainties involved when assessing the effect of certain measures through modelling, and the variability of effects related to climate variability, (c) a reflection on the problems of obtaining case-specific data on costs, (d) the potential to derive more general conclusions on the ranking of specific measures regarding their cost-effectiveness in WF reduction through more research across cases (different crops and different regions), and (e) the future relevance of MCCs for WF reduction once companies start aiming to reduce the WF of their crop products down to sector-agreed regional-specific benchmark levels and once governments are going to apply farm-specific WF permits based on the maximum sustainable WF in a catchment.

Technical comments: (all minor comments are incorporated)

Line 21: write "are" instead of "is" in "different cases are considered..."

Line 68: add "to" for "in relation to WF reduction"

Line 304: write "... the soils are taken from..." deleting is used

Figures 7-8: the text on the Y axis is put in the middle of the graph and cannot be read.

References:

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