RV#1:

The authors describe the development of a global data set of irrigated land. Irrigation mapping was performed by using such a data set published before (Siebert et al., 2013), remote sensing based vegetation activity and ancillary information such as cropland masks, suitability maps and climate data (Table 1). Better knowledge where and when irrigation is used is very important for many applications, therefore attempts to reduce the present uncertainty are highly welcome. The manuscript is well written and the figures presented in it are of high quality. However, I think that the article needs to be revised and rewritten completely before the manuscript might be considered for publication in HESS:

Authors:

Thank you for reviewing our manuscript, your valuable and sophisticated comments and your general recognition of the meaning of the topic. In the following we try to address your concerns – please find below our suggestions for improvement.

RV#1:

1) Title and abstract of the manuscript show that the authors cannot put their contribution into the context of the present knowledge and completely fail to describe the scientific merit and the innovation of their research. Title and abstract suggest that previous attempts to map irrigation were restricted to the use of survey based land use statistics and indicate that using of remote sensing and of suitability maps represents a major innovation. This is definitely wrong.

Authors:

We agree that title, abstract and some parts of the methodology leave space for misinterpretation. Accordingly, we revised both, title and abstract completely as well as parts of the methodology to better put our contribution to the scientific context. To address your concerns, we suggest a new title:

"A global approach to estimate irrigated areas – a comparison between different data and statistics"

As you mentioned, the irrigation map by Siebert et al. (2013) allocates irrigation to agricultural land according to statistical data and land use classification data. On the basis of this map we include irrigated areas that are not mapped in the approach by Siebert et al. (2013). We do this by following a decision tree that uses several input data (crop suitability based on topography, soil and climate, multi-temporal NDVI data, land-use classifications). Given the decision tree, we decide that a pixel which is not classified as irrigated in Siebert et al. (2013) must be irrigated or not. Thus, our approach allows allocating more irrigated areas than statistically designated for a specific region. A spatial detection and quantification of these additional irrigated areas seems scientifically important and innovative, since it illustrates a gap between different data from different sources and methods. Analyzing these differences (between the statistically calibrated Siebert et al. (2013) data and our new irrigation map) could be of interest for the scientific community.

RV#1:

At global scale, there are three other data sets of irrigated land which were published before: Thenkabail et al. (2009) used remote sensing and ancillary information to map irrigation but they did not apply survey based land use statistics in their mapping algorithm at all. The same *appears for Salmon et al. (2015). Siebert et al. (2013) is the only study that uses survey based land use statistics for mapping irrigated land but in addition they also apply a huge variety of remote sensing based national land cover products and remote sensing imagery as well. Therefore, using remote sensing products and suitability information is certainly not an innovation; it is the present standard in mapping irrigated land.*

Authors:
We are aware of these publications and cited all of them. It is well-known that previous approaches already derived irrigated areas from remote sensing products and suitability information. We do not state that just the application of remote sensing data and crop suitability data would be an innovation. Our approach differs from previous studies by using different remote sensing and suitability data as well as a different methodology. In the revised manuscript we will enlarge the description of applied data and methodology so that the difference to other approaches is getting clearer.

RV#1:
2) Developing new methods to combine a variety of different data sets for irrigation mapping is interesting from an academic perspective. However, the major challenge is to show that new methods improve present irrigation maps and reduce the uncertainty with regard to the extent and timing of irrigation. This requires in depth validation of the new data set and comparison to products published before. Unfortunately the validation described in the article is very poor and insufficient. The only data set used for validation are ground observations for Europe but the method used for validation is not appropriate. The authors compare their grid based product to point observations and it remains completely unclear how this can help to validate the accuracy of area estimates. What means an accuracy of 72% in this regard? What can we learn from this about the accuracy of the irrigated area estimate for countries like Spain or Italy where the authors detect more irrigation than in other studies before? The minimum requirement is that the authors present errors of commission and errors of omission for different countries separately. In addition they need to describe how relevant the point estimates contained in the LUCAS sample are for pixels of 1 km2 used in the product developed by the authors.

Authors:
We completely agree with you that the validation of the new irrigation map could be improved. Basically, a validation with national statistics is methodically not appropriate, since we are interested in the differences to the statistics. Therefore, we used proven ground truth information for samples, unless we are aware of scale issues when comparing it with our 1 km² grid. The LUCAS samples represent an unknown area (not a point) of the field in which the sample is located. Usually the size of an irrigated field in Europe should be close to our resolution of approx. 600 m². Thus, we assume that the LUCAS samples are suitable to compare with our gridded results. We also requested for ground truth data outside Europe, but it was not possible to get some.
For improving the validation and also the comparison with existing approaches, we will include a statistical comparison of our results with Salmon et al. (2015) and Thenkabail et al. (2009). An error of commission and an error of omission will be part of the validation.

RV#1:
3) Since irrigation is less relevant in Europe as compared to other continents the authors should focus their validation on other regions, in particular those where the new irrigation data set

differs considerably from the products published before. For sure this should be India, China and Central Asia. There is a variety of high resolution irrigation data sets available for these countries or regions which could be used as a reference. Ambika et al. (2016) should certainly be used as a reference for India while Zhu et al. (2014) could be used for China. In addition, there are inventories for the US (Ozdogan and Gutman, 2008) and Australia (http://www.agriculture.gov.au/abares/aclump/landuse/ data-download) that could be used to validate the product for these regions. All these data sets were developed by using time series of high resolution remote sensing images and a lot of local background knowledge that the authors of the present article cannot have.

Authors:
We agree that a regional validation should be part of the study. We will follow your suggestion to focus the validation on where irrigation is an important part of agriculture. If we get access to the data we suggest to compare the irrigation map with the publication of Ozdogan and Gutan (2008), Ambika et al. (2016) and Zhu et al. (2014).
The comparison with Ozdogan and Gutan (2008) showed +33 % more irrigated area for the USA, while the Siebert et al. (2013) approach showed 25 % more irrigation than Ozdogan and Gutan (2008). The comparison with Ambika et al. (2016) showed +22 % more irrigated area for India, while the Siebert et al. (2013) approach showed -18 % less irrigation than Ambika et al. (2016). A spatial regional analysis will be shown in the revised version.

RV#1:
4) Based on the validation exercise before the authors should also discuss more critically limitations and constraints of their own approach. A variety of assumptions are made in the classification (e.g. specific thresholds) that have a big impact on the result.

Authors:
The decision tree and the thresholds are a result of a sensitivity analysis and a comparison of different existing studies in the literature (Pervez et al. (2014), Ozdogan & Gutmann (2008), Pervez & Brown (2010), Wardlow & Egbert (2008), Aparicio et al. (2000)). In the revised manuscript we will discuss the difficulty of using NDVI as a vegetation indicator and the risk of over- or underestimation using hard thresholds.

RV#1:
In addition there are limitations because of the spatial, temporal and categorical detail in the input data used by the authors. Ozdogan and Woodcock (2006), for example, describe that in parts of China and Africa even Landsat imagery with a 30 meter resolution might be to coarse for land use classification because field sizes are smaller. The coarse resolution of the imagery used in the present study and the binary (irrigation yes or no) decision tree could be one reason why in many regions the share of rainfed and irrigated fields cannot be distinguished resulting in considerable over – or underestimate of the irrigation extent.

Authors:
Land use classifications always have a scaling problem – temporally and spatially. We tried to argue why we chose the size of 30 arc seconds. The installation of irrigation technique is expensive and for only one field or a small field not economic. For Africa and Asia, field size in general may be much smaller than our resolution, but usually, irrigated fields may be much bigger in size, since irrigation is often applied by large scaled farms with large fields or small

fields are agglomerated since irrigation infrastructure and water is available. Accordingly, we assume an agglomerate of fields rather than a single field within a pixel.

The resolution is a source of uncertainty. Salmon et al. (2015) solved this problem with a field size factor. If they had information about field size they recalculated their results, if not, they assumed that only 80 % are in agricultural use (50 % in case of a mosaic class). The global results without the field size factors are very close to our findings: 368,076 mha (see manuscript) and 376,7 mha (Salmon et al. 2015).

This part is very short in our manuscript. In a revised manuscript we will enlarge the explanation and try to clarify our arguments and discuss the advantages of using field-size factors or not.

RV#1:

Furthermore, the suitability data used by the authors will certainly not reflect the diversity of land use patterns at the ground, in particular for regions with multiple cropping. What about permanent crops like citrus or olives?

Authors:

The agriculture suitability data represents an overall suitability of the 16 most common crops and considers the annual course of the growing period and multiple harvests. One of the main finding was that the NDVI courses indicate double or multiple cropping in regions where only one harvest would be possible without irrigation.

The suitability considers oil palm – as a permanent crop. Olive-, date-, almond- and citrus trees are not considered in the suitability, since their global area is relatively small, but even plants which are used to grow in a dry area need a minimum of water and if the climatic conditions do not provide enough rain the plants have to be irrigated. We will add this point to the discussion.

RV#1:

What about regions in which irrigation is mainly used for pasture (New Zealand, Australia). There are many sources of uncertainties but little information how the mapping product is impacted by these uncertainties.

Authors:

Most of the irrigation is used for cereals and staple crops, a minor share for vegetables, fruits, oil crops and pasture. In developed countries the share of irrigated pasture or permanent crops may be higher, but in using the existing study of Siebert et al. (2013) as a basis in our approach, the irrigated pastures should be part of the data set and therefore also be part of the new irrigation map, especially as you consider that irrigated pastures are more important in developed countries where the official statistics are less susceptible to inaccuracies and are more reliable.

RV#1:

To my opinion it is not helpful to release products without a proper validation and uncertainty analysis. There is already a lot of confusion in the community caused by poorly validated land use products and for countries like India just the remote sensing based estimates of irrigated land vary between 70 and 220 million hectares. Hydrological modelling has shown that even an extent of 70 million hectares would result in a drastic overuse of water resources so that it is extremely hard to believe that there should even be much more irrigated land at the ground.

Authors:
We would like to clarify this issue. The paper was not about increasing irrigated area clueless, but to compare existing products with official national statistics. The irrigated areas in India are a good example and shows the wide spread of the results. Our analyses for India show 88.4 million hectares of irrigated land. This is close to the results of Ambika et al. (74.14 million ha) and are far away from Thenkabail et al. (220.22 million ha).
For ending the confusion between the different data and improving validation and discussing uncertainties, we suggest adding a table on total irrigated area for the different global and regional approaches (e.g. Thenkabail, Ambika, Ozdogan, etc.) together with national statistical data for each country worldwide for a detailed comparison between the different irrigation data in a supplement.

RV#1:
To conclude: what is needed is not to publish just some more figures with unknown accuracy but to develop products that are better than the products developed before and to prove this by an appropriate validation.

Authors:
We absolutely agree with your opinion on this and we tried to improve the manuscript implementing suggestions to your comments above.
Again, thank you for your interesting and constructive comments. We hope we could eliminate your major concerns and clear up some misunderstandings. We are very confident that the improvements through your review make the goal and the intention of our study clearer and the methods more understandable and transparent.

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