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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Global-scale drought risk assessment for agricultural systems" *by* Isabel Meza et al.

Isabel Meza et al.

meza@ehs.unu.edu

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Anonymous Referee #1

The authors present a relevant and interesting manuscript, where they have studied and mapped composite drought risk at the global scale. For assessing agricultural drought risk, they have separated drought hazard/exposure in irrigated and rainfed cropping systems, and combined these hazard indicators with socio-ecological vulnerability. Finally, they have compared the obtained drought risk metric, with reported drought hazard events from EM-Dat. In general, I like and agree with the approach described in the study. My notes about the study are written below.

Response: Many thanks for the overall positive feedback.

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Discussion paper

1. I very much agree with looking into drought hazard for irrigated and rainfed cropping systems separately. However, the way these hazard indicators are combined, is potentially misleading. The hazard indicators are combined in a way that equalizes the weight of drought hazards in irrigated and rainfed cropping systems. However, as irrigated systems are, in general, more resilient to drought (irrigated systems can mitigate drought impacts by irrigation while rainfed systems cannot), equalizing the hazard associated with rainfed and irrigated systems, does not seem sensible. Further, if I understand correctly, based on the analyses, drought is more frequent in irrigated cropping systems compared to rainfed systems, which is not something that would be initially expected (Page 7, Lines 193-194). To make the methods comparable across rainfed and irrigated cropping systems, the authors could potentially define droughts for rainfed systems as for irrigated systems, but without the option to compensate the demand deficit by irrigation.

Response: We agree that combining the indicators for rainfed and irrigated drought risk may be misleading, and we have highlighted this aspect already in the discussion section (lines 430-441). However, we don't agree that irrigated systems are in general more resilient than rainfed systems. The way how rainfed and irrigated systems mitigate drought is different. In rainfed systems crops are often cultivated in the wet season and soil conservation methods or water concentration are used to accumulate soil moisture in the cropped soils. Irrigated systems allow crop cultivation in arid regions or in the dry period of the year. For example, half of the global irrigated land is located in arid and semi-arid regions (Siebert et al., 2015) and the majority of irrigation water requirement in South Asia is in the dry Rabi season (Biemans et al., 2016). However, these systems rely heavily on the functioning of the water supply infrastructure, which is often extremely complex. There are many reasons why water supply to irrigated fields often fails in practise, in particular during drought events. We account for these differences by using different indicators to calculate drought hazard for rainfed and irrigated systems.

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Discussion paper

We agree that our assumption of a similar weight for irrigated and rainfed hazard is questionable, but to quantify these weights would require a lot of region specific information that is not available at global scale (we mention this aspect in the discussion).

We want to highlight that the reasoning for the calculation of the total risk in this manuscript was less to support comparisons across countries but to account for the different extend of irrigated and rainfed systems within the specific countries. There are countries in which crop production is completely rainfed and countries in which all crops are irrigated so that only the risk for the rainfed or irrigated systems are relevant. Except from these extremes, crop production in most countries is either predominantly irrigated or predominantly rainfed. We account for this by calculating total risk as the harvested area weighted mean of the rainfed versus irrigated drought risk. We will add one section to the revised version of the manuscript to explain this reasoning and to support the interpretation of the total risk maps.

2. The vulnerability assessment includes a high number of indicators. Although, the authors have excluded variables that have >0.9 correlation, many of the indicators are still most likely highly correlated. Considering the method used for calculating the vulnerability metric, this would lead to some phenomena being unproportionally weighted in the composite vulnerability index. Further, with this many variables, it is also more difficult to pinpoint and isolate potential socio-economic entry-points for reducing drought vulnerability. Hence, it might be worthwhile to analyze how the variables correlate and identify the most relevant indicators using e.g. PCA.

Response: Thank you for the comment. For the multicollinearity analysis we follow a standard approach for composite indicator construction, as e.g. described by OECD in their Handbook on Composite Indicator Construction (OECD, 2008). Indeed the multicollinearity analysis has revealed that several of the indicators are highly correlated with correlations >0.7. As mentioned in the methods section (lines 245-246) we have decided to keep highly correlated indicators when they present different drivers of vulnerability (and hence different entry points for vulnerability reduction). We will add some lines in the discussion, where we mention this as a potential limitation of our work.

Regarding PCA, we understand that there are different approaches to identify a final set of weighted vulnerability indicators, incl. statistical approaches (e.g. PCA) and expert-based approaches. Here, an expert-based approach is applied where indicators were identified based on a review of the literature and their relevance was evaluated based on expert judgment (n = 78 experts participated in the weighting). We will add a few lines in the discussion that statistical approaches (e.g. based on PCA) could have been an alternative to the expert-based approach used here, and will indicate this as an outlook for future research to compare the findings of statistical and expert-based approaches. Such a comparison (PCA vs. expert-based approach) was conducted by Hagenlocher et al. (2013), who did not find significant impacts of the choice of the approach on the final vulnerability index.

3. Fig. 6: The comparison between the drought risk indicator developed here and the drought hazards observed in EM-DAT is a relevant and nice addition to the study. However, visually it does not seem that the amount of observed drought hazards correlate with the risk indicator presented. I would recommend showing a scatter plot about this relationship (especially, since the authors refer to this section as a validation of the proposed drought risk indicator), at least for those areas where data exist for both sources, so that the reader can assess their agreement more easily.

Response: Thank you for the comment, a scatter plot will not improve the visualization of the results just because EM-DAT is not based on physical parameters to record droughts. The number in EM-DAT depends highly on data availability (some countries in Africa are frequently affected by drought, but this is not recorded consistently) and the size of a country is important (larger countries often indicate a higher number of drought events, e.g. China, USA, Russia). This is described in the manuscript (lines 397-402; 492-502) and countries are mentioned as an example.

4. The authors have assessed the risk of drought by combining the associated hazard, exposure and vulnerability components. However, the difference between hazard and exposure is currently not clearly stated and defined in the manuscript. For example, what are the drought exposure and hazard components used for deriving the results in Figs 2 and 3. Further, it would be good to explicitly explain the exposure component in the text (exposure of what?), since also some of the vulnerability indicators could be viewed as being related to drought exposure (e.g. % of GDP from agriculture etc., rural population).

Response: Thanks for the comment, following the IPCC (2014) definition of exposure as "elements located in areas that can be potentially affected by hazards", exposure in our analysis is directly related to the hazard. As described in section 2.1, we used rain-fed and irrigated croplands according to the Monthly Irrigated and Rainfed Cropping Areas (MIRCA2000) dataset (Portmann et al., 2010) as the exposed element. We will add the definition of exposure in the methods section (2.1 chapter). GDP from agriculture was included as a vulnerability indicator since countries with high dependency on agriculture, are more vulnerable to droughts; this indicator was also the most relevant indicator ranked by the experts.

5. The GCWM was forced with monthly data, which were transformed into pseudo daily climate. As products that readily have daily records exist (e.g. AgMerra, ISI-MIPforcing), why they chose to use monthly forcing data?

Response: We agree that the way how pseudo-daily climate is generated from monthly input data represents a source of uncertainty. However, since drought is an event that develops slowly, we are confident that our basic findings are not affected by this limitation. For the methods how drought hazard is calculated in our study it does not matter much whether a rainfall event is a few days earlier or later.

We are aware of alternative data sets that could be used as climate input and in fact we started to process global reanalysis data to explore the potential of using these daily data in GCWM and WaterGAP as climate input. However, the products mentioned by the reviewer have own limitations. AgMerra is only available for the period until 2010, similar to some other climate data sets used by ISIMIP. Other data sets do not provide all the variables needed to calculate potential evapotranspiration using the Penman-Monteith method. WFD and some other products, for example, do not provide daily maximum and daily minimum temperatures which are essential to quantify accurately the vapor pressure deficit. Finally, ISIMIP input data have a resolution of 0.5 by 0.5 degree while GCWM is running on a native 5 arc minute resolution (0.0833 degree). Because of these challenges, we decided to use the well established CRU monthly climate input for the present paper and refer to future activities and future studies in which we will explore the use of daily climate input data.

6. Minor comment for structure: would be good to be consistent between methods and results in which order you present the results (method: rainfed, irrigated; results: irrigated, rainfed)

Response: Thank you, we will change it accordingly.

7. It would be worthwhile to cross-refer to Fig. 1 in describing the methods, as it would make the methods easier to understand. This would also bind Fig. 1 better to the rest of text, as now it is a bit isolated from it.

Response: Thank you, we will change it accordingly.

8. I would recommend tabulating also the other data than vulnerability indicators used for the study, so that the reader can get an understanding of the data more quickly and easily.

Response: Thanks for the suggestion. For a better understanding of which data was used for the hazard/exposure analysis we will add an explanatory table with datasets and sources in section 2.1.

9. Page 5 Rows 116-117: The definition of the MIRCA-areas is a bit unclear.

Response: Thank you, we will re-run the rainfed hazard/exposure assessment at pixel level, therefore it will be no need to describe the MIRCA-areas anymore, the text will be revised to omit the lines that describe it (e.g. lines 116-118, 131-133, 136, 149, 186, 190, 202-204) and emphasis will be placed on the analysis at pixel level.

10. Figures 2 and 3: The range for color scales of the figures should be the same, at least for the hazard and vulnerability figures. Currently, it is very difficult to assess the contribution of each component on the total risk factor, and it seems that the hazard component has a way stronger influence on the drought risk compared to vulnerability (the mapped patterns are essentially the same for hazard/exposure and risk).

Response: We agree and are aware of this as a limitation from the values perspective, since the number depends on the set of variables and the methodology used. The different components have the same color scheme to better differentiate the minimum and maximum values of each one. However, the advantage of showing values is that readers can reproduce why the risk map is colored like it is. We add how the classes were made in the caption of the figures to help the readers to make their own categorical classification while keeping the numerical info.

11. Why hazard/exposure for rainfed is computed at national/sub-national level? Further, why these are aggregated to national level in analyses of for agricultural systems? These aggregations make it hard to compare the different results. It is of course ok to finally aggregate the results to country scale, but would be good show also the non-aggregated results for all the results.

Response: Thank you for the comment. The rainfed hazard/exposure will be computed at grid cell level and the figures will be changed accordingly.

12. Fig. 5: Would be good to have the y and x axes in same scale, not to give misleading impression of the results. And/Or you could show 1:1 line, and with that it would be easier to see in which countries risk irrigated agriculture is higher/lower than in rainfed agriculture

Response: Thanks for the comment. We will change the axes to normalized risk scores.

13. Page 7, Lines 170-173: Why is IH transformed logarithmically?

Response: IH describes the volume of irrigation water needed additionally in drought periods. In most grid cells these volumes are relatively small but there are also some grids with extremely high values. In 569 out of the 26,478 irrigated grid cells the additional irrigation water requirement per drought event is lower than 100 m^3; in 1,450 grids it is lower than 1,000 m^3. These are grids with very small irrigated areas. However, there are also 95 grids where the additional irrigation water requirement per drought event is larger than 100,000,000 m^3. The logarithmic transformation accounted for the specific value distribution.

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