Review: Sahana & Mondal - Evolution of multivariate drought hazard, vulnerability and risk in India under climate change, NHESS

Summary

This paper presents a drought risk assessment for India for a baseline period and for two RCPs and two SSPs. The methodology used seems appropriate for the data used and spatial scale considered. The authors found that drought risk was primarily comprised of the drought vulnerability component, rather than the hazard, these results were shown effectively using bi-variate maps. Overall, I found this an interesting paper with results and outcomes that could be useful for drought planning and mitigation at the high level in India. However, I found that the clarity of the paper could be improved and made more expansive making it easier to follow and reproduce elsewhere. Specific examples are discussed below. I recommend that this paper is revised before publication to clarify key methodological points highlighted below.

Major comments

I found the description of the methods to calculate the DHI and DVI in the supplementary information unclear, with not enough detail provided on the steps and processes with no further information provided (some examples listed below regarding weighting and standardisation). I would like to see the methods in the main body of the paper expanded. I recommend that all the whole methodology is moved to the main body of the paper, rather than the fundamental steps being in the supplementary information. I would also suggest that Figure 1 in the main body of the paper is expanded, with more detail and steps added to fully capture the methodological steps described in the paper – this is further discussed below.

Use of terminology – literature usually talks about vulnerability factors – i.e. the factors that make a person or location vulnerable to drought impacts. Also regarding vulnerability terminology, you mention components of vulnerability in the introduction (L35-38), how do the indicators (or factors) you used map onto these? This could be included in Table 1. Did you consider using for example, WorldPop data such that the vulnerability assessment could be disaggregated by sex? A final question on the factors used, how do the vulnerability factors selected address the exposure component? Although a population may be vulnerable to the impact of drought, they may not be exposed to drought or may be exposed to a lower severity of drought hazard than in other locations, for example.

The baseline period used (1980-2015) excludes the past six years, excluding significant drought events in 2016-2018 and 2021. Is there a way that updated precipitation data could be obtained and analysed to include these recent events?

L140-142: the first sentence here states that variability of the two scenarios increased over time, but the second states that the baseline period is more variable than the projected period. I am not sure how both of these statements can be true, nor am I convinced I can see these difference in the time series for precipitation or soil moisture. Please clarify this point further. This also applies to Table 3 and the text in L199-205, and Table 4 and text L232-233. Figure 7 is mentioned only on two lines at the end of Section 3.3.1, could this summary be referred to in the previous discussions of hazard, vulnerability and risk as it is a more intuitive figure to understand than tables shown in Tables 2, 3 and 4.

L233-238: Here you state that the RCP6.0-SSP2 Far future scenario is not the worst case for drought vulnerability, but was the most severe for drought risk due to the hazard component (L233-235).

Then on L236-238 in the discussion of Figure 6, you state that drought vulnerability makes up the majority of the drought risk for the same scenarios. Please could you clarify these seemingly contradictory statements. I do not disagree with the point that we need more holistic drought risk assessment though.

Section 3.3.2: At what spatial scale is this information useful to policy makers? You could consider whether the gridded data used here is relevant to that of decision makers.

L269-270: You say here that this study is an improvement for decision makers over existing drought risk assessment in India. Please briefly state what this improvement is.

Supplementary information

The description of the categorisation of the MSDI at the bottom of page 2 is not clear and should be expanded – for example, it should be clearly stated which categories from McKee et al., - presumably extreme drought, severe drought, moderate drought etc., but you should include the thresholds and categories used in this study here. The meaning of the following two sentences ("Further, each category is organised into sub-groups based on the occurrence probabilities of the selected category. While the weightages are assigned to MSDI categories to account for drought magnitude, ratings are assigned to the sub-groups of each MSDI category to account for drought occurrence probability") are aren't sufficiently clear; the methodology of how weights were assigned should be described more clearly – for example, you start talking about ratings and clusters, and it is not clear what these are used for.

The description of the drought vulnerability index is also overly complex and should be clarified by describing the process in words. You should also be specific for example on how exactly data were standardised and what is meant by 'suitable weights' – what makes them suitable, how have these be validated and checked?

Minor issues

In several places e.g. L119 and in the supplementary information you mention that data have been standardised, please explain how these data are standardised (e.g. across time or space).

L99-100: '…and brought to a monthly time-scales.' This isn't clear – how and what metric? Total precipitation? Average soil moisture? Please expand on this comment.

L139: 'the country-accumulated data of these hydro-climatic variables…' please clarify how these data were accumulated

L145: ' …many regions is less **severe** compared to the baseline period.' Word missing

L168-169: It is not clear whether this choice of low skill GCMs was in the current study or Koutroulis et al and Cook et al. – note that this same comment is also made on L209-210.

L193: Highest differences… → The biggest difference in…

L198: many region of the country **are** expected to

L211: …sub-division ~~wise~~…

L211: Here you mention meteorological sub-divisions, what exactly does this mean, how were these defined?

L222: …expected to be under high risk to drought compared… → …expected to have a high drought risk compared…

A mix of tenses seems to be used throughout, this should be reviewed, ensuing that the past tense is used where appropriate.

In some places 'Far Future' is capitalised and others it is not – you should ensure this is consistent.

Tables and Figures

Table 1: Please also included the last date that the factors were updated and the date range that was available. Some of the descriptions of the datasets are unclear, for example, Water Bodies Fraction and Groundwater – it is not clear what these data actually are, and what they're measuring. It would be useful to include the unit of each factor where appropriate, e.g. for 'Groundwater', 'Water Bodies Fraction'

Table 2: I find these tables unintuitive and difficult to marry up with the description of results in the text. e.g. L149-15150: 'The future drought hazard assessment using the projected hydro-climatic variables revealed that more than 35% area of the country is expected to be under the low hazard class, as compared to 8% in the baseline period' – I can't seem to make any of the very low hazard boxes up to these numbers or the difference between them. You could consider adding a more detailed example walk through of what this table means. There is also no reference to or legend for the colour scheme used here.

Table 3 & 4: I assume these are all showing SSP2 scenarios, please clarify in the caption.

Figure 1: it would be helpful to refer to this figure in the description of methods included in the Supplementary Information. The DHI and DVI should be directly referenced in this figure to clarify when these are calculated in the processing chain – including mention of the baseline period.

Figure 4: There are some parts that are white, yet white is not mentioned in the legend.

Figure 5: I recommend adding another colour to the legend here to highlight the higher risk areas (such as a dark red or similar). Do the classes used represent any specific categories of risk?