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Discussions



# *Interactive comment on* "Exploring the link between drought indicators and impacts" *by* S. Bachmair et al.

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Response to A. van Dijk (referee #2)

We thank referee # 2 for the encouraging review and the constructive comments. We especially appreciate the ideas on the interpretation of some of our findings. Below please find a reply to each comment:

[1] "Line 8 and a few other places) It seems you are using the term "ground truthing" here to describe the translation of drought index to impact. By contrast, the interpretation a reader may well make (like I did) is that 'ground truthing' means testing the accuracy of estimation using ground measurements of the same thing. Hence suggest rephrasing."



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Thank you for drawing our attention to this. We use "ground truthing" in terms of evaluating drought indicators with impact information. We will add an explanation to the manuscript to delimit it from the remote sensing terminology.

[2] "Please provide a some description of the nature of the drought impacts contained in your data base to go with Figure 2. What sort of impacts were reported in each of the 12 categories, in what sort of sources were they reported, and in what way were they described?"

We will add a short description of the types of impacts, but would like to refer to the full report on the European Drought Impact report Inventory (see Stahl et al. (2012) in reference list) for further details of the nature of drought impact data.

[3] "When comparing Fig 2 a and c there is suggestion of a drought impact cascade, in that minor drought lead to reported impacts mainly in agriculture, whereas the severest drought in 2003 had a whole host of impacts, several of which I imagine may have been experienced never or rarely before. This is important in the context of resilience and adaptive potential; it is far easier to adapt to predictable drought impacts (typically associated with droughts with a shorter return time) than to poorly predictable ones associated with return times of say 25 years. In fact, there is a case to be made that a drought that returns more often than that should not be called a "drought" but just a "dry year", as it is evidently not an extreme event. For rare events landscape, infrastructure, society, agricultural practices, water management etc can all change enormously in the intervening time, to the extent that we may barely be able to anticipate drought impacts and hence also not robustly manage for them. (For an example in an Australian context see http://onlinelibrary.wiley.com/doi/10.1002/wrcr.20123/abstract). None of this invalidates your analysis, but some discussion of these aspects is necessary for appropriate interpretation and also will enhance the insights from this study."

Highlighting differences in impact types for different drought events is a well-taken point. We agree on the suggested "drought impact cascade". Nevertheless, events



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like in 2011 and 1976 also show a diversity of drought impacts, not only 2003. To exclude less severe events (the suggested "dry years" by referee #2) we set a threshold of 35 impact occurrences per event to be considered in the analysis. The issue of low adaptive potential to drought impacts that only rarely occur is a good point. Systematically collecting impact information and disseminating knowledge about drought impacts of past events may, however, add to a stronger visibility of drought impacts and recognizing the need for adaptation and management actions. We will pick up this issue in the discussion of the revised manuscript and appreciate the suggested interpretations.

[4] "Given the prominence of the 2003 drought some interpretation and discussion of the relative importance of extreme temperature and low rainfall is needed. In your opening sentences you use a (fairly old) 'rainfall-focused' definition of drought but both the better performance of SPEI and the wider range of impacts in 2003 suggests that you cannot ignore the importance of compounding extremes."

Again, this is an interesting point raised by referee #2. We will pick this up in the discussion of the revised manuscript.

[5] "Please define what impacts are considered associated with hydrological drought, and which not. For example, where do crop damage, wild fires related to desiccation and water quality problems fit? Which drought impacts are clearly not hydrological?"

This question was already raised by referee #1. We answered that "The differentiation between I and Ih is based on a keyword search of the impact description and does not strictly follow any impact category or impact subtype. When an impact is mentioned to be associated with surface or groundwater (keywords: stream, river, creek, lake, reservoir, groundwater, water supply, etc.) it is defined to be a hydrological drought impact. Impacts excluded from hydrological drought impacts are, e.g. agricultural and forest impacts, impacts due to heat waves, soil subsidence, or fire. We will add this additional information."

[6] "To call a correlation >0.9 perfect is a contradiction in terms. Call it 'very strong', or



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such."

Thank you for this comment, we will change this.

[7] "If I am interpreting the analysis results correctly you are typically dealing with very small sample sizes (e.g. 7 drought years, 14 states). I don't see this as a huge problem but it does require you to be more careful with interpretation of correlations and significance and use methods developed for small samples. Please describe how you did this."

The answer to the issue of small sample size has several strands. In general, we will put more weight on discussing data limitations including small sample size in the revised manuscript.

1) Regarding the correlation analysis over time with each timeseries consisting of 204 months we think this generally does not fall under "small sample size". We agree, however, that for some states there are only a small number of months with impact occurrences in the entire timeseries; these timeseries are zero-inflated. Please note that in table 2 we only show the number of months with impact onset, which is used for the threshold calculation, but not the number of months with impact occurrence. The number of months with impact occurrence is higher, at least doubled. We will add this information to the revised manuscript. Nevertheless, we decided to set a threshold of at least 10 months with impact occurrence to be considered in the analysis. This will remove the state Thuringia from the correlation analysis over time and four other states when only considering hydrological drought impacts. Additionally, we tested the robustness of the calculated correlation coefficients through bootstrap subsampling (90% drawn per run, 500 iterations), which showed that the median of the calculated r based on the bootstrap subsamples is similar to the presented r. Please also note that we revised our analysis to consider autocorrelation in the cross-correlation analysis as requested in the additional short comment. This does not address the sample size issue, but we would like to mention this in this context.



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2) Regarding the correlation analysis over space the small sample size is definitely an issue (e.g. n=12 or n=13 or n=14 depending on chosen indicator). We are well aware of this, but we will put more weight on this in the discussion section of the revised manuscript. We think the event-based analysis adds extra information since it clearly shows that a best indicator threshold also varies over time. Nevertheless, given the small sample size it needs to be interpreted with care.

3) Regarding the "threshold" calculation (=indicator values associated with drought impact onset), where the small sample size is also an issue, we plan to slightly adapt our methodology, which does not change the content of the results, but will likely make a stronger argument to the reader. Referee #1 also expressed difficulties in interpreting the boxplots, where we replied that "The boxplots are based on number of months with I onset. If several impacts started to occur in a month this information is not reflected in the boxplots. Therefore, we overplotted the boxplots with the data points sized according to the number of impact onsets. [. . .] Another option to show this would be to base the boxplots not on number of months with impact onset but on number of impact onsets (multiple counting of monthly indicator values if several impact onsets took place in one month)." The reasoning behind the initially chosen methodology was to give less weight to months with many impacts (e.g. July 2003). Nevertheless, given the raised concern by referee #1 (regarding interpretability) and referee #2 (regarding small sample size) we prefer to proceed with boxplots based on multiple counting of monthly indicator values if several impact onsets took place in one month. Figure 4 and 7, and Tables 2 and 3 will be modified accordingly. We will hold on to n=5 as minimum number for calculating boxplots and showing individual data points for n<5, as recommend by Krzywinski and Altman (2014), Nature Methods.

[8] "Section 4.2. There are links between return time, resilience and efficiency that could be discussed here. It is relatively easy to adapt to frequent drought events, but typically at the cost of reduced production efficiency in normal years. By comparison, adapting management to be resilient to rare events is usually prohibitive from the per-



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spective of opportunity costs. Furthermore, at the end of this section, you might like to consider the difference between “event-dependence” between regularly recurring ‘droughts’ (dry years) and rare extreme events.”

Good point, thank you for drawing our attention to this. We will add this to the discussion.

[9] “page 7604, top) It strikes me that this provides a clear argument to focus on developing (bio-) physically meaningful drought measures rather than conceptual indices? After all, that would allow us to take into account any spatial differences in susceptibility to drought as a function of soil properties, vegetation type, etc?”

We agree that large regions are likely to possess differing inherent vulnerabilities to drought and therefore the selection of a “best” indicator and indicator thresholds should be carefully made by analyzing vulnerabilities and impact patterns at smaller spatial scales.

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 2, 7583, 2014.