Reply to Referee 2

We would like to thank Referee 2 for his/her constructive comments and feedback on this manuscript. We think that the suggested revisions based on the Referee's comments will certainly improve the article. Please find our responses (in blue) to each point raised by Referee 2 (shown in black) below.

Major points

Although the title of the paper sets out the aim to explore the benefits of such a multidisciplinary approach for drought research, however I feel like the discussion would really benefit from a discussion of how these results and type of analysis is beneficial for real world applications or drought managers. In the UK for example, water companies must plan for droughts that are the worst on record (and actually now, worse than those on record using stochastic approaches), so having a good understanding of what droughts were severe, where and from what perspective is extremely important for the drought planning process. I am interested to see how this research will benefit water/drought management from the German perspective. The discussion could also be strengthened in terms out how the results compare to other studies in the region and how the droughts identified may differ in terms of their severity/impact – what was the effect of using multiple indices and the impacts here compared to these other studies?

Response: 1) We like the idea of discussing the benefits or the potential of our study for drought management and will include it in section 4.2. This is indeed crucial given the lack of a centralized drought management authority in southwestern Germany. For drought monitoring the State Institute for the Environment of Baden-Württemberg might offer a low flow monitoring system in near future and the DWD provides monthly maps of an aridity index for Germany but there is no overall drought management authority in place. With our drought catalogue we get a better understanding of past drought events. The worst case droughts can be used as inputs for future drought planning. We suggest to provide a discussion point where we stress the need of a multi-sectoral regional drought management plan and how this or similar multidisciplinary studies could provide a basis and help to develop such a plan. 2) In section 4.2 we will also include a comparison to other drought studies in our region to discuss the added value of a multivariate drought study instead of a single variable drought study (even though most drought studies in the study region focus on methodological aspects).

Minor and technical points

Thank you for the minor comments. We agree with your suggestions and comments on grammatical changes and minor technical points and will address them in the revised manuscript. Please find below our replies to some comments that we thought needed some clarification or discussion.

Figure 1: Overall I like this diagram, however have a few comments. 1) in the combined drought frequency index box you mention S1, S2, S3 events, but it's not clear from the rest of the diagram where this categorisation has come from (and I don't think is mentioned elsewhere in the paper) is there a typo here? If not, perhaps clarify? 2) The red arrows on the right of the diagram show the outcome of the meteorological, hydrological and vegetation drought indices feeding into the

distinctiveness analysis, but the impact data also feed in to this section – amend the arrows to show how the impacts feed into the final part of the analysis.
Response: to 1) Indeed, that was a mistake. We will change that to D1, D2 and D3 for the different drought classes. 2) Thanks for the hint! We will add the missing arrow.

L1157-119: You use three categories of impact (agriculture, ecology and hydrology), the EDII has ~14 categories, from what you've said I think that you have grouped EDII categories to create 3 groups of impacts, is this the case? Please clarify in the text.
Response: Yes, we have grouped the EDII categories into three new groups of impacts (agriculture, ecology and hydrology). We will include a Table in the supplement where we list which impact type from the EDII categorisation was assigned to the three groups and will also clarify this in the text.

Figure 2: It is quite difficult to see the colour of the points for the tree locations against the elevation layer – you could either make the elevation slightly transparent to make it paler or change the colour of the points (or both) to make it easier to read
Response: We will change this Figure and use less colors.

L129-145: This section on the use and calculation of SPI and SPEI would benefit from a discussion of the distributions selected and the potential impact this choice may have had on the results – e.g. recent papers have tested appropriate distributions for such standardised indices Stagge et al. 2015 (https://doi.org/10.1002/joc.4267) and Svenssson et al. 2017 (https://doi.org/10.1002/2016WR019276). It isn't clear if a reference period was used, or whether data were standardised against the whole time series available – please clarify in the text.
Response: We will clarify that we selected the gamma distribution for the SPI, because of its general good fit with precipitation sums of different accumulation periods for Europe and refer to Stagge et al., 2015. For the SPEI, we clarify that we used the generalized logistic distribution as suggested by Beguería et al. (2014, https://doi.org/10.1002/joc.3887) and refer to the latter paper. As reference period we used the longest available common period for both meteorological stations (which is 1810 to 2018). We will clarify this.

L151: You mention that tree ring data were gathered from 70 locations, but from looking at Figure 2 there doesn't look to be 70 points representing tree stands – is this correct (or are there many overlapping points on the map?)
Response: Indeed, that was a mistake. The initial dataset consisted of tree-ring data from 70 locations. After quality control and removal of short series the final dataset consisted of tree-ring series from 55 locations (see also Table S1). We will change this in L151 and use open symbols in Figure 2 to improve visibility of overlapping locations.

L174-176: This point isn't very clear (also mentioned in the comments for Figure 1) – perhaps worth adding a section to the diagram? If the diagram gets too big for the width of the page perhaps you could add it horizontally?
Response: We agree that this sentence needs clarification. However, it is already included in Figure 1 (Drought Severity Classification). In this part we described that a year was defined to be in drought whenever the variable of interest was abnormally low, in this study below the 20th percentile. Drought years were further classified according to three different severity classifications: D1 (moderate; <20th percentile), D2 (severe; <10th percentile) and D3 (extreme <5th percentile). We will clarify how we

defined drought years in section 2.2.

L196-203: sorry this section is a bit unclear, particularly the last sentence of this paragraph. Do you mean that if one of the impact groups (e.g. tree rings) is removed, you identify 12 fewer events as these weren't identified in any of the other series? Please clarify.
Response: Yes, in this analysis we assess which extreme droughts we would miss if we exclude one of the groups of indices. We will clarify this in the revised version and change the last sentence of the paragraph to "The distinctiveness value is the number of extreme droughts we would miss if we exclude a specific dataset."

Figure 3: I wonder if part b might be better grouped so that all the SPI indices are together, all the SPEI indices together, all Rhine and all Danube together, with a small break or line between each group. Please add a title (as in 3a) or a yaxis label to 3c.
Response: We think in this figure it is more important to have the accumulation periods together because we want to emphasize the difference between SPI and SPEI (which is more clearly visible by plotting the SPI-3 below the SPEI-3) and not the differences between accumulation periods. We will add the label to Figure 3c as suggested.

L270-276: It's not clear how you arrived at 17 years here from Figure 3c – please clarify. Perhaps you could mark on Figure 3c which years meet your criteria. (I think the criteria is more clearly explained in the caption for Figure 5).
Response: In the revised manuscript we will include in L. 270, that we focused on the 20 drought years, where most indices point to a drought. In L. 272 we will rearrange the sentence to "After 1900 all 17 years (the period for which streamflow data was available) were identified as drought years based on streamflow indices."

Figure 5: Please explain what the numbers within each section of the rings refers to in the caption.
Response: They refer to the number of indices per group pointing to a drought. We will clarify this in the revised manuscript.

Figure 6 & Figure S7: group datasets/indices as suggested for Figure 3 (and all other relevant figures in Supplement). There are two grey colours on the plot, the caption indicates that grey = no extreme drought, but it doesn't say which grey this refers to. There's also some white cells in the plot – what does this mean? Please add to the legend to include white, pale grey and dark grey. The colour scale doesn't show much differentiation between colours, I recommend you add a colour to the scale (e.g. yellow) so it is easier to visually see the difference in relationship.
Response: In Figure 6 and S7 we used only one grey color. The grey color used just seems darker when surrounded by dark red boxes. The white cells indicate 0 similarity while the grey boxes indicate that no extreme drought was identified by either of the two indices. We will clarify this in the legend and figure caption. In the revised version of the manuscript we will use symbols instead of grey color to avoid confusion.

L355: what's meant by double or triple drought years?
Response: Here we meant 'two or three consecutive years of extreme droughts'. We will clarify the sentence.

L386-388: can you comment on the changing anthropogenic influences in these catchments over time?
Response: We will add a sentence on this in the discussion. In general, human influences on river flow are susceptible to changes over time and further provide some detail and references how (changing) anthropogenic influences might have affected flow in the considered rivers.

L428: could this also be a result of improved impact data in more recent times as well?

Response: We agree, the lack of distinct events in the last decades might be the result of both improved impact and hydrometeorological data. We will add a comment on this.