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Comment on nhess-2021-129

Anonymous Referee #1

Referee comment on "Evaluating integrated water management strategies to inform hydrological drought mitigation" by Doris E. Wendt et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-129-RC1, 2021

This paper by *Wendt et al.* investigates the effect of different drought policies on hydrological drought characteristics and is a relevant contribution for the community and water and drought management. The study uses a virtual catchment and embeds different hydrogeological settings in a model experiment. Different drought strategies are then implemented as different scenarios to simulate streamflow and groundwater storages under different conditions. The scenarios are well-chosen and help to evaluate different challenges in future drought management. I recommend publication after moderate revisions.

Title: For me the paper title would be more informative/stronger if it states what it is found rather than what is done in the study. I suggest to go into the direction of "Integrated drought policies on hydrological drought led to …" However, the readers might be more interested in the "implications" of the study than in a "demonstration of the impact".

Introduction: I liked the condensed format of the introduction and a lot of recent publications are embedded there. However, it remains unclear for me whether the focus of this study is on hydrological droughts, groundwater (L35-36) or on both, or human-modified droughts (L31) – this should be clarified (although it gets clearer later on in the manuscript). "Hydrogeological conditions" are mentioned the first time in L64 in the introduction (in the Study Aims paragraph). How is it justified to consider different hydrogeological settings? This might be a logical approach for a drought researcher, but should be referenced and/or better introduced for a broader readership. There is also a mixture of objectives and method description (L63-71) in the introduction. Clear, tailored objectives or research questions could help to explain what exactly the science is in this paper? The key elements of drought policies (L39-41) are given but no further used in the

introduction. Why is the list of those six elements important?

Major comments

- High, medium, low groundwater storage systems (L70, L143) are crucial definitions to understand the analysis. I wonder if the authors described/used here large, medium and small (or shallow) groundwater storage systems, i.e., characterizing the ability of the system to store more (large) or less (small) water in the subsurface. High/low is rather confusing here as high/low is often used for high or low permeability of the aquifer, i.e., the degree of infiltration of water into the aquifer. Has a high groundwater system (also) a large storage? This should be clarified (or changed) and a distinct definition of the three systems is needed in a prominent way in the manuscript. Wording should be revised also to other sections in the manuscript, e.g., "companies with access to principal aquifers might depend more on groundwater compared to companies with access to shallow, less productive aquifers" (L83-84).
- Furthermore, I found the only linkage between hydrogeology and groundwater systems in L139-149. Is the linkage only for some kind of justification for different GW model boxes in HBV or was the aim really to quantify the impact of integrated drought policies on hydrological droughts in different hydrogeological settings? For me it is not clear why the hydrogeological features of the virtual catchment (karstic, porous and fractured) are linked 1:1 to high, medium and low groundwater systems? I guess this could be clarified, however, the hydrogeological context could be better integrated in the study. To be honest, my first concern reading the manuscript was on the added value of the hydrogeological settings (i.e., karstic, porous, fractured). See also point (4) below.
- I suggest to have a separated section "virtual catchment" where the modelling approach is explained (in single steps) using HBV (with a specific model structure) a set of average forcing data for England. Do I understand it correctly that no calibration was done in HBV as fixed parameter values were derived from literature etc. and there is no observed runoff? This should be mentioned more clearly! Consistent terms would be beneficial (at the moment idealized, simplified and virtual catchment is used). Perhaps this could also be done with an extension of Fig.1 showing (a) the HBV model structure (+ extension with three different GW boxes) and forcing data and (b) the socio-hydrological model approach next to each other.
- What is the advantage to have three different GW model representations for the three different groundwater systems if also variation of the parameterization of the same model structure could do this job? Stoelzle et al. (2015) showed that the FLEX GW structure outperforms the three structures POW, 1LBY and 2PA used in this study and the hydrogeological clustering of catchments is also better/clearer for FLEX than for other structures (Fig. 4 in Stoelzle et al., 2015). Wouldn't it be easier to compare the effects of larger and smaller groundwater systems on different drought policies if the model structures across those different GW systems stay the same?
- I like the section 5.3 model limitations as this discussion is really important to understand the results of the study. Beside the fact that this section could be incorporated into other sections of the manuscript or at least should not be placed at the end of the discussion section (to gain a more positive ending of the paper), I asked myself what would have been happened if another forcing than an England's average

was used? Are average conditions a good starting point for such drought analysis like here? Additional analysis could shed light on this, however, at least more discussion is needed to evaluate how representative the average approach is for the different regions in England or different water companies.

- Regarding the publication in NHESS my first impression was that a more hydrological journal such as HESS would be a better choice for this manuscript. Terms like risk, hazard, vulnerability are not or seldom embedded in this manuscript. But as the paper is planned to be published in the SI: "Drought vulnerability, risk, and impact assessments: bridging the science-policy gap" it is definitely a valuable contribution for this journal. It is in the scope of NHESS and the SI as the paper focuses on drought impact assessment. However, as the readership of NHESS (compared to HESS) is certainly less familiar with hydrological modelling approaches and differences in groundwater model structures, more explanation on model setup, role of model structures and e.g., response times of aquifers is needed (see other comments for more details).
- Around the half of all Figures are placed in the Appendix. This is a nice approach to have additional information for the reader. However, reading the manuscript a lot of references were made to Fig. in the appendix even for major outcomes of the results and discussion section.
- L232-241: Is the also a presentation of results according to the different storages models (Eq.4-6)? Different models will have more or less ability to buffer mild droughts. L284-L303: Again, more elaboration is needed here on the effect of the different groundwater models on the found drought characteristics. Is this included in the discussion section? L324-325 also suggests different effects of the same scenario for different groundwater systems (high, low etc).
- As there are major differences between high and low groundwater systems (suggested by Fig. 5) a comparison of both systems across the different drought metrics might be helpful.
- Water import is identified as important component in a future water management. Would be nice to have more discussion on potential ways to store redundant water (e.g., during winter high flows) to increase summerly low flows.

Minor/technical comments:

- First sentence in the abstract is rather long, I suggest to split into two.
- L24: 'sustained' means 'prolonged' here?
- L27: what is meant with "is available longer"?
- I suggest do move the sentence "In this study,…" (L31-33) to the end of the paragraph or to integrate it in a better way at the end of the introduction (L63-71) as here the aims/objectives of the study could be summarized.
- More elaboration on the term "conjunctive use of water" (L55) might be helpful here.
- "large impact on streamflow droughts" (L59). Have Jaeger et al. (2019) performed a comparison of all the above-mentioned drought policy components (L53-57)? If so, that should be clarified. If not, I suggest a rephrasing "reservoir regulations and timely interventions have a larger impact on streamflow droughts than X, Y, Z...".
- What is the share of surface water/groundwater use for the 13 of 18 companies (L79)? Could be summarized from Table A1 here.

- Trigger levels are communicated as percentages (e.g., L200-202) or as kind of return periods (e.g., L198). Return periods could be understand as probability. I wonder why SPI has then to be used? Of course, SPI as a trigger level can also be converted to a probability, but is there an additional value to communicate SPI (as proxy for drought severity) instead of the probability (or percentiles?). Are there references or experiences from stakeholders that justify the SPI as a more valuable metric in drought assessment? Compared to that the reservoir triggers are nor communicated as a deviation from the mean and that reduces the clarity in trigger level communication here.
- Code availability: I suggest to enable open access to the code with at least a simple example code file (and data set) to reproduce the major parts of the analysis.
- L210: 80th percentage? Is this 80th percentile (exceedance level)? Is this percentile calculated on monthly basis or for the entire series?
- L219-L223: Would be helpful to have periods of reduced recharge etc. and the model spin-up also as color-coded information in Fig A2.
- "the overall hydrological drought intensity and duration reduce for most scenarios" (L327) – here is missing something.
- What are examples of high costs for providers and users (L421) ?
- "larger inter-annual storage" (L449), here is missing something or it should be a comparison with larger than?

Figures/Tables

Many Figures have a nice formatting and I especially like the different point shapes (e.g. Fig 6). However, please remove the grey background in the Fig. to increase the readability (e.g. Fig A6).

Table A1: Please add numbers (1-13) to Table A1 to increase the connection to the numbers in the columns 3+6 in Table 1. I do not understand what "headroom" means here.

Table 1: Why are some drought plan numbers (#) like 2 or 11 not mentioned in this table? Add "yr" to the numbers in square brackets (e.g., average 8.5 yr, range 5 yr - 20 yr) for clarification or add return period in this column description.

Fig. 6: Try out a 2x2 panel instead of 4x1 and consider to add a regression line to evaluate the deviation of specific points from the "average". At the moment this Fig. is to wide compared to its height. Same is partly an issue in Fig A7.

Fig. 3: Stacked barcharts are critical here. Please move to a dodged version with 4 single

bars for each category on the y-axis. Baseline, Scenarios and Combination could be placed in facets (4 facets in one column) to highlight the different groups here. 0%-label is missing and I cannot find the explanation for the dotted vertical line. The colored categories could also be placed into facets (if the dodged version doesn’t work out).

FigA6: Is it 12000 days in panel 2? Removing the outlier would improve the data representation (outlier comment could be added in the caption). Drought duration could be transformed to months (easier to read, but this is just a recommendation).