



EGUsphere, referee comment RC1
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Review of Lam et al. (2022): Linking reported drought impacts with drought indices, water scarcity, and aridity: the case of Kenya

Anonymous Referee #1

Referee comment on "Linking reported drought impacts with drought indices, water scarcity and aridity: the case of Kenya" by Marleen R. Lam et al., EGU Sphere, <https://doi.org/10.5194/egusphere-2022-458-RC1>, 2022

General comments:

In this study, Lam et al. explore statistical links between drought impacts, drought indices, and water scarcity in five counties in Kenya from 2014 to 2020. The authors use seven impact factors retrieved from the monthly bulletins of the National Drought Management Authority in Kenya and four drought indices at various time scales. A random forest model was used to measure statistical associations between the impacts and drought indices. Their result shows the drought indices that are best linked with each of the impact factors and indicate that these associations are also influenced by the aridity level of the regions.

This study on droughts is in the scope of the NHESS journal and is a good contribution to the field of drought impacts, mainly as it is one of the few studies focusing on the African continent. However, the method and the analysis in the manuscript are not sufficient to support some of the authors' arguments, and the overall presentation of the manuscript (some figures and discussions) needs to be improved. I suggest some major revisions before considering a possible publication in the journal. Below find my comments.

Specific comments:

- **Abstract**

It would be nice to add two or three more sentences about the results (for example, which indices were included in the study, which one is the most associated with which impact factor, etc.) to give more information to the readers. As it is presented, the abstract sounds very general, and hard to see what the significant contribution of this study is. Also, if the authors' study is the first one (or one of the few) that explores the link between drought impacts and drought indices in the African continent, that should be emphasized.

1. Introduction

Line 22) "Due to the projected increase in drought frequencies": In which regions and when will this increase become significant? Note that the increases in drought frequency and intensity are not globally equal. See Chapter 11 in the new IPCC The Physical Science Basis report (Seneviratne et al., 2021) and cite this new report instead of the 2014 version.

Line 26) What do the authors mean by "a hydro-meteorological event"? "Hydrometeorological events" in general or "drought" or "extreme hydrometeorological events"?

Line 27) I am not convinced here how "Linking drought impacts to drought indices" could contribute to "the development and improvement of the M&EW.". Will it improve drought forecasting (in which way)? Help with better preparedness? Please elaborate on this sentence better.

Line 30-43) This paragraph should go after the first paragraph (from line 22), as it introduces drought indices before discussing "Linking drought impacts to drought indices."

Line 31) In this study, as impacts on society are considered, I would also add a definition of socio-economic drought, which occurs when water as an economic good cannot meet demands due to a weather-related shortfall. For the definition, see, for example, Mishra and Singh (2010).

Line 33-35) Add a citation for this argument.

Line 41) I suggest adding an explanation of some drought indices associated with each drought type after Yihdego et al. (2019) (at least the indices the authors use for this study). So the readers can grasp a better idea of which indices are usually used in drought studies.

Line 41) "Models using drought indices to forecast drought can detect climate signals": It is unclear what the authors mean by models (which models?) and climate signals. Please elaborate on this better.

Line 42) "Yet, the link between drought indices and socio-economic impacts has rarely been analyzed": But the authors have mentioned several papers on linking drought indices and impacts in the discussion and conclusion section (Blauhut et al., 2015; Bachmair et al., 2015, 2016, 2018, Stagge et al., 2015, Ma et al., 2020; Wang et al., 2020, among others.), right? Even in the next paragraph, the authors claimed that some works on the topic already exist and they are focused on Europe and the U.S. If these previous works had motivated the authors to perform this study, these works should be acknowledged and elaborated better in the introduction: which indices and methods were the previous studies used? What do their results say about the link between droughts and drought impacts? What is the difference between these studies and the authors' study? Also, was there any previous research analyzing the impacts of droughts over Kenya or the African continent?

Line 48) What does EDII stand for?

Line 65-67) I would remove "because of." and split the sentence in two: "In this study, we focus on Kenya. The country is characterized by strong gradients in precipitation ...".

Line 74) I am not sure what the authors mean by "arid circumstances.". Drought? Aridity index?

Line 75) "It is expected that drought indices will show a somewhat similar response across different climatic zones in Kenya because of the standardized nature of drought indices": For me, it is not very clear why the authors expect this. Standardizing indices standardize a water balance variable with respect to the climate of a region to facilitate the comparison across the different climates. But this does not make all regions have similar spatial and temporal variability of a drought index or respond similarly to drought drivers. Droughts can be local or regional events caused by different drivers. In addition, different surfaces, vegetation, and geographical conditions affect the spatiotemporal characteristics of droughts. Thus, even neighboring regions can present different drought conditions. For example, see the plots in Spinoni et al. (2015) which show different drought frequencies

and extent (using SPI, SPEI, and RDI) in Europe.

2. Data and Methods

2.1. Study Area

Line 98) "This study will specifically focus on a region in Nyeri, namely Kieni...". This sentence is confusing. So, if I understood it correctly, inside of Nyeri, the authors will focus only on Kieni. Then, I would rephrase a sentence like, "This study specifically focuses on one region in Nyeri, namely Kieni. From now on, with Nyeri, we refer to only the Kieni region.".

If this is the case, why is only Kieni selected in the Nyeri region?

2.2. Data

Line 108) Add a citation for the MSWEP version 1.1.

Line 111) The spatial resolution of MSWEP is 0.25 degree based on Beck et al., 2017.

Line 117) Add a citation for MSWEP v2.8.

Line 117) Add a citation for Priestley and Taylor equation.

Line 118) Add a citation for ERA5.

Line 125) Add a citation for GLOFAS.

Line 127) What do HTESEL and LISFLOOD stand for? Also, add a citation for each of the data and models, including ERA5, if the ERA5 dataset used in this part is a different version from the previously mentioned one.

Line 128) The last sentence about LISFLOOD can be removed if this is only the input model used to generate the GLOFAS data.

Line 130) I would suggest changing the subtitle to "Impact data from the National Drought Management Authority" to make it more consistent with the other subtitles.

Line 138) Add a citation for the VCI Index and a brief description of this index (how is this index estimated?)

Line 138) Add a citation after the Food Consumption Index and briefly describe this (how is this index estimated?)

Line 139) Add a citation for the malnutrition index.

Line 140) I suggest splitting the sentence into two. For example, "This study has utilized water scarcity (WS) data from McNally et al. (2019). The data is a monthly water scarcity dataset with a spatial resolution of 0.1 degree for Africa from March 2018 to the present."

Line 143) FLDAS is driven by the satellite-based CHIRPS precipitation. I can see that the authors mention this in the Appendix, but also add a sentence about it in this section to make it consistent with the description of other datasets.

CHIRPS is a different precipitation dataset and is not included in generating the MSWEP data. How would this WS based on a different set of precipitation affect your final result? This could be briefly discussed in the Discussion section.

Line 144) Add a citation for the Falkenmark index.

Caption for Table 1) Mention here that the Falkemark index is for the water scarcity level. Something like: "Falkenmark index for the water scarcity level".

2.3. Methods

2.3.1. Drought Indices

Line 158) The values are not fit through a standard normal distribution from the beginning. The cumulative precipitation is transformed to a normalized distribution by first "fitting a parametric statistical distribution" (Stagge et al., 2015a), which in general, they are a Gamma or Pearson III distribution for SPI (2015a) and a log-logistic distribution for SPEI (Vicente-Serrano et al., 2010; Beguería et al., 2014). Read Stagge et al. (2015a) and Stagge et al (2015b) to see different types of distributions for precipitation. Which type of distribution did the authors use?

Line 159) Are the values area-weighted averaged? If yes, mention it.

Lines 160) Is the same procedure for SPI and SPEI (cumulating monthly values, fitting a specific type of parametric distribution, then normalizing the distribution) also applied to SMI and SSMI? If yes, which parametric distributions were used for these two variables?

Line 162) "incorporates temperature by including evaporation anomalies": It is the other way around: SPEI incorporates the effects of potential evapotranspiration, which depends strongly on the temperature. And for the calculation, "potential evapotranspiration" is included, not "evaporation anomalies". See Beguería et al. (2014).

Line 166) Is GLOFAS or GloFAS? Previously, the authors used GLOFAS (Line 125). Be consistent with the acronyms.

Line 179) The authors never define what they consider "drought". What is the threshold the authors set to define drought periods?

General comments about Section 2.3.1) As the authors already mentioned in the introduction, each drought index represents different types of droughts: SPI is usually for

meteorological drought that only considers the effect of precipitation, while SPEI and SMI are agricultural or soil moisture droughts, and SSI is the hydrological drought (See Yihdego et al., 2019). This difference between the indices should be clearly explained here.

2.3.2. Drought Impact data

Line 176) A citation or a link to this website should be added if this is an official website. Also, is this impact data categorized by the authors available online?

Lines 181-183) Could the authors explain more about how this impact data was transformed into a binary value? With binary values, it means 1 if there was an impact and 0 with no impact? What do the authors mean by normal values compared to the previous years? How are these normal values defined (based on the years with no drought?), and what is the threshold to distinguish impact and no impact? (For example, when there is 30% or 50% -or whatever percentage – of crop failures compared to the normal no-drought year?)

Line 181) How do the authors define drought impacts? Bachmair et al. (2016) define a drought impact as “a negative environmental, economic, or social effect experienced under drought conditions (based on EDII).”.

Did the authors initially categorize all the impacts from NMDA, then select only drought impacts (impacts under drought conditions) for the analysis?

Line 187) What is exactly food insecurity? How is this impact factor measured, and how independent is this factor from crop losses and milk production?

Line 191) Add a brief explanation of Jaccard similarity. How does this method work?

2.3.3. Random Forest model

General comment about the section) The overall explanation of RF should be improved, and many parts of the appendix should be included in this section. For instance, partitioning the data in training and testing sets is essential information for readers to know how the RF model was built. Have a look at Bachmair et al. (2016) to see how they introduce the RF method for their work. And more technical parts related to sampling (lines 196-201) could be moved to the appendix.

About the RF model) Usually, machine learning techniques aim to deal with large datasets. How sensitive is the output of an RF model to the number of total values or the length of each variable? Is there any metric that shows how statistically significant is the fitting of your data?

I'm asking this as I can see the Kenya dataset is only for 7 years, which is 84 months in total. Based on the Appendix, 75% of the dataset is used to feed and train the model (63 months) and the rest of the months to validate the output (11 months).

How can the authors ensure that the RF is a good tool for this dataset?

Could the authors repeat their analysis by using a very simple approach, such as a sort of correlation analysis (Spearman rank or Pearson correlation analysis, similar to Bachmair et al., 2016, or a simple linear regression model.) between the impact data and drought indices? This analysis takes into account the number of datasets in the significance test (by considering the degree of freedom). This additional analysis can be compared to the output of the RF, helping to see whether the result from the RF is robust enough and whether the sample size affects the final output.

Line 201) Mention here more clearly that the regions are divided by their aridity indices or levels to assess the relationship between aridity levels and drought indices.

Also, what do the authors mean by aggregated? The three regions are averaged to be one input data in the RF?

Line 204) Add a citation for the ROC method and explain briefly how this is calculated.

3. Result

3.1. Drought Impacts

Line 225 - 234) The authors mainly discuss the impacts and droughts in Masarabit and Nyeri. But what about other regions? Why are the other three regions not included in the result? The plots for impacts and drought indices of other regions should also be included, at least in the appendix or supplement.

Line 210) "Drought impacts": The same as the comment for line 181. Are these the total impacts during 2014-2020, or only the impacts during droughts? How do the authors define a drought impact? As I can see from Fig 1., some impacts occur during the non-drought period in SPEI (for example, September 2020).

Table 2) The same comment as above. Are these "drought impacts" or the total impacts?

And I would suggest replacing "Count" with "Number of impacts".

Line 219) Replace "A timeline" with a "time series".

Figure 2 (and also for other figures)):

- Enlarge the texts and labels, please. They are challenging to read. Also, enumerate each subplot (with a. b. c. d.) to indicate the part the authors want to discuss clearly.

- The plots for impacts (the upper two panels) are complicated to read and distinguish the years. I wonder if there is a better way to visualize these plots: for example, by transforming them to line or bar plots, or somehow finding a way to make the font bigger and add a vertical line to divide the years.

- In the caption: "time series" instead of "timeline".

Line 226) The same comment as line 210: Is this the number of total impacts or drought impacts?

Lines 235-138) What is the authors' criterion to claim "a bit of relation" and "no relation"?

Why is 0.63 slightly similar but 0.4 not? Also, add a significance level of the Jaccard similarity.

Table 3) How statistically significant are these correlations? One can add asterisks next to the values when they are statistically significant.

Line 230) What do the authors mean by "a direct relation"? Could you clarify it?

Line 231) What and when is the onset of drought? This question is also a continuation of the comment in line 179: To mention the onset of drought, what the authors define as drought periods should be clarified first.

Overall comment about the section) I'm quite skeptical about including the indices with 2 years time scale (24 months) in this study. A higher time scale index is appropriate to represent relatively long dry and wet conditions. Even though these indices have a monthly time scale, one monthly value of the index represents two-year hydroclimate condition (Hence, also showing a strong persistence.).

The Kenya dataset is too short (7 years) to include these indices for the analysis. If one drought occurs in one month in this index, this indicates a dry period of almost 30% (2 years) of the study period. The authors can also see this in the time series of SPEI-24 for Masarabit: more than 50-60% of the time series shows a drought condition covering a large portion of the impacts. The plot basically indicates that there is only one long drought event for the analysis, and I don't think one can derive a significant statistical association from this time series.

Another study, for instance, Bahmair et al. (2016) can include this long-time scale index, as their dataset starts in 1970.

3.2. Drought impacts and water scarcity.

Line 240) Start the paragraph mentioning that the association between WS and droughts is done from 2018 due to the length of the WS dataset.

Line 241) Remove "(start of timeframe WS dataset)".

Figure 3) The same for all figures: Enlarge the text and labels in the plots. And I suggest putting the enumeration and the subtitles of the plots at the top and not at the bottom of the figures, as they are mixed with the captions.

Fig.3a) Suggest replacing "amount of months" with "number of months in a year"

General comment about the section) How is water scarcity associated with drought conditions? Have the authors made some comparisons between water scarcity and drought indices? Whether water scarcity always occurs during droughts or not should be analyzed and included in the section.

I am asking this as in 2020, there is no drought in Masarabit and Nyeri (Fig. 2), and many regions are under no water stress during 2018-2020 (Fig 3.b). Can it be that this no-water stress situation occurs mainly in 2020 (during no-drought condition)?

And do all the impacts during 2018-2020 occur under droughts, or are these the total impacts during 2018-2020 (including non-drought period)?

Line 246) The same comment about the "drought impact" in line 181.

3.3. Drought Indices and Random Forest

General comment about the section) For this section, the question is again, why do the authors show and discuss the results for only some regions? In addition, in Fig.4 only some specific impacts are discussed for a few regions and not all. Why is that? If some regions do not show significant connections with impacts, they should still be mentioned and included in the plot. If including everything enlarge the plots, the authors can think about putting dots in different colors for different impact categories.

Line 250) I suggest changing the title to something similar to "association between drought impacts and drought indices" or "Random Forest to link drought impacts and drought indices" instead of the name of the method the authors use.

Line 251) Mention here again that the regions are aggregated by their aridity levels or indices to make clear that the analysis in this part also considers the aridity levels of different counties.

Table 4) How is this performance measured? Clarify it in the caption.

Line 262) What do the authors mean by "best linked"? How is the threshold for the best and worst defined? Please clarify.

Line 265) The authors never mentioned what the MDA and Ginni Index are. Add a brief description of these scores and how they are estimated in the Method section. Some explanation of these scores is in the appendix, but this information should also be included in the Method.

Fig 3 and 4) Enumerate each of the plots to distinguish the Ginni and MDA plots.

Line 270) SPEI is clearly not a meteorological index. The authors also mentioned in the introduction that meteorological drought considers only a precipitation deficit.

4. Discussion

4.1. Data sources and methods

Line 290) How many monthly gaps does this report have (how many percentages of the total years)? This should be mentioned in the data section.

Line 292) What do the authors mean by iterative processes? Which kind of iterative process is applied to deal with the missing months? Please include this in the Method section.

After all, how would these missing gaps affect the result of this analysis?

Line 295) What does DIR stand for? Also, add a citation for EDII and DIR.

Line 299) What does EM-DAT stand for? Add a citation for EM-DAT and DesInventar.

Line 305- 306) I am not sure whether the AUC supports this statement. The authors are only using one method here. How can one confirm the output of the model if this is not compared to other methods? Also, how sensitive is an RF model to the number of samples? See my comment for Section 2.3.3.

4.2. Relations with aridity

Line 310) I'm not sure if the result partially supports the first sentence. All the activities included here are mainly pastoral and not other activities, right? Then how do the authors know the impacts on other industrial or economic sectors?

Line 320) What do the authors mean by the onset? The authors never defined when an actual drought starts and when is the onset of these droughts. See my comments for line 179.

Line 322) After evapotranspiration, add some citations referring to this argument (for example, Seneviratne et al., 2021).

Line 322) "However, this study cannot link drought occurrence to aridity.". This sentence is not very clear to me what the authors want to say. Aridity is a constant arid condition. Do you mean the aridity level of the regions, constant desertification due to climate warming, or just the impacts of drought frequencies related to global warming? Elaborate on the sentence, please.

Line 322) "short time period (10 years)". Why 10 years, if based on what I understood, the authors are taking the study period from 2014 to 2020? (7 years, including 2020).

Line 323) "interannual trend": Do the authors want to say "long-term" trend? The interannual trend does not make sense for a longer time scale analysis that the authors claim to be necessary.

Line 323-325) Overall, these two sentences are pretty difficult to understand what the authors want to say. How would a longer time series help to understand drought events and drying climate? Do you mean a long-term drying trend and a change in the climate? How is this connected to aridity and droughts? Please clarify this part.

4.3. Water scarcity and drought impacts

Line 329-331) "Increased distance from water sources was reported in arid and semi-arid regions during most of the months when meteorological and hydrological drought conditions occurred (Figure 3b)": I don't see this result in Fig. 3b.

Line 346-347) I cannot see any statistical relationship between WS and droughts as the authors haven't compared the two datasets in the Result section (see the comment for Section 3.2). In addition, for me, 2020 looks like an almost drought-free period in Masarabit and Nyeri (Fig 2.)

4.4. Drought indices and the Random Forest model

Line 358) See my comment about the drought indices with a 24-month time scale in Section 3.1. SPEI-24 is not appropriate for this analysis with a 7-year-long time series to derive a robust statistical association.

Line 361) "These differences between the best match between drought impacts and drought indices implies therefore a link with human activities": The argument here is not very convincing for me. How are the authors' results on the best and worst indices related to human activities and the propagation of droughts? Please elaborate on this argument better.

Line 363) Again, SPEI is not a meteorological drought. It is an agricultural or soil moisture drought, and when the time scale becomes longer, it also shows memories that are comparable with the soil moisture anomalies.

Line 367) "Noticeable is that SSI gives a possible link with water-dependent activities while SSMI shows a possible link with agricultural practices.": Isn't this expected as SSI represents hydrological drought and SSMI the soil moisture drought? Clarify the division between different drought indices in the Method section (See my comment for Section 2.3.1).

Line 369) Again reiterating. SPEI is clearly not a meteorological drought.

Line 371-372) Note that Dai et al. 2020 use only SPI which is a meteorological drought index. They do not include SPEI in their analysis.

Line 375) Again, for this short dataset of 7 years, I would not include an index with a time scale of 2 years for statistical analysis.

Line 378-381) Could this difference in the result between the authors' work and Bachmair et al. (2016) in Europe be related to each country's economic and resilience capacity to droughts? It would be worth discussing how the economic condition of each country affects drought impacts and the result of this study.

Line 386) The same comments about the indices with a 24-month time scale (line 375).

Line 387) If the authors claim that long SPI and SPEI are the hydrological droughts, the hydrological index (SSI) at various time scales must also show a significant association to those impacts associated with long SPI and SPEI. The association of SSI should be discussed in more detail here and in the Result section.

Line 396) I can imagine that the adaptation measures will increase the resilience of smallholders. However, the sentence does not clearly explain how these measures will affect the result of this study.

Line 396-398) Difficult to understand. I suggest splitting the sentence into two.

Overall comments) Also, the effects and drawbacks of short time series and the RF method should be discussed briefly in this section.

5. Conclusion

Line 406) The same as the comment for line 22. Where and when?

Line 412) Again, why is the discussion mostly about Masarabit and Nyeri?

Line 418) What do the authors mean by "unreliable water condition"? Please clarify.

Line 419) I can see that in 2020, not many drought months occurred. Again, are all the impacts counted during the drought conditions or for the entire period?

Line 426) Same comments for the drought indices with a 24-month time scale.
Line 432-433) Do the authors mean over the entire globe or in Africa? Clarify it.

Line 433-434) What about the temporal resolution of the dataset?

Line 434) What do the authors mean by "other research areas"?

Technical corrections:

Line 6) include "that" between "indices" and "best".

Line 7) Remove ":".

Line 10) "aridity" to "aridity level of the regions".

Line 15) "impactful" instead of "impact-full".

Line 52) Replace "setting" with "regions".

Line 98) Remove "However".

Line 103) "reanalysis" instead of "re-analysis".

Line 104) Remove "extracting".

Line 109) the complementary nature of "the" highest.

Line 115) Remove (v3.5a).

Line 122) Add e.g., before the papers.

Line 140) "has" instead of "have".

Line 141) "from March 2018 to the present." instead of "between".

Line 146) Replace "However" with "For this" or something similar. "However" here does not make sense.

Table 1) Add a horizontal line between the first row and the second row.

Line 176) Instead of "between ... and ..." use "from ... to ...".

Line 236 and 247) Replace "a bit" with "slightly".

Line 317) Add "Also" after the first sentence. "Also, the interference...".

Line 320) Replace "a kind of" with "some time" lag.

Line 322) "cannot " instead of "can not".

Line 338) Remove ";" after Kenya.

Line 340) in "the" ASAL counties.

Line 362) "imply" instead of "implies".

Line 397) Add "Our" in front of the Result.

Line 399) "the first step".

Line 400) I'd use "exploring the link" instead of "analysing".

Line 409) Remove "In addition".

Plots in general) Enlarge the fonts and dots.

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