Editor:

The manuscript is generally well written and addresses a topic that is of importance and high relevance to NHESS journal. However, several comments requesting further clarifications and explanations have been raised by the reviewers, therefore my recommendation is to reconsider a revised version of the manuscript after major revisions. Please address carefully and clearly all the points raised by the reviewers in the revised version of the manuscript.

Response: *Thanks for give us an opportunity to revise the manuscript. We have revised the manuscript following the reviewers' comments, and point-by-point reply to the comments can be found from the responses below and revised manuscript with changes tracked.*

Reviewer #1:

This is a comprehensive manuscript which discuss the environmental flows and droughts in the entire Indus basin in Pakistan. Overall manuscript is well written, figures and results are well presented and conclusions are valuable. However, the quality of manuscript needs to be further improved, here are few comments which may be useful in this regards.

Authors are thankful to the reviewer for the positive feedback and valuable comments. All the comments are considered carefully, and the manuscript are revised accordingly. Response to each comment is given below in blue color.

1. In abstract section authors concluded " The alterations are subject to several factors, including climate change, seasonality of the river flow, land use changes, topography, and anthropogenic activities" which type of analysis have been performed to reach these conclusions which seems to be generic.

Response: This conclusion has been made based on the results from our recently paper under review. However, no such analyses are carried out in this manuscript to support this claim. Therefore, the statement has been removed from the abstract.

2. In the Introduction section authors stated "The Indus River basin is one of the typical basins facing substantial climate and land use changes, resulting in limited water availability". However, no references have been added to support this statement authors should state which part of the Indus basin has faced serious land use and climate changes?

Response: References are added to support this statement.

"The Indus River basin is one of the typical and most depleted basins due to substantial climate and land use changes, resulting in limited water availability (Azmat et al., 2019; Immerzeel et al., 2010; Laghari et al., 2012; Sharma et al., 2010). Upper Indus Basin (UIB) is the hotspot for climate change, whereas Middle Indus Basin (MIB) and Lower Indus Basin (LIB) are dependent on the availability of water from UIB. Several studies have reported an increase in future precipitation and temperature (Forsythe et al., 2014; Nepal and Shrestha 2015; Rajbhandari et al., 2015);

however, Shahid and Rahman (2021) reported that the findings in most of the studies are not consistent with global trends due to a number of reasons".

Azmat, M., Wahab, A., Huggel, C., Qamar, M.U., Hussain, E., Ahmad, S. and Waheed, A.: Climatic and hydrological projections to changing climate under CORDEX-South Asia experiments over the Karakoram-Hindukush-Himalayan water towers. Sci. Total Environ., 703, p.135010, 2019.

Forsythe, N.; Fowler, H.J.; Blenkinsop, S.; Burton, A.; Kilsby, C.G.; Archer, D.R.; Harpham, C.; Hashmi, M.Z.: Application of a stochastic weather generator to assess climate change impacts in a semi-arid climate: The Upper Indus Basin. J. Hydrol. 517, 1019–1034, 2014.

Immerzeel, W.W., Van Beek, L.P. and Bierkens, M.F.: Climate change will affect the Asian water towers. Sci., 328(5984), pp.1382-1385, 2010.

Laghari, A.N., Vanham, D. and Rauch, W.: The Indus basin in the framework of current and future water resources management. Hydrol. Earth Sys. Sci., 16(4), pp.1063-1083, 2012.

Nepal, S., Shrestha, A.B.: Impact of climate change on the hydrological regime of the Indus, Ganges and Brahmaputra river basins: a review of the literature. Int. J. Water Res. Devel. 31, 201–218, 2015.

Rajbhandari, R.; Shrestha, A.B.; Kulkarni, A.; Patwardhan, S.K.; Bajracharya, S.R.: Projected changes in climate over the Indus river basin using a high resolution regional climate model (PRECIS). Clim. Dyn. 44, 339–357, 2015.

Shahid, M. and Rahman, K.U.: Identifying the annual and seasonal trends of hydrological and climatic variables in the Indus Basin Pakistan. Asia-Pacific J. Atmos. Sci., 57, pp.191-205, 2021.

Sharma, B., Amarasinghe, U., Xueliang, C., de Condappa, D., Shah, T., Mukherji, A., Bharati, L., Ambili, G., Qureshi, A., Pant, D. and Xenarios, S.: The Indus and the Ganges: river basins under extreme pressure. Water Int., 35(5), pp.493-521, 2010.

3. How did the authors categorize the flow data into extreme low flow and low flow?

Response: The Indicators of Hydrologic Alterations (IHA) usually consists of a total 67 parameters, which are grouped into IHA parameters (33) and Environmental Flow Components (EFCs) (34). The EFCs are grouped into five major categories, (i) low flows, (ii) extreme low flows, (iii) high flow pulses, (iv) small floods, and (v) high floods. The detailed information about the IHA parameters and EFCs are available in user manual (*https://www.conservationgateway.org/Documents/IHAV7.pdf*).

Since the flow in rivers are minimum during the drought period; therefore, this study considered on the extreme low flow (ELF) and low flow (LF) components from the five major EFC classes to understand the impact of drought (i.e., threshold that triggers the ELF and LF) on EF.

4. Various data qualities issues have been reported regarding the hydrological and meteorological datasets of the Indus basin. How authors addressed the missing datasets and which type of analysis have been performed to check the data quality?

Response: Data in Pakistan (Indus Basin) is usually manually collected by Pakistan Meteorology Department (PMD) and Water and Power Development Authority (WAPDA). Therefore, the collected data has several issues, including errors due to personal and instrumental errors, splashing due to climate, errors due to winds, topography, etc. These errors result in poor quality and missing data. The initial attempts are made by PMD and WAPDA to rectify the data following the standard code of WMO-N issued by the World Meteorological Organization. Besides, we have also performed data quality tests including the kurtosis and skewness methods to check the data quality, and the missing data is filled by zero-order methods following Rahman et al. (2018).

5. On which basis authors have done the demarcation of the indus basin into UIB, MIB and LIB?

Response: The demarcation of the Indus Basin into UIB, MIB, and LIB is done following Aftab et al., (2022), Rajbhandari et al., (2015), and Shahid et al., (2021).

Aftab, F., Zafar, M., Hajana, M.I. and Ahmad, W.: A novel gas sands characterization and improved depositional modeling of the Cretaceous Sembar Formation, Lower Indus Basin, Pakistan. Front. Earth Sci., 10, p.1039605, 2022.

Rajbhandari, R.; Shrestha, A.B.; Kulkarni, A.; Patwardhan, S.K.; Bajracharya, S.R.: Projected changes in climate over the Indus river basin using a high resolution regional climate model (PRECIS). Clim. Dyn. 44, 339–357, 2015.

Shahid, M., Rahman, K.U., Haider, S., Gabriel, H.F., Khan, A.J., Pham, Q.B., Mohammadi, B., Linh, N.T.T. and Anh, D.T.: Assessing the potential and hydrological usefulness of the CHIRPS precipitation dataset over a complex topography in Pakistan. Hydrol. Sci. J., 66(11), pp.1664-1684, 2021.

6. Various studies have been performed to understand the drought in the Indus basin Authors can open the scholar and search from key word droughts in Indus basin. However, no discussion has been performed to compare the results of this study with literature. Discussing the results with previous studies will be useful for readers and this manuscript has potential to be extended for a brief discussion.

Response: A detailed discussion section is added to the manuscript following the recommendations of reviewer. However, there is no such studies available in literature that identified the drought severity causing low flow and extreme low flow in the rivers, and quantified the impact of drought on environmental flow:

Pakistan has been added to the list of water-stressed countries due to water scarcity issues under severe climate change and land use change scenarios. However, it is relatively difficult to precisely assess the impact of climate change on water availability in the Indus Basin because of uncertainties due to topographic complexity, local changes in climate that influence the natural glacial and snow melt process, glacial retreat, and shifts in precipitation pattern (Janjua et al., 2021).

The UIB contributes approximately 45% of the flow to the main rivers in Indus Basin, suggesting the high vulnerability of glacial melt to climate change and results in a 40% of surge in riverine flow (Janjua et al., 2021). However, on the long run, the average flows in the main tributaries of the Indus Basin are reduced by almost 60% (Briscoe and Qamar, 2006). This reduction in river flow is mainly associated with the global warming, i.e., the evapotranspiration is likely to increase significantly in the irrigated areas of the Indus Basin resulting in the increase of water demand for irrigation (National Research Council, 2012). The Indus Basin (Pakistan) receives highest magnitude of precipitation (50%-60%) during the monsoon season that results in approximately 85% of the annual discharge in the Indus Basin, which will be significantly altered in a couple of decades due to climate change (National Research Council, 2012).

Extreme events, i.e., droughts and floods resulted due to climate change has tested the inhabitants of the Indus Basin in a number of ways. Pakistan is an agricultural country, where the economic development depends on sustainable agricultural production (Rahman et al., 2023b). Besides the direct impact of droughts on agricultural productivity, the droughts also cause significant reduction in surface water availability and consequently the irrigation water supply. The estimated water consumption by municipal and industrial sectors in Pakistan is approximately 5.3 km^3, which is projected to increase to 14 km^3 by 2025 (Condon et al., 2014). Therefore, there will be limited available water for irrigation purpose and will significantly impact the water availability in rivers and in turn the sustainable EFs.

The Indus Basin Irrigation System (IBIS) irrigates approximately 150,000 km^2 out of 190,000 km^2 of cultivated crop area in the Indus Basin (Ahmad, 2005), resulting in the deterioration of environmental water and the Indus delta ecosystem because of lack of sustainable minimum flow in the riverine system (Janjua et al., 2021). The conditions required for minimum flow in rivers becomes more critical during the drought periods; for instance, the difference between water demand and supply was 20% during the 2000–2002 drought period (Briscoe, 2006). Keeping in view the worse condition of EF in the Indus Basin, it was suggested by the experts in 2005 that we should sustain a minimum flow of 141.58 m^3/s in the Indus River from Kotri Barrage to the sea (González et al., 2005). Due to the extensive withdrawal of surface water from the rivers by the IBIS, it was decided to ensure a 30 km^3 of cumulative flow for a period of 5 years in the Indus River (González et al., 2005).

Beside the water withdrawal through IBIS, drought has significant contributions in reducing the flow in rivers of the Indus Basin (Rahman et al., 2023a). The persistent meteorological drought reduces the water availability in river flows, which then ultimately translates into insufficient release of EF (Pena-Guerrero et al., 2020). The frequency and intensity of drought in the Indus Basin has been increased substantially in the recent decades, which resulted in high variability in meteorological and hydrological droughts. Rahman et al. (2023a) propagated drought from one catchment to another in a systematic approach using the principal component analysis (PCA) to understand the variability in both meteorological and hydrological droughts. Results showed high variability in hydrological droughts compared to meteorological droughts in most of the catchments in the Indus Basin. In other words, most of the catchments experience a decrease in river flow associated with meteorological drought and thus depicting that drought is one of the major threats to sustainable ecosystem and EF.

Very few studies have assessed the impact of drought (meteorological) on EF. For instance, Młyński et al. (2021) have studied the impact of drought (Standardized Precipitation Index, SPI) on EF across mountainous catchments in Poland. The study reported that drought has the potential to alter the EF, whereas the alterations in EF are dependent on several factors such as topography (slope), local climate and hydrogeological conditions. However, the impact of drought on EFs is yet to be investigated in details; therefore, this study is first of its kind that evaluated the impact of drought on EF under two distinct scenarios: i) drought severity that causes LFs and ELFs in the rivers, and ii) the months where drought caused LF and ELF. Keeping in view the importance of maintaining minimum flow in rivers and frequent severe drought events in the Indus Basin, the relationship between drought and EF in the Indus Basin should further be investigated in more details. Overall, results obtained in this study will help the policy makers to devise a plan for the sustainable management of EF in the Indus Basin.

Ahmad, S.: Water balance and evapotranspiration. In: J. Briscoe, ed. Pakistan's Water Economy: Running Dry. Oxford University Press, Oxford, 2005.

Briscoe, J. and Qamar, U.: Pakistan's water economy: running dry. The World Bank, 2006.

Condon, M., Kriens, D., Lohani, A. and Sattar, E.: Challenge and response in the Indus Basin. Water Policy, 16(S1), pp.58-86, 2006.

González, F. J., Basson, T. and Schultz, B.: Final Report of IPOE for Review of Studies on Water Escapages Below Kotri Barrage, 2005.

Janjua, S., Hassan, I., Muhammad, S., Ahmed, S. and Ahmed, A.: Water management in Pakistan's Indus Basin: challenges and opportunities. Water Pol., 23(6), pp.1329-1343, 2021.

Młyński, D., Wałęga, A. and Kuriqi, A.: Influence of meteorological drought on environmental flows in mountain catchments. Ecol. Ind., 133, p.108460, 2021.

National Research Council.: Himalayan Glaciers: Climate Change, Water Resources, and Water Security. National Academic Press, Washington DC, 2012.

Peña-Guerrero, M.D., Nauditt, A., Muñoz-Robles, C., Ribbe, L. and Meza, F.: Drought impacts on water quality and potential implications for agricultural production in the Maipo River Basin, Central Chile. Hydrol. Sci. J., 65(6), pp.1005-1021, 2020.

Rahman, Khalil Ur, Anwar Hussain, Nuaman Ejaz, Songhao Shang, Khaled S. Balkhair, Kaleem Ullah Jan Khan, Mahmood Alam Khan, and Naeem Ur Rehman.: Analysis of production and economic losses of cash crops under variable drought: A case study from Punjab province of Pakistan. Int. J. Disas. Risk Red. 85, 103507, 2023b.

Ur Rahman, K., Shang, S., Balkhair, K. and Nusrat, A.: Catchment-Scale Drought Propagation Assessment in the Indus Basin of Pakistan Using a Combined Approach of Principal Components and Wavelet Analyses. J. Hydrometeorol., 24(4), pp.601-624, 2023a.

7. I have some minor comments regarding use of abbreviations which are unnecessary, should be reduced and must be explained at first use e.g. In abstract section authors should explain EFs before first use.

Response: Corrected as suggested. The term EF is already explained in the first line of the abstract before its use.

Reviewer #2:

General comments:

In this study, Rahman et al. explore the impact of drought on environmental flow (EF) in 27 catchments in the Indus basin, focusing on the period 1980-2018, using the Indicators of Hydrologic Alterations (IHA). The authors use SPEI to quantify drought at various timescales. Drought impact on low EFs is quantified using RVA. Their results show that the Lower Indus Basin (LIB) is more vulnerable to drought than the Upper Indus Basin (UIB) and that drought is related to extreme low flow (ELF) and low flow (LF).

The study on drought is in scope of the NHESS journal and is a good contribution to the field of drought and environmental flow. The figures are well presented. However, the method and analysis need some elaboration, especially the explanation on the IHA. The text is well written although some paragraphs can be shortened because of repetition. The Discussion need some elaboration to discuss the findings with existing literature. Below find my comments.

The authors are thankful to the reviewer for the careful revision and insightful comments, which has significantly improved the manuscript readability and the quality. The manuscript is revised following the comments from reviewer and response to each comment is given (in blue) in the response file.

Specific comments:

- **Abstract**

The abstract is very concise, I suggest to provide a bit more information on the Indicators of Hydrologic Alterations (IHA) in relation to the Range of variability analysis (RVA). In addition, line 29-30 sound a bit too generic and is not directly studied here, please be more specific.

Response: Thank you for the valuable comments. The abstract is revised as suggested.

a. Threshold regression is used to determine the severity of drought (scenario-1, drought severity that causes low flows)) and month (scenario-2, months where drought has resulted in low flows) that trigger low flows in the Indus Basin.

b. The impact of drought on low EFs is quantified using Range of variability analysis (RVA). RVA is an integral component of IHA, which is mainly used to study the hydrological alterations in environmental flow components (EFCs) by comparing the pre- and post-impact periods of human and climate interventions in EFCs.

The original Lines 29-30 have been removed.

1. **Introduction**

Line 33) "to the quality, timing and quality of freshwater flows": The word "quality" is repeated.

Response: Corrected. Thank You for highlighting the mistake.

Line 37-39) The authors mention here that 65% of the discharge in rivers poses a moderate to severe threat to biodiversity; in what way, in relation to water quantity or quality? In addition, since when are those numbers altered? Please be more specific.

Response: The statement is revised as "On a global scale, it is estimated that approximately 65% of the discharge and the supported aquatic habitat is under moderate to high threat (Vörösmarty et al., 2010), connectivity of 48% of rivers is diminished (Grill et al., 2019), and fish biodiversity has been significantly altered in 53% of the rivers (Su et al., 2021).

The research was published in 2010, where the authors (Vörösmarty et al., 2010) studied threats to water security and biodiversity due to anthropogenic activities. There is no specific time frame mentioned in the study to understand that temporal variations in magnitude of global river discharge.

Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R. and Davies, P.M.: Global threats to human water security and river biodiversity. Nature, 467(7315), pp.555-561, 2010.

Line 46) "**the** alterations in flow regime": which alterations?

Response: The statement is revised as "the hydrological alterations in flow regime".

Line 55-56) "Eckstein et al. (2018) that …": this part does not fit into the sentence, what is meant here?

Response: The statement is revised as "Pakistan (Indus Basin) is highly vulnerable to climate change and placed at 8th position among the countries most affected by climate change (Eckstein et al., 2018). Therefore, the Indus Basin experienced more frequent and severe extreme events in the recent few decades."

Line 58) Note that soil moisture drought is more specific than agricultural drought, see Van Loon (2015).

Response: It is quite right that soil moisture drought is more specific than agricultural drought, and agricultural drought is a phenomenon that occurs when there is insufficient moisture in the soil to support crop growth. In many references, drought is broadly classified into meteorological, hydrological, agricultural, and socio-economic droughts. As agricultural drought / soil moisture deficit is not studied in this manuscript, this sentence was kept in the manuscript without revision.

Line 70) Where refers “this” to?

Response: Thank You for pointing out the mistake. The statement is corrected as “this study for the first time evaluated the impact of drought on EF using the Indicators of Hydrologic Alterations (IHA)”.

1. **Study area**

Figure 1) Where do the colors refer to in Figure 1d?

Response: The figure is revised into a single color consistent with the remaining colors.

Line 96-97) This is mentioned before already in the same section.

Response: The lines are removed as suggested.

In general, there is some overlap in text between the Introduction and Study area as the Indus basin has been addressed in the Introduction already. I suggest to better align those texts to avoid overlap and to address the urgency and the knowledge gap of studying EF in relation to drought in the Introduction.

Response: the repeating statements have been removed from the introduction and study area sections.

1. **Methodology**

Line 141) Please provide more information about using PCA in this regard? Has it done before in this way etc.?

Response: Yes, the authors (Rahman et al., 2023a) have used the PCA method to systematically propagate drought from one catchment in the Indus Basin to another catchment. To avoid the repetition, we have added the reference in line 143 in the revised version of the manuscript.

Ur Rahman, K., Shang, S., Balkhair, K. and Nusrat, A.: Catchment-Scale Drought Propagation Assessment in the Indus Basin of Pakistan Using a Combined Approach of Principal Components and Wavelet Analyses. J. Hydrometeorol., 24(4), pp.601-624, 2023a.

Line 180-181) How are the IHA used to compute the EFC and how are ELF and LF defined?

Response: Thank you for your valuable comment. The application of IHA mainly depends on its calibration procedure. In this study, the IHA is calibrated using advanced calibration technique following the guidelines in the use manual (*https://www.conservationgateway.org/Documents/IHAV7.pdf*) to capture both high flows and low flows, which is already mentioned in the manuscript (Lines 182-188). After calibrating the IHA's EFC parameters with the observed input data, we selected only the ELF and LF because ELF and LF are only observed during the drought period.

Line 184) What are the EFC parameters?

Response: The Indicators of Hydrologic Alterations (IHA) usually consists of a total 67 parameters, which are grouped into IHA parameters (33) and EFCs (34). The EFC parameters are grouped into five major categories, (i) low flows, (ii) extreme low flows, (iii) high flow pulses, (iv) small floods, and (v) high floods. The detailed information about the IHA parameters and EFCs are available in user manual (*https://www.conservationgateway.org/Documents/IHAV7.pdf*).

Since the flow in rivers are minimum during the drought period; therefore, this study considered on the ELF and LF components from the five major EFC classes to understand the impact of drought (i.e., threshold that triggers the ELF and LF) on EF.

Line 191) "widely used to assess hydrological alterations". Please include references.

Response: The following references are added to the manuscript to support the statement:

Pal, S. and Sarda, R.: Measuring the degree of hydrological variability of riparian wetland using hydrological attributes integration (HAI) histogram comparison approach (HCA) and range of variability approach (RVA). Ecol. Ind., 120, p.106966, 2021.

Rahman, K.U., Shang, S., Shahid, M. and Wen, Y.: Hydrological evaluation of merged satellite precipitation datasets for streamflow simulation using SWAT: a case study of Potohar Plateau, Pakistan. J. Hydrol., 587, p.125040, 2020.

Shiau, J.T. and Wu, F.C., 2006. Compromise programming methodology for determining instream flow under multiobjective water allocation criteria 1. JAWRA J. Am. Water Res. Assoc., 42(5), pp.1179-1191.

Zheng, X., Yang, T., Cui, T., Xu, C., Zhou, X., Li, Z., Shi, P. and Qin, Y.: A revised range of variability approach considering the morphological alteration of hydrological indicators. Stoch. Environ. Res. Risk Assess., 35, pp.1783-1803, 2021.

Line 197) "major steps in implementing RVA include..". However, the authors are not considering all those steps, which steps do the authors use and why?

Response: Authors have used most of the steps mentioned in the paragraph. For example, i) we have studied the hydrological alterations in streamflow using the rate and magnitude of flow in the rivers (ELF and LF), ii) we quantified the degree of alterations using the HAF (Hydrological Alteration Factor) and results are shown in Figures 7-8, iii) before the application of RVA analysis, our hypothesis tested in this study was that drought causes significant alterations in streamflow,

iv) the above hypothesis was tested using threshold regression and HAF, and v) since we quantified the impact of drought (i.e., shown the terms of drought severity that causes ELF and LF (Table 2), time where the drought caused ELF and LF (Tables 3-5), and Figures 7-8), the results and recommendation in this study will help in implementing the necessary ecosystem measures across the Indus Basin.

Line 201-202) Why are the drought years considered a post-impact period and the whole period a pre-impact period? The impacts of drought are felt during drought and afterwards. Please explain this division.

Response: As mentioned in the guidelines of IHA and RVA, we have to divide the study period into pre-impact and post-impact periods to analyze the hydrological alterations. For instance, in order to analyze the impact of a structure (e.g., dam) built on river, we have to consider the entire study period as pre-impact (before the dam construction) and post-impact (after the dam construction) period. However, decrease in the magnitude of streamflow might not only be associated with the drought. Therefore, we have considered the entire study period as a pre-impact period and the representative drought years as post-impact period.

Line 217-223) The authors explain here that threshold regression differs from change-point analysis. Why is this explained and why is threshold regression chosen instead of change-point analysis? Please elaborate on this better.

Response: The authors preferred the use of threshold regression over change-point analysis mainly on the bases of the following three reasons.

i) threshold regression is capable to understand the non-linear relationship between the threshold variables (drought and environmental flow in our case), while change-point analysis can be used to see the changing trend in a time-series data (for instance, we can only see the change point in drought or in environmental flow).
ii) threshold regression is more robust than change-point analysis in dealing with non-linear relationship between the variables, and comparable with other non-linear regression models (e.g., spline regression model).
iii) threshold regression has the potential to adapt any shape (explained by Fong et al., 2017) depending on the threshold variable and its threshold value

Line 225) How do the authors define drought severity in this study? Please explain this either in the Introduction or Methodology. For example, are specific gradations of SPEI used to consider drought severity (moderate drought, extreme drought etc.)?

Response: Drought is classified into different classes following the recommendations from McKee et al., (1993), where the classification is based on the Standardized Precipitation Index (SPI) algorithm.

1. **Results and Discussion**

Line 241) Where are the authors referring to with "Representative catchments"? Furthermore, this sentence is probably not necessary.

Response: The statement is removed as suggested.

Line 245) The authors mention here "extreme, severe, and moderate drought events", coming back to my earlier comment, how are those defined?

Response: An explanation to drought severity classes has been added in the methodology section.

Line 283-284) How are ELF, LF, high flow pulses, small floods, and large floods defined?

Response: As mentioned previously, the output from IHA is classified into IHA parameters (33) and EFCs (34). The EFC parameters are further divided into five major classes, including i) ELF, ii) LF, iii) high flow pulses, iv) small floods, and iv) large floods. The detailed information about further division of these five main classes into other sub-classes can be found in the user manual (*https://www.conservationgateway.org/Documents/IHAV7.pdf*).

Table 2) Indicate in the table that the first values are related to ELF and the second to LF.

Response: The Table 2 actually shows the drought values that resulted in ELF and LF. Since we are correlating the ELF and LF to drought, we did not differentiate between the two EFC parameters in this study because both LF and ELF are mostly linked with drought (no precipitation for longer period thus turning meteorological drought into hydrological drought and results in LF and ELF). Therefore, the table only shows the drought severity (values) that causes ELF and LF in each of representative catchments in the Indus Basin.

Line 347) "three and four", is meant here "three locations"?

Response: The Table 3 shows the time zone for a specific threshold (i.e., drought severity) where there are no significant alterations in the flow as explained in lines 341-342. The "three and four" mentioned by authors are not associated with locations, it is actually associated with the time zones where the flow in rivers have no significant alterations. It can also bee seen in the table; for instance, the entire study period in Gilgit catchment is divided into three time zones (i.e., 1980-1991, 1992-2011, and 2012-2018).

Line 395) The 18 EFC components is coming a bit out of the blue, what are those 18 components?

Response: As explained previously, the five major EFC components are further divided into different sub-classes. Here in this study, we have picked 18 sub-classes from the ELF and LF main classes. These 18 sub-classes include the magnitude, frequency, and rate of ELF and LF at each month (12 sub-classes from January to December) and 6 classes (including 1-day, 7-day, 30-day, and 90-day minimum flows, low pulse count and low pulse duration.

Line 397) "Overall, environmental flow … catchments in LIB": why is this the case?

Response: The vulnerability of catchments to drought in terms of ELF and LF is categorized into no alterations, moderate alterations and high alterations using the HAF. The conclusion mentioned in lines 397-398 is based on the Figure 7 and explained in the text.

Figure 7) Please include more information in the caption; is it averaged over which time period, which years etc.?

Response: Corrected. It is averaged over the entire study period.

There is no discussion (either in the Introduction or Discussion) about drought literature in the Indus basin in general; did other authors use other methods to look at flows in the Indus basin in relation to drought and what makes this study so innovative? Please elaborate on this in the Introduction and/or Discussion (to compare it with the results of this study). In addition, it is probably interesting to address catchment memory in relation to drought as it plays a huge role in drought impact on river flows and the prediction of hydrological drought, see for example Sutanto & Van Lanen (2022).

Response: The discussion section is added into the manuscript following the recommendation of both reviewers. Actually, this study is first of kind to link drought with environmental flow using threshold regression; therefore, very limited literature is available on this topic. However, the discussion section is added and novelty is highlighted following the guidelines and suggestions from reviewers.

Authors are thankful to reviewer for the suggestions related to linking the current study with catchment memory. Catchment memory, as explained by Sutanto and Lanen et al. (2022), plays an important role in the transition of meteorological drought to hydrological drought in the most upstream catchments without flow from upstream. However, for catchments in MIB and LIB, flows are mainly from the corresponding upstream UIB/MIB catchments and less from local runoff. Therefore, catchment memory is likely to have a minor influence on the hydrological drought in the MIB and LIB catchments. As the study catchments cover the whole Indus Basin in Pakistan, we did not add analysis related with catchment memory in this manuscript. However, analysis related with catchment memory for the UIB catchments can be carried out in our future study.

1. **Conclusion**

Line 456) "The analyses have … occurrence of droughts": how did the authors show that temperature plays an important role in the occurrence of drought? This study does not compare drought indicators or look specifically at evapotranspiration or other definitions of drought.

Response: Actually, the climate of catchment in the LIB are mostly hyper-arid in nature and this study found that drought is more severe in LIB than in other catchments of the Indus Basin. Therefore, this conclusion was made that temperature plays a critical role in the onset of drought. However, no such detailed analyses are carried out in this study and the statement is removed from the revised manuscript.

Line 465) "In other words" does not really seem appropriate here as the text is not summarizing what is said before.

Response: The term "In other words" has been removed in the revised manuscript.

Line 475-476) “In addition, the … in specific catchments”: the SPEI coefficient increases with increasing drought; do the authors mean the accumulation periods? At the moment, this sentence is not clear.

Response: The statement is revised as “In addition, the SPEI coefficient from threshold regression in scenario-2 (shown in Tables 3 and 4) increases with increase in drought severity, suggesting that SPEI has a significant impact on environmental flow in specific catchments”.

References:

Sutanto, S. J., & Van Lanen, H. A. (2022). Catchment memory explains hydrological drought forecast performance. Scientific Reports, 12(1), 2689.

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