Interactive comment on "Assessment of probability distributions and minimum storage draft-rate analysis in the equatorial region" by Hasrul Hazman Hasan et al.

Anonymous Referee #1

Referee #1 Comment:

Summary - The study by Hasan et al. focuses on low flows, drought, and minimum storage draft-rates in seven catchments in the Selangor region in Malaysia. The study consists of four types of analyses: (1) a non-parametric trend analysis on annual mean, minimum, and maximum flows using the Mann-Kendall and Sen's slope tests; (2) a low flow frequency analysis on annual minimum flow using the Lognormal 2P distribution; (3) an analysis of drought characteristics determined using a fixed drought threshold at the 90th flow percentile; and (4) the determination of minimum storage draft rates necessary to ensure sufficient water supply during low flow periods.

General remarks - The study performs a variety of analyses related to low flows and drought and in my opinion has several deficiencies. (1) It does not seem to follow a clear aim and motivation and lacks the specification of a research question; (2) it has an unclear structure and shows elements belonging to Introduction, Methods, Results, Discussion, Conclusions all over the place (i.e. not all introductory material is in the introduction,…); (3) the method descriptions are confusing and it is hard to tell how the analysis was exactly done. I was only able to understand what was approximately done when I finished reading the conclusions; (4) the presentation of the results could be significantly improved; (5) a novel aspect is missing, which leads to insignificant conclusions. I do not think that this study is publishable in NHESS. I still discuss some major points below which may help to improve the study design and presentation.

Authors Response:

We would like to thank you for your constructive comments. We have improved the whole manuscript based on your suggestions.

Referee #1 Comment:

Major points - Title: I would replace 'in the equatorial region' by 'in Malaysia'.

Authors Response:

Thank you for your recommendation. Malaysia is located in the equatorial region. We want to acquaint Malaysia as one of the countries located in the equatorial region, therefore would like to keep the current title.

Referee #1 Comment:

Abstract - The abstract is missing a clear problem statement. The study region of interest should be mentioned. I would give it a clear structure by listing the four elements of the analysis: (1) trend analysis, (2) low flow frequency analysis, (3) drought analysis, and (4) storage draft rate analysis. The abstract should also include a short summary of the main findings and end with a concluding statement (this requires a clear problem statement at the beginning).

Authors Response:

Thank you for your suggestion. We agree with the reviewer. We have revised the abstract based on your recommendation with a summary of the main findings and clear problem statements.

Referee #1 Comment:
Introduction - The introduction needs a clear research question and should introduce the problem and some background knowledge related to this research question (or questions). Currently, the introduction lists various statements related to low flows and droughts but does not tell a compelling story. The introduction would profit from a clear distinction between low flows, droughts, and water scarcity (for a discussion on these different concepts see e.g. [*Van Loon et al.*, 2016]). In addition, a short introduction to the concept of 'storage rate' should be provided (e.g. does storage refer to reservoir storage or another type of storage?). I suggest to restructure the introduction as follows: (1) introduce why are droughts, low flows, and water scarcity important and what is the relationship between the three, (2) introduce factors influencing drought and water scarcity characteristics, (3) introduce the storage-draft rate concept and how this is related to drought, (4) provide a short introduction of study area and the problem you are trying to solve, (5) state research question, and (6) provide a short overview of methods used to answer this question.

Authors Response:
Thank you for your recommendation. We have revised the introduction part based on your recommendation.

Referee #1 Comment:
Data - The study lacks a proper introduction of the dataset used for the analysis. The following specifications are necessary: are you working with observed or simulated streamflow data?

Authors Response:
The analysis is based on the observed streamflow data. Streamflow data were obtained from the Department of Irrigation and Drainage Malaysia, which covers approximately 40 years (1978 to 2017) of records for all streamflow gauging stations. Precautions were taken to ensure reasonable low flow regimes are captured. The daily observed streamflow data have consistent statistical properties and analysis of streamflow for determining the threshold level values to drought analysis. Lastly, the minimum storage draft rate required for Selangor was determined using a mass curve analysis.

Referee #1 Comment:
Are the streamflow time series natural or influenced by water abstraction and storage (at least some of them seem to be influenced)?

Authors Response:
The streamflow time series are influenced by many factors. The importance of natural hydrological regimes in maintaining the integrity of rivers has been widely recognised. Anthropogenic pressures, such as dams, point source discharges, surface water abstractions, and hydropower, may modify the natural regime of a river with a negative impact on water ecosystems.

Referee #1 Comment:
Why are inconsistencies a problem? What types of streamflow regimes do the catchments represent (i.e. what is the seasonality of the Indian and Asian monsoons)?

Authors Response:
We have explained the details in the study area part (line 146-156, page 5). The equatorial climatic regions are influenced by two monsoons, which are the southwest Indian monsoon and the northeast Asian monsoon contribute two rainy seasons with a significant amount of storm events resulting in a mean annual rainfall of about 2500 mm (Mamun et al., 2010). Even

though Selangor is located in the humid region, it occasionally encounters drought periods. Dry spells, low rainfall, and increased soil impermeability due to population growth are the leading causes of low flow events. The low flow usually refers to a stream regime that indicates the average annual streamflow variability associated with the regional climate's annual cycle. A stream's regime can display one or more low flow events depending on the climate. Two rainy and two dry seasons represent the equatorial climate, and the two streamflow regimes have two corresponding periods of high flow and low flow.

Referee #1 Comment:
Methodology - In my understanding, the analysis consists of four main steps: (1) Trend analysis of annual mean, maximum, and minimum flows, (2) low flow frequency analysis based on annual minimum flows, (3) analysis of drought characteristics for individual events, and (4) storage draft analysis. Is this correct. If this is what was actually done, I would restructure the methods section accordingly. It is unclear which types of variables are used for which type of analysis. I only figured out e.g. which variables were of interest in the trend analysis when I started to look at the tables presented in the Results section. The methods descriptions are confusing and unclear and include a lot of unnecessary detail instead of providing essential information. I do for example not understand why a detailed description of Flow Duration Curves is necessary (these were just used to determine the drought threshold, right?).

Authors Response:
Thank you for your comments. We have explained clearly in the manuscript.

Flow Duration Curve (FDC) steps are essential because FDC can describe the ratio of a specified percentage of time with discharge is equal to or surpassed (Croker et al., 2003; Mohamoud, 2008; Vogel and Fennessey, 1994), which reflects the relationship between streamflow magnitude and length of time that relates to the average percentage of time a specific flow is exceeded (Sung and Chung, 2014). Thus, FDC consists of a complete record of streamflow magnitude for 40 years.

Referee #1 Comment:
Instead, it should be specified (a) which distributions were used to fit the low flow datasets and why (i.e. which distributional properties are essential here),

Authors Response:
Thank you for your recommendation. We have revised the manuscript in line 330-340, page 11-12.

The primary aim of the probability distribution fitting is to represent the low flow probability most accurately. Among all the stations, it was found that among all distributions, the Lognormal 2P yielded the most cases of best-fit distributions, while the Gumbel and Gamma yielded the second and third amount of best-fits respectively. Comparatively, it is proposed that 2P Lognormal distributions predict low-flow discharges for all the rivers under analysis, which can be used in water quality and quantity management at gauged and ungauged areas. When the best fit probability distribution of the low flow series of the D-day has been determined, the low flow discharge of the D-day can be estimated according to any given return period. It should be noted that the research is station dependent on this analysis. The low flow-duration-frequency curves were therefore obtained at the base of gauging station. The low flow-duration-frequency curves are powerful tools for many applications, but particularly for engineering practice. An engineer may get any discharge of the low flow-duration-frequency curves from any low flow model. The fraction of non-zero flows in this river basin is always 100 per cent allowing one to measure up to 100-year return cycle D-day low flow discharges.

Referee #1 Comment:
(b) how low flow is defined (based on the results I believe as the minimum annual flow but this is not clear from the methods section),

Authors Response:
Thank you for your recommendation. We have revised the manuscript in line 131-135, page 5:
The low flow indicator applied to the available time series is the minimum low flow for weekly or 7-day low flow. For calendar years, the annual indicators were taken out. The low flow index chosen in our study is mean annual minimum flow on a 7-day average (MAM7) basis. For this study, two indicators are chosen which characterise low flow differently: Q95 and MAM7. Both parameters are less sensitive to measurement errors than the minimum discharge.

The MAM7 represents the annual minimum of the mean on seven consecutive days of daily flows. It is used in the Netherlands, in Germany and also in the United-States and United Kingdom. The percentile 95 is the flow that is exceeded 95% of the time. This indicator is spread mainly in Europe for his pertinence in numerous fields of water resources management.
The average of the annual series of minimum 7-day average flows known as Mean Annual 7-day Minimum flow (MAM7) and is used in some countries, e.g. the UK for abstraction licensing. The 7-day period covered by MAM7 eliminates the day-to-day variations in the artificial component of the river flow. Also, an analysis based on a time series of 7-day average flows is less sensitive to measurement errors. At the same time, in the majority of cases, there is no significant difference between 1-day and 7-day low flows.

Referee #1 Comment:
(c) for which variable/events return periods were determined

Authors Response:
The frequency analysis consists in the adjustment of a statistical law to the hydrological observations for each station. The objective is to calculate the critical low flow QT that corresponds to a given return period T. T is defined as the mean time between two occurrences of low flows. To do so, we used probabilistic models. These models are mathematical formulations that aim at simulating natural hydrological phenomenon such as probabilistic processes based on the probabilistic analysis of the considered random variables (in this study, Q95 and MAM7).

Referee #1 Comment:
(d) whether the determination of return periods relies on empirical or theoretical distributions,

Authors Response:
Return period relies on theoretical distribution.

Referee #1 Comment:
(e) which drought characteristics were analysed in the below threshold drought analysis,

Authors Response:
To identify streamflow drought occurrences, we used a threshold level approach, a methodology introduced by Yevjevich (1967) and widely used in recent studies. The threshold levels (also referred to as truncation levels) were derived from the flow duration curve as the flow equalled or exceeded for 70% (Q70), 80% (Q80) and 90% (Q90) of the time, as indicators of moderate, severe and extreme streamflow droughts, respectively.

The thresholds were selected in order to balance the appearance of multi-year droughts and zero-drought years (when the flow never falls below the threshold level in a year), both essential features when choosing a consistent threshold level. A significant advantage of this methodology in comparison with the use of standardised drought indices is that it allows quantification of the deficit volume, which is a vital characteristic in water resources management. A drought event starts when the flow falls below the threshold and ends when the flow exceeded the threshold level. The threshold level approach is mostly used to estimate a hydrological drought. A sequence of drought events can be obtained using the streamflow and threshold levels. Each drought event is characterised by duration, deficit-volume and time-of.

Referee #1 Comment:
(f) whether a short pooling window of 7 days (l.220) actually guaranteed independence of events,

Authors Response:
The minimum seven days average discharge was obtained for each gauge for each dry year by first smoothing hydrographs with a 7-day moving average filter. Given that the use of the threshold level method applied on daily data introduces the problem of dependency between deficits and minor drought events, the streamflow time series were smoothed with a 7-day moving average prior to the threshold level calculation, following the World Meteorological Organization (WMO) (2008) recommendation.

Referee #1 Comment:
(g) whether minor droughts were removed or not (methods section says yes, results section says no (l. 297)),

Authors Response:
We have revised the manuscript in line 270-273, page 9: In this paper, the 7-day moving average was applied as a pooling procedure to obtain smooth data. Through these methods, the mutually dependent drought events will combine into individual and independent drought events (Fleig et al., 2006). The minor drought events will be eliminated or combined with individual drought events automatically (Yahiaoui et al., 2009).

Referee #1 Comment:
(h) what the storage-draft rate method does and what kind of storage it refers to (an illustration of the concept would help).

Authors Response:
Thank you for your recommendation. We have revised the manuscript in line 274-299, page 9-10: The water supply or inflow is depending on low flow characteristics in the stream. When the inflow rate is less than the outflow (demand) rate, the maximum amount of water drawn from storage is the cumulative difference between supply and demand volumes of dry seasons. In channel storage, the function of both outflow and inflow discharge can be considered under two categories as prism and wedge storage. The water surface flow in the channel is not only unparallel to channel bottom but also varies with time. The storage, which is the maximum cumulative deficiency in any dry season, is obtained from the maximum difference in the ordinate between the mass curve of water supply and demand. Thus, the storage required can be expressed as in Eq. (10):

$$S = Maximum\ of\ (\Sigma V_D - \Sigma V_S)\ , \quad (10)$$

Where, V_D = Demand Volume; V_S = Supply volume.

The minimum storage draft rate was determined by using the mass curve of low flow at a monthly interval (Bharali, 2015). Although specific evaluation of storage requirements is essential for design, reconnaissance planning can frequently be facilitated by using draft-storage curves based on low-flow frequency analysis. Alrayess et al. (2017) determined the capacity of river storage by the mass curve method. The mass curve has many useful applications in the design of storage capacities, such as to determine the reservoir storage capacity and flood routing (Gao et al., 2017). The procedure for the mass curve method has the following steps; first, construct a mass curve of the historical streamflow (monthly streamflow); determine the slope of the cumulative draft line for the graphical scales; next, superimpose the cumulative draft line on the mass curve; lastly, measure the largest intercept between the cumulative draft line and the mass curve (Figure 1). The term draft rate refers to the residual flow to be maintained at downstream and the user demand. The storage means active storage that is available for inflow regulation.

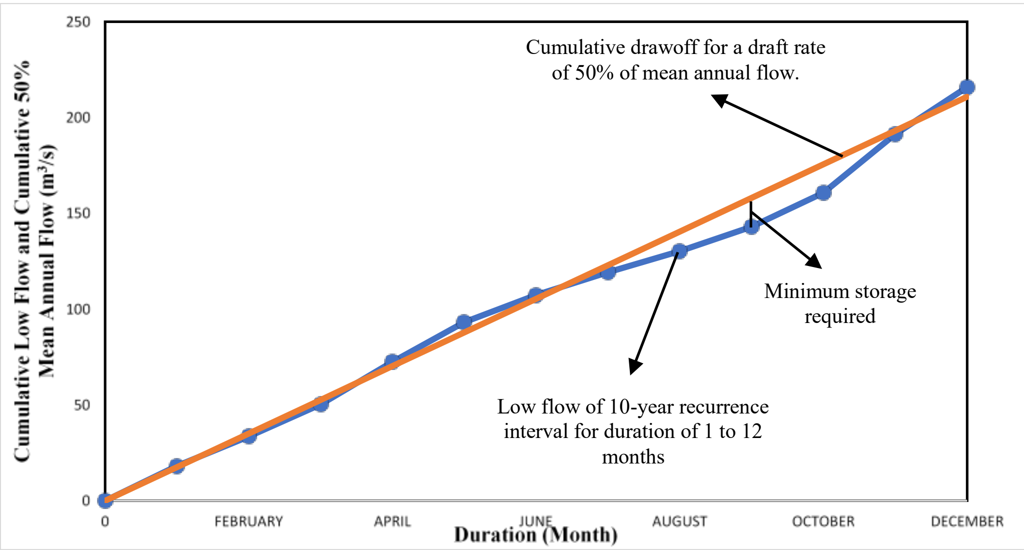

Figure 1. Minimum storage required using mass curve analysis

The estimation of the storage draft rate in this study will determine the minimum storage of a river to sustain the water supply during low flows and droughts. The mass curve of the monthly low flow rate is used in this analysis to obtain the minimum storage rate of the river. The mass curve analysis of low flow for the duration of January to December plotted against duration for recurrence interval of 10-year. The cumulative draw off corresponds to a constant draft rate of 50% of the mean annual flow and connected by a straight line. The slope of the line represents the average rate of flow that can be maintained between time. Thus, the slope of the straight line joining the starting point and the last points of the mass curve represents the average of discharge- over the whole period of plotted records.

Referee #1 Comment:

Results - The results section contains several paragraphs actually belonging to the methods and introduction sections (e.g. l. 246-250: and by the way I thought the trend analysis was performed using the non-parametric Mann-Kendall test and not linear regression).

Authors Response:

Thank you for your recommendation. We have restructured the manuscript based on your comments.

Referee #1 Comment:
There is even a statement that belongs to the introduction describing the 'primary purpose' of this study (l. 260-261).

Authors Response:
We have revised the manuscript in line 101-107, page 4.

Referee #1 Comment:
I would in some instances replace results presented in tables by figures. This particularly concerns l.300 -351. I would try to visualise these results instead of presenting them as plain text. E.g. number of events as barplots, durations, and deficits as boxplots for all stations. This would allow for a comparison across stations. In addition, you could also plot deficit time series per station to compare particular events.

Authors Response:
Thank you for your recommendation. We have restructured the manuscript based on your comments in Figure 4, 5 (page 25), Figure 6 and 7 (page 26).

Referee #1 Comment:
Discussion - The discussion presents a lot of material that in my opinion belongs to the introduction (l. 393-411). I would instead discuss the implications of your findings for water management in the region.

Authors Response:
Thank you for your recommendation. We have revised the discussion part based on your comments in line 445-448, page 15.

Referee #1 Comment:
Conclusions - Instead of providing a summary of the methods, focus on the insights we gain from this study. Currently this seems to be: 'Based on the analysis of the study, the estimated minimum storage-draft rates for each station cannot meet the water demand during low flow at specific return periods, which is 10-year recurrence interval for this research.' (l. 448-449). Formulating conclusions will be easier once you have identified a clear research question.

Authors Response:
We have revised the conclusion according to your comments in line 514-520, page 17.

Referee #1 Comment:
References - Should be carefully checked. There is at least one duplicate (Sarailidis et al. 2019), and I would consistently use lower caps for nouns (e.g. Bakanogullari et al. 2014).

Authors Response:
We have edited the references part.

Referee #1 Comment:
Language - The article needs editing with respect to the use of tense and sentence structure. Some redundant information can be removed (e.g. l. 102 and l. 107).

Authors Response:
We have removed the redundant information.

Referee #1 Comment:
Figures and Tables - Figure 1: I would indicate the locations of the dams mentioned in l.90-99 if they are important for the analysis. But I am still unsure whether the storage-rate refers to reservoir storage or something else. I would reduce the density of the stream network displayed in order to increase the distinctiveness of the colors.

Authors Response:
Response: Thank you for your recommendation. We have restructured the figure 1 based on your comments.

Referee #1 Comment:
Figure 2: Is this figure really needed?

Authors Response:
Thank you for your comment. Figure 2 shows the example of plotting position using Weibull distribution with the fitting distribution for station S01. This figure can increase the reader's understanding of why the fitted distribution should be conducted for extreme events.

Referee #1 Comment:
Figure 4: Increase legend font, provide one legend for all subplots not per subplot. What does the dark grey bar mean? Increase size of axis labels.

Authors Response:
Thank you for your recommendation. We have revised the manuscript in Figure 8, page 27.

Referee #1 Comment:
Table 1: Can in my opinion be removed as information is also contained in Figure 1.

Authors Response:
Thank you for your comment. Table 1 is consisting of detail information such as the size of the area, coordinate and river name.

Referee #1 Comment:
Table 2: Introduce in methods section, reference should be provided for each distribution.

Authors Response:
Thank you for your recommendation. We have revised the manuscript in Table 2, page 28.

Referee #1 Comment:
Table 4: It seems as if trends were not only determined over the whole period but also for very short time periods of 7 years. This sub period analysis does in my opinion not make sense. I think I would plot time series of mean, minimum, and maximum flow for each catchment to illustrate the trends and instead remove the sub period analysis.

Authors Response:
The trend analysis has been performed on every 8-years sub period to find the sign of a trend. When using the 10-year sub-period, the study area does not reflect any significant trend in streamflow and no relative different for 10-years sub-period.

Referee #1 Comment:
Table 10: Is this table related to Figure 4, and if so how or could it even be removed?
Authors Response:
Thank you for your recommendation. We have removed the Table 10.

Referee #1 Comment:
Minor points -

- Trend detection and attribution is a pretty active research area and I would not agree that we are 'beginning to pay more attention to trend analysis' (l. 118).
- A goodness-of-fit test rejects or non-rejects a hypothesis but does not 'accept a fit' (l. 163).
- The return period in a univariate setting is defined as T=1/(1-p), where p is the non-exceedance probability, i.e. T it is not the probability of occurrence itself (l. 188).
- l.353-359: move material to introduction.
- l. 363-367: move to methods section
- No further editing suggestions are provided as the manuscript in my opinion needs to be completely revisited.

Authors Response:
Thank you for your comment. We have revised the manuscript.

References

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