Responses to Editor

1. The Authors introduce the concepts of severity-duration-frequency (SDF) curve and magnitude-duration-frequency (MDF) curve.

Ans) In the first submitted manuscript, we proposed two types of curves for streamflow based drought analysis. The first type is the severity-duration-frequency (SDF) curve and the second type is the magnitude-duration-frequency (MDF) curve. Anonymous reviewers recommended that the use of the proposed MDF curve isn't expected to contribute to drought analysis. Therefore, we removed all results and statements related to MDF. Furthermore, we extended the durations of SDF curve until 270 days to consider the long-term droughts like DDF concept.

1.1 However in the Methodology section they did not explain how these curves are calculated, reporting conversely, details well known in literature (like GEV, Gumbel distributions or their L-moments).

Ans) We rewrote the study procedure and redrew the flow chart for clear description as follows:

2.1 Procedure

This study consists of five steps, as shown in Fig. 1. Step 1 is to determine the threshold levels for fixed, monthly, daily, and desired yield for water use. The threshold selection description is shown in section 2.3. Step 2 is to calculate the severities (total water deficits) and durations for all drought events at the four threshold levels. The methodology to derive severity and duration is shown in section 2.2. Step 3 is to derive the annual maxima of severity and duration and to identify the best-fitted probability distribution functions using L-moment ratio diagrams (Hosking and Wallis, 1997). The calculation procedure is shown in section 2.4 using related equations and descriptions. Step 4 is to calculate the streamflow drought severities using the selected probability distribution with best-fitted parameters and to develop SDF curves. Step 5 is to develop the duration-frequency curves of four threshold levels using appropriate probability distribution.

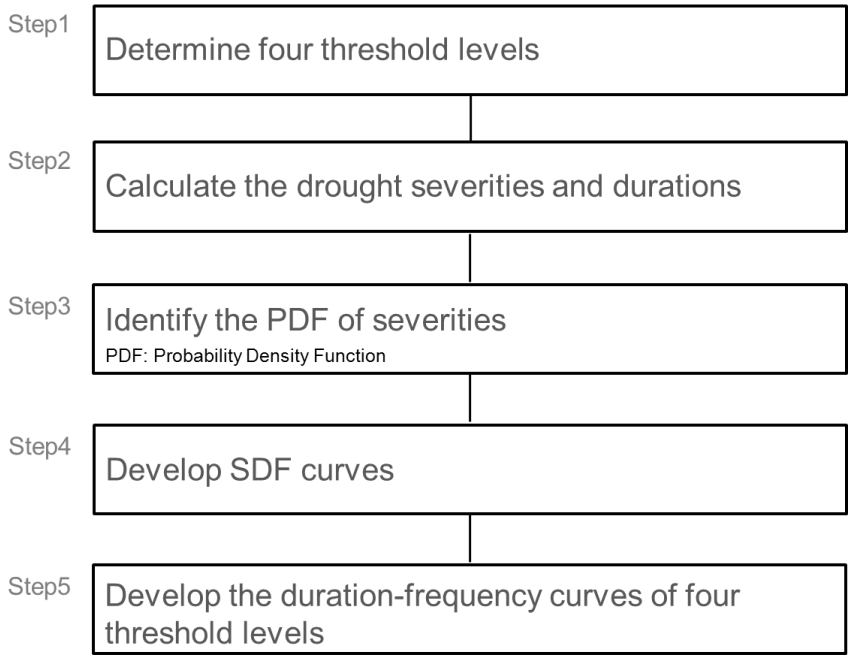

Fig. 1. Procedure of this study

1.2 Reading the manuscript, it seems the Authors have calculated empirically SDF and MDF curves. Is it right? This point must be clarified in the text.

Ans) In this revised manuscript, we proposed SDF curve and excluded MDF. SDF curve which is analogous to depth-duration-frequency curve was derived using traditional frequency analysis. For the clear description, we added section 2.5 as follows:

2.5 Development of SDF relationships

IDF or Depth-Duration-Frequency (DDF) curves can be defined as "allow calculation of the average design rainfall intensity (or depth) for a given exceedance probability over a range of durations" and results from the rainfall frequency analysis (Okonkwo and Mbajiorgu, 2010). Statistical frequency analysis for drought event has been frequently utilized such as rainfall analysis. It, however, cannot fully explain drought without any consideration of severity and duration. It has resulted in development of SDF curve. Thus, extreme drought events can be specified by frequency, duration and either depth or mean intensity (i.e. severity). The frequency is usually described by its return period which defined as the average interval of time within which the magnitude of the event is reached or exceeded once. Since its magnitude is given by the total depth occurring in a particular duration, SDF relationship can be derived. For the estimation of return periods for drought events of particular depth and duration, the frequency distributions can be utilized (Dalezios et al., 2000).

In the case of an urban catchment, the design of the pipe is largely a function of the flow rate, which depends on the rainfall intensity, while for attenuation or storage structures, the volume of flow (i.e. the depth of rainfall) is important (Mansell, 2003). Based on rainfall DDF concept, streamflow drought SDF curve developed in this study can be potentially exploited to design storage structures using the water deficit for the natural streams as well as reservoirs.

1.3 One thing that could improve the manuscript is providing a theoretical law to obtain SDF and MDF curves, like the IDF or DDF curves.

Ans) We added the backgrounds of SDF using IDF and DDF and described the theoretical law to obtain SDF as follows:.

2.5 Development of SDF relationships

IDF or Depth-Duration-Frequency (DDF) curves can be defined as "allow calculation of the average design rainfall intensity (or depth) for a given exceedance probability over a range of durations" and results from the rainfall frequency analysis (Okonkwo and Mbajiorgu, 2010). Statistical frequency analysis for drought event has been frequently utilized such as rainfall analysis. It, however, cannot fully explain drought without any consideration of severity and duration. It has resulted in development of SDF curve. Thus, extreme drought events can be specified by frequency, duration and either depth or mean intensity (i.e. severity). The frequency is usually described by its return period which defined as the average interval of time within which the magnitude of the event is reached or exceeded once. Since its magnitude is given by the total depth occurring in a particular duration, SDF relationship can be derived. For the estimation of return periods for drought events of particular depth and duration, the frequency distributions can be utilized (Dalezios et al., 2000).

2. Drought is a multivariate event where the variables like severity, duration and intensity of the drought are dependent one from the other. Please clarify this in the introduction, and update the references given with recent works available on this issue.

Ans) Since drought is a multivariate event, we added four general drought types and their definitions in terms of severities and durations as follows:

American Meteorological Society (1997) groups drought definitions and types into four categories: meteorological or climatological, agricultural, hydrological, and socioeconomic droughts. The meteorological drought is resulted from the absence or reduction of precipitation and short-term dryness results in an agricultural drought that severely reduces crop yields. Precipitation deficits over a prolonged period reducing streamflow, groundwater, reservoir and lake levels, will result in a hydrological drought. If hydrological drought continues until the supply and demand of some

economic goods is damaged, a socioeconomic drought happens (Heim, 2002).

In addition, we updated the references given with recent works and added the detailed described objectives of this study as follows:

Thus, there is a growing need to integrate drought severity, duration with frequency based on multivariate theory (Bonaccorso et al., 2003; Gonz´alez and Vald´ es, 2003; Mishra et al., 2009; Song and Singh, 2010a, b; De Michele et al, 2013). Therefore, based on the typical drought characteristics (water deficit and duration) and threshold levels, this study developed quantitative relationships between drought parameters, namely severity, duration and frequency and use them in plotting drought iso-severity curve of certain return period and duration. This study quantified the streamflow drought severity which is closely related to hydrological and socioeconomic drought, using fixed, monthly, daily and desired yield threshold levels. Furthermore, this study proposed the streamflow drought severity-duration-frequency (SDF) curve using traditional frequency analyses. This framework was applied to the Seomjin River basin in South Korea.

3. I found several mistakes in the text. Thus I suggest to the Authors to improve the English before resubmitting the revised version of the manuscript.

Ans) As your opinion, this manuscript has been proofread by native English before submitting.

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EDITORIAL CERTIFICATE

This document certifies that the manuscript listed below was edited for proper English language, grammar, punctuation, spelling, and overall style by one or more of the highly qualified native English speaking editors at American Journal Experts.

Manuscript title:
Development of Streamflow Drought Severity- and Magnitude-Duration-Frequency Curves Using Threshold Level Method

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Minor issues:

1) pag. 14676 line 5 “e.g., a rainfall intensity-duration-frequency curve”. This is not clear. Please clarify otherwise delete it.

Ans) As the review pointed out, we modified the sentence as follow:

This study developed a streamflow drought severity-duration-frequency (SDF) curve which is analogous to the well-known depth-duration-frequency curve used for rainfall.

2) pag. 14678 line 7 change “variable” in “variables” and “levels” in “level”.

Ans) It is suggested to keep verbs in present for new developments and results and use past and present perfect for previous works. We changed change “levels” into “level”.

3) pag.14679 lines 11-12, “the ratio ... zc”. The sentence is not clear.

Ans) We revised the wrong expression as follows:

If the ‘inter-event’ time t_i between two droughts of duration d_i and d_{i+1} and severity s_i and s_{i+1}, respectively, are less than the predefined critical duration t_c, and the pre-allowed inter-event excess volume z_c, the mutually dependent drought events were pooled to form a drought event as

4) pag.14687 lines 11-13, what is SDI? Probably SDF.

Ans) We deleted the word.

5) pag.14697 change “events” with “event”

Ans) We changed “events” with “event”

6) pag.14696 simplify the figure. Probably you can take out the four boxes (Fixed Q70, ...) from each step because these are repeated identically.

Ans) We deleted the four boxes.

7) pag.14693 Report the units of measure.

Ans) We deleted Table 3 and relevant statements.

8) pag.14701 Report just one legend for the three sub-figures.

Ans) We deleted sub figure related to magnitude and relocated legends in the figure.

Added references are as follows:

Okonkwo GI and Mbajiorgu CC. 2010. Rainfall Intensity-Duration-Frequency Analyses for South Eastern Nigeria. *Agricultural Engineering International: the CIGR Ejournal*. Manuscript 1304. Vol. XII. March.

De Michele C, Salvadori G, Vezzoli R, Pecora S. 2013. Multivariate assessment of droughts: Frequency analysis and dynamic return period. *Water Resources Research*, **49(10)**: 6985–6994

In the revised manuscript, we had totally restructured and revised our previous first-submitted manuscript. We are sure that the new version has been innovatively improved due to two anonymous reviewers and editor. You can see the responses to the previous two reviewers’ opinions as follows:

Interactive comment on "Development of Streamflow Drought Severity-Duration-Frequency Curve Using Threshold Level Method"

Jang Hyun Sung[1], Eun-Sung Chung[2]*

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We would like to thank all of the reviewers for their detailed and useful comments on our paper. A number of extremely constructive comments were made which when implemented will improve this review article considerably. We adopted all reviewers' opinions and then revised a lot.

Responses to Review #1

The authors propose two types of curves for streamflow-based drought analysis. The first type is the severity-duration-frequency (SDF) curve and the second type is the magnitude-duration-frequency (MDF) curve. They define severity as the total water deficit volume and magnitude as the daily average water deficit for each drought event. To calculate the water deficit, they employ the threshold level method through using four different approaches for the determination of threshold levels. Last, they apply the proposed methodology to a Korean basin.

The subject treated in this paper is of high interest to hydrological sciences and certainly falls within the scope of HESSD. With regard to the proposed methodology the following observations can be made: (1) the severity-duration-frequency (SDF) curve for drought analysis has been proposed by Dalezios et al. (2000); (2) those researchers have used the GEV distribution as the authors of the current paper do; (3) since drought is a slowly developing phenomenon it needs to be analyzed only at coarse time scales (e.g., greater than a month); as a result, daily deficit is of no practical use in drought analysis; (4) a direct consequence of the previous statement is that the use of the proposed MDF curve is not expected to contribute to drought analysis; (5) the approaches used to determine thresholds are known. In view of the above, the originality of the SDF curve cannot be claimed while the MDF curve cannot yield any meaningful information for drought analysis.

Ans.) The reviewer showed that this article is short of originality for the above five reasons. We partially agree with it. However, this article has its originality for the following reasons.

(1) Even though Dalezios et al. (2000) had already developed Palmer Drought Index (PDSI) SDF curve, this study focuses on streamflow drought severity-duration-frequency curve. They are largely different similar to the difference between meteorological and agricultural drought and hydrological and socioeconomic droughts. In addition, this study combined streamflow drought severity with four threshold levels including the desired yield.
(2) GEV is very common and useful distribution in statistical hydrology as well as extreme data in all fields. So, the usage of GEV in this study means that the selection of probability distribution is appropriate.
(3) As the reviewer's comments, we deleted the explanations and descriptions related to MDF

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curve. In addition, although this study used the daily streamflow data, the period this study is focusing on is greater than a month. The time resolution in this study (defined as duration) is variable from 30 to 270 days. The threshold selection is totally different from drought time scale. The daily variable threshold is Q70 of FDCs obtained from the antecedent 365 daily streamflows. So, it is daily-varied values.

(4) As to the reviewer's opinion, we removed all results and statements related to MDF. Although MDF is our trial, we need more discussions and improvements.

(5) The fixed and monthly and daily variable thresholds are well-known. However, the desired yield threshold for sufficient water supply is new. This study is focusing on the usage of the desired yield threshold since the events defined with the varying and the fixed threshold from the past streamflow data should be called streamflow deficiency or streamflow anomalies rather than streamflow drought (Hisdal et al., 2004). In addition, since streamflow drought severity-duration-frequency curve has never been proposed and applied, this study proposes an effective means to identify any streamflow droughts using total water deficits (severities), durations and frequencies. To include the above originalities, we rewrote the abstract as follows:

Abstract *This study developed a streamflow drought severity-duration-frequency (SDF) curve which is analogous to the well-known intensity-duration-frequency curve used for rainfall. Severity was defined as the total water deficit volume to target threshold for the specific drought duration. The fixed and variable threshold level methods were introduced to set the target instream flow requirement, which can significantly affect the streamflow drought severity. The four threshold levels utilized were fixed, monthly, daily, and desired yield for water use. The fixed in this study is the 70-percentile value (Q_{70}) of flow duration curve (FDC) which resulted from all available daily streamflows and the monthly is monthly-variable Q_{70}s of each month's FDC. The daily variable threshold is Q_{70} of FDC obtained from the antecedent 365 daily streamflows. The desired yield threshold determined by central government consists of domestic, industrial and agricultural water uses and environmental instreamflow. As a result, the desired yield threshold can identify the streamflow drought using total water deficit to the hydrological and socioeconomic targets while the fixed, monthly and daily derived the streamflow deficiencies or anomalies because of the just usage of streamflow data. Based on individual frequency analysis, SDF curves for four thresholds were developed to quantify the relationship among severities, durations and frequencies. For more specification, the drought duration-frequency curve was developed. It can be an effective tool to identify any streamflow droughts using severities, durations and frequencies.*

The authors adopt the approach of the drought event in which each event is determined by the time of onset, duration, total deficit and average deficit. This is a theoretical approach to analysing droughts since, at the operational level, requirements are different: the question is whether a drainage basin is at drought for a specific time period (e.g., the first trimester of 2013). Thus, the drought onset and duration become meaningless.

Ans) We agreed with the reviewer. Therefore, we deleted Table 3 and its relevant explanations.

To respond to the operational requirements a systems-based approach has been proposed by Tsakiris et al. (2013). Within the frame of that approach, the two types of curves examined in this paper loose their usefulness. Given the above information the authors are invited to clearly identify their contribution with respect to the existing knowledge and revise their manuscript by bringing forward their contribution.

Ans) Tsakiris et al. (2013) presents an innovative system-based typology of drought and water scarcity concepts. Also concepts of water scarcity drought, water shortage, aridity and desertification are viewed within the perspective of this new approach. So, we frequently mentioned the usefulness of Tsakiris et al. (2013) on the drought concept for operational management in the revised manuscript.

Page 14676, lines 5-6: The phrase "(e.g., a rainfall intensity-duration-frequency curve)" is, in my view, inappropriate here; a phrase such as "which is analogous to the well-known intensity-duration-frequency curve used for rainfall." would be better.

Ans) We adopted the review's recommendation.

Page 14676, line 10: In cases that the threshold varies per month one normally would expect a family of twelve curves; to prevent confusion an epigrammatic comment on this is needed.

Ans) We added the relevant sentences to prevent the readers' confusion as follows:
The fixed is Q_{70} of FDC which resulted from 37-year daily streamflows. The monthly thresholds are twelve Q_{70}s of monthly FDCs which resulted from all daily streamflows of January, February … and December for the past 37 years, respectively. The daily threshold is Q_{70} of FDCs which resulted from the antecedent 365 daily streamflows. Thus, the daily changes smoothly every day.

Page 14676, line 11: The term "desired yield" cannot be assumed known to readers; it requires a brief definition.

Ans) We added the brief meaning of desired yield in this study as follows:
The desired yield threshold for sufficient water supply and environmental instreamflow was determined by Korean central government. That is, it is related to social and economic droughts since it associates the supply and demand of some economic goods and environmental safety. The desired yield threshold differed considerably from the other levels and represented more realistic conditions because the desired yield is equivalent to the planned water supply.

Page 14676, lines 15-16: The statement "These SDF and MDF curves are useful in designing water resources systems for streamflow drought and water supply management" is rather vague since: (1) unlike the IDF curves for rainfall, no practical use of the SDF and MDF curves is established so far, and (2) the authors avoid proposing any framework for the usage of these curves; a revision of this phrase is, in my view, necessary to remove vagueness.

Ans) That is quite general and vague. As the review pointed out, we deleted the sentence.

Page 14676, line 18: The qualifier "multi-dimensional" is left unexplained; adding the dimensions of the phenomenon would help; it is noted that the spatial dimension is ignored in the paper.

Ans) We deleted this sentence for clarity.

Page 14676, lines 19-20: The phrase "Droughts have dramatically increased in number and intensity over the last few decades (ComEC, 2007)" is too categorical; first, we recall the subtle difference between drought and water shortage (Tsakiris et al., 2013), i.e. that drought is the natural form of temporary water scarcity, while water shortage is temporary and human induced water scarcity; second, the population growth and the subsequent increase of water demand leads to much more frequent water scarcity episodes the causes of which are difficult to identify in all cases; hence, unless the natural causes of water scarcity episodes are known, speaking of dramatic increase in drought episodes is too categorical. I would tend to suggest removing the word "dramatically".

Ans.) We deleted the word and restructured the introduction.

Page 14676, line 22: Here the authors say that "water scarcities have occurred", while in line 23 the

term “drought risk analysis” appears; again the difference between “drought” and the general term “water scarcity” is ignored which causes serious confusion.

Ans) We deleted the first two sentences and added the following new paragraphs. We deleted all phrases “water scarcity” in this manuscript. Also, we rewrote that paragraph for clarification as follows:

American Meteorological Society (1997) groups drought definitions and types into four categories: meteorological or climatological, agricultural, hydrological, and socioeconomic. The meteorological drought is resulted from the absence or reduction of precipitation and short-term dryness results in an agricultural drought that severely reduces crop yields. Precipitation deficits over a prolonged period reducing streamflow, groundwater, reservoir and lake levels, will result in a hydrological drought and socioeconomic drought that associate the supply and demand of some economic good with elements of meteorological, agricultural, and hydrological drought (Heim, 2002).

Especially, hydrological and socioeconomic droughts are very difficult to be approached. Hydrological drought is defined as a significant decrease in the availability of water in all its forms appearing in the land phase of the hydrological cycle. These forms are reflected in various hydrological variables such as streamflow including snowmelt and springflow, lake and reservoir storage, recharge of aquifers, discharge from aquifers and baseflow (Nalbantis and Tsakiris, 2009). That is, streamflow is the key variable to analyze in describing hydrological droughts since it embeds outputs of four different sub-systems, i.e. surface runoff from the surface water subsystem, subsurface runoff from the upper and lower unsaturated zone and baseflow from the groundwater subsystem (Tsakiris et al., 2013). Furthermore, streamflow crucially affects the socioeconomic drought for many water supply activities such as hydropower generation, recreation, and irrigated agriculture where crop growth and yield are largely dependent on water availability in the stream (Heim, 2002). Hence a hydrological and socioeconomic drought event is related to streamflow deficit with respect to hydrological normal condition or target water supply for economic growth and social welfare.

Page 14677, lines 9-12: The drought components listed here are often referred to as forms or expressions of drought; these are however ambiguous since it is unclear what part of the hydrological cycle these characterize; a clarification of the subject is provided by Tsakiris et al. (2013); in my view, saying “Based on these definitions, various indices have been proposed over the years to identify drought” is sufficient.

Ans) We revised the sentence as you had recommended.

Page 14678, line 3: Saying “Based on the reported drought definitions” is ambiguous; a clarification is necessary.

Ans) We added the clear explanation as follows:

Based on the typical drought characteristics (water deficit and duration) and threshold level approaches

Page 14678, lines 13-14: According to the definition of "daily average water deficits (or magnitude)" the "magnitude" is functionally related to severity as: (magnitude) = (severity)/(duration); a clear explanation is needed regarding the reason why the MDF curve conveys information which is different from that of the SDF curve.

Ans) We deleted the explanations related to MDF.

Page 14678, lines 15-16: The phrase "the best-fitted probability distribution functions of annual maximum SDF and MDF" causes confusion; a step is missing here which will refer to the calculation of annual maxima; also, it is absolutely necessary to name the variable on which the annual maxima are taken.

Ans) We added the explanation on the hidden step as follows:

Step 3 is to derive the annual maxima of severity and duration and to identify the best-fitted probability distribution functions using L-moment ratio diagrams (Hosking and Wallis, 1997).

Page 14678, line 16: After "...using L-moment ratio diagrams" a reference to this method is needed.

Ans) We added the reference: Hosking and Wallis (1997).

Page 14678, line 16: Step 4 involves two calculation steps: threshold calculation and construction of curves; please consider inserting an extra step by augmenting also the numbers of subsequent steps.

Ans) We added the explanation on the hidden step as follows:
Step 4 is to calculate the streamflow drought severities using the selected probability distribution with best-fitted parameters and to develop SDF curves.

Page 14678, line 21: Here the authors say "to estimate a hydrological drought" thus creating the impression that they will focus on this drought form; yet, reference to SPI (line 23) and PDSI (line 24) creates confusion since these two indices refer to meteorological and agricultural droughts respectively;

Ans) We added the explanation for two indicated indices as follows:

SPI (Standardized Precipitation Index) for meteorology (Yoo et al., 2008) and PDSI (Palmer Drought Severity Index) for meteorology and agriculture (Dalezios et al., 2000)

Page 14679, lines 11-12: The phrase "the ratio between the inter-event excess volume zc" is unclear; the numerator and the denominator should be indicated.
Ans) The term "ratio" is not correct. We revised the wrong expression as follows:
If the 'inter-event' time t_i between two droughts of duration d_i and d_{i+1} and severity s_i and s_{i+1}, respectively, are less than the predefined critical duration t_c, and the pre-allowed inter-event excess volume z_c, the mutually dependent drought events were pooled to form a drought event as

Page 14680, line 4: Symbols "Q70" and "Q95" have to be defined.
Ans) We added the meaning as follows:

Q_{70} means a 70% flow of FDC. That is, 70% is the percentage of time that the streamflow, Q_{70}, is exceeded.

Page 14683, sub-section 4.1: The material of this sub-section is confusing; it is suggested to describe the steps for the calculation of thresholds in a more rigorous and analytical manner.

Ans) We added the explanations how to derive four threshold levels used in this study as follows:

This study used four threshold levels. The fixed is Q_{70} of FDC which resulted from 37-year daily streamflows. The monthly thresholds are twelve Q_{70}s of monthly FDCs which resulted from all daily streamflows of January, February … and December for the past 37 years, respectively. The daily threshold is Q_{70} of FDCs which resulted from the antecedent 365 daily streamflows. Thus, the daily changes smoothly every day. The desired yield threshold for sufficient water supply and environmental instreamflow was determined by Korean central government. That is, it is related to social and economic droughts since it associates the supply and demand of some economic goods and environmental safety. The desired yield threshold differed considerably from the other levels and represented more realistic conditions because the desired yield is equivalent to the planned water supply.

Page 14683, line 26: The result announced in the phrase "The daily threshold displays the highest number of drought events" is expected; it is however of no practical significance since, as already said, drought analysis at the daily time scale has no meaning.

Ans) Because we agreed with reviewer's thought, we deleted.

Page 14684, lines 19 – 20: The phrase "To confirm the consistency of our approach, the correlation coefficients among the four results were calculate" announces a test within the results section for the first time; since this reduces readability, it is suggested to create a new sub-section titled "Description of tests" (sub-section 2.5) in section 2, where all tests will be described and justified.

Ans) We used correlation coefficient for the comparative representation. So the term "consistency" is wrong. Due to this reason, we are so sorry that we couldn't find any particular theory for "description of tests". We deleted the wrong expression and rewrote the relevant statements for clear descriptions as follows:

To compare the differences from four threshold levels, the correlation coefficients were calculated as shown in Table 3. The similar trend was observed in the monthly and daily threshold levels. However, the durations and severity from the desired yield threshold level were completely different from those for fixed, monthly and daily levels. That is, it can be guessed that the drought identification techniques based on general threshold levels cannot reflect the socioeconomic drought in terms of water supply and demand. Therefore, two-way approaches which are anomaly type (fixed, monthly and daily) for hydrological drought and desired yield threshold for socioeconomic drought should be separately included for specific drought characteristics identification.

Page 14684, lines 25 - 26: The term "two-way approaches" is too general and creates confusion.

Ans) We clarified it as follows:

Therefore, two-way approaches which are anomaly type (fixed, monthly and daily) for hydrological drought and desired yield threshold for socioeconomic drought should be separately included for specific drought characteristics identification.

Page 14685, lines 2 – 10: The whole material "The L-moment ... the best-fit distribution" normally belongs to the methodology section and should therefore be moved there.

Ans) We deleted because that part was already used in Section 2.4.

Page 14685, lines 10 -11: What do the authors mean by "To develop an SDI MDF curve"? Also, SDI needs to be defined.

Ans) We deleted the explanation related to magnitude.

Page 14685, lines 16-18: The expression "... and of those three distributions, fewer than half of the observations approached the GEV line." creates the impression that the GEV distribution will be rejected; yet, the text that follows ("Thus, the GEV distribution was selected as a representative distribution.") reveals the opposite conclusion; a clarification is necessary on this.

Ans)
The L-moment ratios are shown as triangular points in the Fig. 7. 3 parameter distributions such as GEV, GNO and Pearson3 were considered as comparatively appropriate distribution for datasets. Generally, the used data for the frequency analysis are extreme values. So, the distributions which have more than 3 parameters are required for expression of upper tail. GEV, GNO and Pearson3 distribution can be applied in this study. And almost half of the observations are appropriate for the GEV among distributions. The most popular distribution used in the frequency analysis these days is GEV distribution. So, the GEV distribution was selected as a representative distribution. So we rewrote the relevant description as follows:

The L-moment ratio diagrams were derived for the four threshold approaches and are displayed in Fig. 7. Of the distribution models tested, 3 parameter distributions such as the Pearson Type 3(PT3), Generalized Normal (GNO), and Generalized Extreme Value (GEV) distributions appeared consistent with their datasets. In the frequency analysis dealing with extreme values, the distributions which have more than 3 parameters are required for expression of upper tail. PT3, GNO, and GEV distribution can be applied in this study. As shown in Fig. 7, this study selected GEV distribution for a representative probability distribution because most observations are appropriate for the GEV. It corresponds to Dalezios et al. (2000) for PDSI and Yoo et al. (2008) for SPI.

Page 14685, line 24: The selected values for duration ("10, 20, 30, and 40 day durations") are not of practical significance in drought analyses. Durations of three, six or more months would be appropriate.

Ans) We extended the durations until 90 ~ 270days. The changed SDF curve for the desired yield threshold is derived as shown in Fig. 8 of revised manuscript.

Page 14687, lines 10 – 11: The statement "This study can be applied to various hydrologic analyses and water resources management systems, such as desired yield and dam safe yield." needs to be supported by evidence on existing methods which can potentially exploit the proposed curves.

Ans) We agree with the reviewer. It is too vague. So, we revised the last paragraph as follows:

Streamflow drought SDF curve developed in this study can be potentially exploited to quantify the water deficit for the natural streams as well as reservoirs. In addition, these will be extended to conduct regional frequency analyses, which can estimate streamflow drought severity at ungagged sites. Therefore, it can be an effective tool to identify any streamflow droughts using severity, duration and frequency.

Technical corrections

Ans) We revised the following errors that the reviewer had indicated.

It is suggested to keep verbs in present for new developments and results and use past and present perfect for previous works.
Page 14678, line 7: Please change "levels" into "level".
Page 14679, line 17: Please change "This" into "These" to read "These numbers ...".
Page 14684, line 8: Please change "large" into "larger" to read "became larger when the duration was longer".

References

Dalezios, N., Loukas, A., Vasiliades, L., Liakopolos, E., Severity-duration-frequency analysis of droughts and wet periods in Greece, Hydrological Sciences Journal, 45(5), 751-769, 2000.
Tsakiris, G., Nalbantis, I., Vangelis, H., Verbeiren, B., Huysmans, M., Tychon, B., Jacquemin, I., Canters, F., Vanderhaegen, S., Engelen, G., Poelmans, L., De Becker, P., Batelaan, O., A System-based Paradigm of Drought Analysis for Operational Management, Water Resources Management, 27(15), 5281-5297, 2013.

Ans) We added the above two references you had proposed. They are very useful in our article.

Responses to Review #2

General comments:
The paper developed streamflow drought severity- and magnitude-duration-frequency curves using four threshold level methods, for The Seomjin River basin which is located in southwestern Korea. Globally, the paper is well written and structured. However, in my opinion, in terms of water supply and water use, the concept of daily drought is embarrassing. The daily deficit concept is better than daily drought. In addition, the results confirm this point of view ““That is, the drought identification techniques based on real precipitation and natural streamflows did not reflect the drought concept in terms of water supply and water use”.

Ans)

In addition, although this study used the daily streamflow data, the period this study is focusing on is greater than a month. The time resolution in this study (defined as duration) is variable from 30 to 270 days. The threshold selection is totally different from drought time scale. The daily variable threshold is Q70 of FDCs obtained from the antecedent 365 daily streamflows. So, it is daily-varied values.

A relevant article “A review of Twentieth Century Drought indices Used in the United States” of Richard R. Heim Jr. (2002) should be cited in this paper.

Ans.) We added the article since it had shown very useful results.

Many concepts and definitions are given and clarified.
P14682 §25: Could you define the drought’s threshold of “River Survey Report (K-water, 1992)”.

Ans) We added the brief meaning of desired yield in this study as follows:

The desired yield threshold for sufficient water supply and environmental instreamflow was determined by Korean central government. That is, it is related to social and economic droughts since it associates the supply and demand of some economic goods and environmental safety. The desired yield threshold differed considerably from the other levels and represented more realistic conditions because the desired yield is equivalent to the planned water supply.

Table 3: “drought order” refers to which characteristic: duration, magnitude and severity? Or is it another characteristic? If we consider the duration, 102 days has the order 146 and not 50. If we consider severity148 052 571 has the order 146 and not 50. In consequence, you should explain your ordering.

Ans) Another reviewer presented that drought onset and duration become meaningless. Since we agreed, we deleted Table 3 and relevant statements. So, it isn’t necessary to explain the order of drought in Table 3.

Technical corrections

P14684 §5: from 28 September to 7 January 1989, instead of October.
Ans) We revised it.

Table 2&3: you should add units in some columns
Ans) We added the missing units.

Figures 8 & 9 are not cited in the text.
Ans) In the section 4.4, the two figures are cited. However, the figures and related explanations were changed since the duration was extended until 270 days.

It seems that a table is missing: table “6” about severity

Ans) We restructured the article. So the table number was changed. It is Table 4 in the revised manuscript.