

## **Review: “GTDI: a gaming integrated drought index implying hazard causing and bearing impacts changing” by Zhao et al.**

**RC3: 'Comment on nhess-2024-45', Anonymous Referee #2**

### **General comments:**

This study created a new integrated drought index (GTDI) by integrating SPEI and SSMI using the game theory method. The GTDI's usefulness in drought identification was evaluated through a case study in the Wei River Basin, and the effects of hazard-causing and hazard-bearing elements on drought episodes were discovered. Overall, this drought study falls within the scope of the NHES journal and offers useful insights for recognizing and tracking drought hazards. However, the method and analysis in the manuscript are insufficient to support several of the authors' arguments, and the general presentation of the manuscript (including some images and discusses) requires improvement. I believe that this work requires certain revisions before it can be accepted for publication. My comments can be seen below.

We greatly appreciate the positive feedback. We would like to express our gratitude for your valuable comments and suggestions. We are grateful for the acknowledgement of the work. We would like to assure the reviewer that we will carefully address all concerns and incorporate the suggestions into an improved version of the manuscript. We are committed to enhancing the quality of our manuscript based on the reviewers' comments.

### **Specific comments:**

#### **Abstract**

Line 31-33, “This study surely serves as a helpful reference for the development of integrated drought indices as well as regional drought mitigation, prevention, and monitoring.” I am not convinced that the integrated drought index developed in this study has practical applications for “regional drought mitigation”. Please improve the phrasing in this statement.

**Answer:** Thank you for noticing. We have improved this sentence and intend to replace it by: *“This study surely serves as a helpful reference for the development of integrated drought indices as well as regional drought prevention and monitoring.”*

#### **1. Introduction**

Line 54, “with drought occurrences becoming more frequent, intense, and extended”, remove “occurrences”.

**Answer:** Thank you for this comment. We will remove “occurrences” as suggested.

Line 89, change “has” to “had”.

**Answer:** Thank you for careful review. We will modify the text as suggested, also check and revise other similar tense issues in the text sentence by sentence.

Line 95, according to the statements in lines 82 to 84, “comprehensive” should be replaced by “integrated” or “composite”.

**Answer:** Thank you for pointing out this issue. We will follow your suggestion to change and check for other inappropriate wording throughout the manuscript.

Line 99-101, provide the appropriate citations for “it has been revealed that the impacts of different factors on drought, such as hazard-causing and hazard-bearing, are changing ...”.

**Answer:** Thank you for this comment. According to your suggestion, we will add some citations as follows:

*“Furthermore, it has been revealed that the impacts of different factors on drought [18,19], such as hazard-causing and hazard-bearing, are changing spatially and game-playing, necessitating the development of effective linear combination methods for measuring their spatial heterogeneity in contribution to drought.”*

[18] Blauhut, V., Stahl, K., Stagge, J. H., Tallaksen, L. M., Stefano, L. D., Vogt, J. (2016). Estimating drought risk across Europe from reported drought impacts, drought indices, and vulnerability factors. *Hydrol. Earth Syst. Sci.*, 20(7): 2779-2800.

[19] Zhang, Q., Shi, R., Singh, V. P., Xu, C., Yu, H., Fan, K., Wu, Z. (2022). Droughts across China: Drought factors, prediction and impacts. *Sci. Total Environ.*, 803: 150018.

## **2. Study area and data**

Line 124-128, the precipitation and temperature conditions in the Wei River Basin are mentioned here, however there are no corresponding subfigures in Figure 1. Please include a matching regional distribution map of precipitation and temperature in Figure 1.

**Answer:** Thank you for your suggestion. We will improve Figure 1 in the revised manuscript as suggested.

Line 134, add a citation for the DEM data.

**Answer:** Thank you for pointing out this issue. However, we have given the source of the data in accordance with the data citation requirements, which is listed in Table 1, and there is no corresponding research literature on this DEM data.

Line 135, add a citation for the precipitation and temperature dataset.

**Answer:** Thank you. We will add a citation for the precipitation and temperature dataset as follows: *“monthly precipitation and temperature dataset [20] from 1950 to 2020 with a grid size of 1 km.”*

[20] Peng, S., Ding, Y., Liu, W., Li, Z. (2019). 1 km monthly temperature and precipitation dataset for China from 1901 to 2017. *Earth System Science Data*, 11(4), 1931-1946.

Line 136, add a citation for GLDAS\_NOAH025\_3H\_2.0 and GLDAS\_NOAH025\_3H\_2.1.

**Answer:** Thank you. In fact, we have given the source of the data in accordance with the data citation requirements, which can be found in Table 1 of our manuscript.

Line 138, add a citation for GLOBMAP leaf area index dataset (Version 3).

**Answer:** Thank you. We will add a citation for GLOBMAP leaf area index dataset (Version 3) as follows: *“GLOBMAP leaf area index dataset (Version 3) [21] with a period of 1981 to 2019 and a spatial resolution of 0.08°.”*

[21] Liu, Y., R. Liu., J. M. Chen. (2012). Retrospective retrieval of long-term consistent global leaf area index (1981–2011) from combined AVHRR and MODIS data, *J. Geophys. Res.*, 117, G04003, doi:10.1029/2012JG002084.

## **3. Methodology**

Line 145, please put the detailed calculation procedure for SPEI in a supplementary file.

**Answer:** Thank you for your suggestion. We will put the detailed calculation procedure for SPEI in the supplementary material, which will be uploaded along with the revised manuscript.

Line 156, please put the detailed calculation procedure for SSMI in a supplementary file.

**Answer:** Thank you for your suggestion. We will put the detailed calculation procedure for SSMI in the supplementary material, which will be uploaded along with the revised manuscript.

In Section 3.2, as a comparison to the GTDI index, the calculation process of the ETDI index needs to be explained in detail.

**Answer:** Thank you for your suggestion. We totally agree with you. The calculation process of the ETDI index will be stated as suggested. However, considering the length limitation of the manuscript, we intend to put it in the supplementary material just like SPEI and SSMI.

In Table 2, the value range for “moderate drought” is wrong and should be changed to “ $-1.5 < \text{Index} \leq -1.0$ ”.

**Answer:** Thank you for noticing. We will correct the value range for “moderate drought” by “ $-1.5 < \text{Index} \leq -1.0$ ”.

Line 199-202, add the appropriate citations for the Pearson's correlation coefficients (PCC).

**Answer:** Thank you for your suggestion. We intend to add a citation for the Pearson's correlation coefficients (PCC) as follows:

*“Thus, the Pearson's correlation coefficients (PCC) [22] between GTDI/ETDI with SPEI and SSMI are calculated for each grid (Eq. 6), and their correlation in different locations is explored.”*

[22] Panda, P. K., Panda, R. B., Dash, P. K. (2018). The study of water quality and pearson's correlation coefficients among different physico-chemical parameters of River Salandi, Bhadrak, Odisha, India. *Am. J. Water Resour.*, 6(4): 146-155.

Line 210, "indexes" is used incorrectly and should be replaced by "indices".

**Answer:** Thank you for noticing and we apologize for the wording error. We will correct "indexes" by "indices."

Line 230-237, the method of using Leaf Area Index (LAI) data to access the performance of the drought indices is not clearly stated. Should the comparison be between the mean values of the LAI rather than the drought indices in arid and non-arid months?

**Answer:** We apologize for the misunderstanding. As you mentioned, the comparison in the calculation is indeed the mean values of the LAI. We apologize for the lack of clarity in our description, which has caused difficulties in your reading. We intend to clarify the statement as follows:

*“If the occurrence of drought has been discovered, it can be determined by comparing the mean values of the LAI during arid months with non-arid months.”*

Line 240, provide the appropriate citations for the Mann-Kendall (M-K) test.

**Answer:** Thank you for your suggestion. We intend to add a citation for the Mann-Kendall (M-K) test as follows:

*“The Mann-Kendall (M-K) test is a non-parametric statistical test method with a simple computational process [23].”*

[23] Yue, S., Wang, C. Y. (2002). Applicability of prewhitening to eliminate the influence of serial correlation on the Mann-Kendall test. *Water resources research*, 38(6): 4-1-4-7.

Line 247-248, it is needed to explain in more detail how to identify drought through the drought index threshold and drought area threshold, and what are the specific identification criteria?

**Answer:** Thank you for this comment. In the drought identification process of this study, as long as the drought index value at a grid point is lower than the drought index threshold of -1, we determine it as a drought grid point. When the total area of drought grid points in a certain month exceeds the drought area threshold, we determine that month as a drought month. Furthermore, when multiple consecutive months are determined to be drought months, if the overlapping area of drought areas in space between two adjacent consecutive drought months exceeds the drought area threshold, we determine that these two months belong to the same drought event, otherwise, they belong to different drought events.

#### 4. Results and Discussion

The manuscript calculated four drought indices: the SPEI, SSMI, ETDI, and GTDI, but except for the GTDI, the calculations of the other three drought indices are not reflected in the results section. It is suggested that the calculation results of the SPEI, SSMI, and ETDI be placed in a supplementary file.

**Answer:** Thank you for your suggestion. In fact, the calculation results of the four drought indices (the SPEI, SSMI, ETDI, and GTDI) can be found on the Preprint nheSS-2023-41 – Supplement link or on the following link: <https://nheSS.copernicus.org/preprints/nheSS-2024-45/nheSS-2024-45-supplement.zip>

Line 267-269, the findings from the final month of each season were used to depict drought conditions throughout the season; why not utilize a multi-month average?

**Answer:** Thank you for this comment. Drought indices at different time scales can reflect the dry and wet conditions of the study area at different time periods in the past. This study calculated the drought index at a three-month scale, and the calculation results of each month reflect the drought conditions in the past three months. The drought index in May, August, November and February of each year just reflects the dry and wet conditions of the four seasons of spring, summer, autumn and winter in meteorology. Therefore, we use the drought index in the last month of each season to reflect the dryness and wetness of the season.

In Figure 4, "PCC" can be marked above the legend on the right, and enlarge the names of the two drought indices in each row on the left.

**Answer:** Thank you for your feedback. We will improve Figure 4 as suggested.

Line 297, "worse" is inappropriately used to describe correlation coefficients (PCC) and should be replaced by "lower."

**Answer:** Thank you for your suggestion. We will replace "worse" by "lower" here.

Line 314, "their" should be changed to "its".

**Answer:** Thank you. We will follow your suggestion to change "their" to "its" here, and we will carefully search and revise the full text for more similar questions. Thank you again for your careful review.

Line 320-321, "to contrast the weight distribution of SPEI and SSMI in ...", "allocation" may be more suitable than "distribution" here.

**Answer:** Thank you. We will modify this sentence as follows:

*"To contrast the weight distribution of SPEI and SSMI in creating the integrated drought indices GTDI and ETDI, the spatial allocation of their weight ratios (SPEI/SSMI) in the WRB is plotted, as shown in Fig. 5."*

Line 328, "comprehensive" should be replaced by "integrated".

**Answer:** Thank you for pointing out this issue. We will replace "comprehensive" by "integrated" as suggested.

Line 343, "as a consequence of comparing GTDI and ETDI, it is discovered that ...", "is" should be changed to "was".

**Answer:** Thank you. According to your suggestion, we intend to change this sentence as follows: "*as a consequence of comparing GTDI and ETDI, it was discovered that ...*"

Line 344-345, "which is essentially congruent with the drought generation mechanism in this basin": what is the drought generation mechanism in Wei River Basin? Please elaborate on this sentence better.

**Answer:** Thank you for this comment. In this study, drought events in the Wei River Basin are dominated by a lack of precipitation. The Standardized Precipitation Evapotranspiration Index (SPEI) is closely related to precipitation. When precipitation is low, the SPEI index will decrease, indicating an increased possibility of a meteorological drought. However, the Standardized Soil Moisture Index (SSMI) is calculated by soil moisture data, reflecting the occurrence of regional drought influenced by the change of soil moisture.

In the construction of GTDI, the weight of the meteorological drought index SPEI is slightly higher than that of the agricultural drought index SSMI, indicating that SPEI, or precipitation, dominates the changes in GTDI more, which is consistent with the occurrence of drought in the Weihe River Basin dominated by precipitation shortage. Therefore, it is mentioned that "*the game theory approach gives an integrated weight geographic distribution compatible with the precipitation-dominated natural drought pattern, which is essentially congruent with the drought generation mechanism in this basin.*"

Figures 6 and 7 can be combined into one figure.

**Answer:** Thank you for your feedback. We agree with your suggestion to a certain extent, but considering that it is not easy to arrange the sub-figures after combining the two figures, we still hope to draw both Figure 6 and Figure 7 separately, because it is also more convenient to compare the comprehensive drought index GTDI focused in this manuscript with the other three drought indices.

Line 371, "the soil moisture data used in this study is only 0 to 10cm of soil surface layer", "is" should be changed to "are".

**Answer:** Thank you for your suggestion. We will change "is" to "are" as suggested.

Figure 9 needs to be streamlined, as the year-month labeling is somewhat repetitive. It is suggested that the three drought indices be marked with only one year-month label under each drought event image.

**Answer:** Thank you for this comment. We will follow your suggestion to modify Figure 9.

Line 463-466, "In addition" and "Furthermore" are repeated, "in addition" can be removed.

**Answer:** Thank you for your feedback. We will remove "in addition" as suggested.

## 5. Conclusions

Line 482, add " between "correlation" and "in".

**Answer:** Thank you for this comment. According to the place you pointed out, we intend to modify it as follows:

*“The correlation between GTDI and SSMI is relatively weak in the winter, only reaching a high correlation level in 54.8% of the basin,”*

Line 492, the same as the comment for line 320-321, "allocation" may be more suitable than "distribution" here.

**Answer:** Thank you. We will modify this sentence as follows:

*“This indicates that the GTDI's weight allocation of SPEI and SSMI is more logical and trustworthy.”*

Line 511-513, the evolution trend of the GTDI is first presented in the results section, why don't authors summarize the findings of this part in the first conclusion?

**Answer:** Thank you for pointing out this issue. This part of the conclusion is not the key finding of this study. It is just a summary of the evolution trend of drought in the Wei River Basin, based on the evolution trend of GTDI in recent decades and the main findings of this study. Therefore, we put it at the end of the conclusion.

We sincerely appreciate your positive feedback and the valuable insights you have provided. Your comments and concerns have been duly noted, and we are committed to addressing each of them in the revised version of the manuscript.