# Responses to the reviewers

**Title:** Identification, Mapping and Eco-hydrological Signal Analysis for Groundwater-dependent Ecosystems (GDEs) in Langxi River Basin, North China (hess-2023-151)

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**Thanks to the experts giving so much valuable advice, now the revision notes are shown as following.**

**RC1:**

This is a manuscript that deserves praise. It is difficult to concentrate on rich field experiments in the current setting. This study presents a framework for locating and mapping GDEs based on a mix of remote sensing, GIS, and hydrogeological field experiments in terms of research content and methodologies. The study's newly suggested normalized difference built-up and soil index, together with the difference between the wet index, may be used to assess changes in the water loss rate of plants at various stages of growth. After then, the spectrum of possible GDEs is defined by factors including slope, lithology, and elevation. Groundwater levels, river bed bottom elevation, plant root depth, karst springs, etc. were used to further infer different forms of GDEs. In the end, three factors were used to verify GDEs: groundwater biology, water chemical isotopes, and hydrological rhythm. Gaining a deeper understanding of a basin may be achieved by employing a variety of techniques to examine its biological and hydrological features. I would want to share a few small ideas and inquiries with the author.

Answer: Thank you very much for your review and the suggestions of the three experts. We have revised the paper according to each suggestion.

1. The author employed aquatic biology, hydrology, water chemistry, isotopes, and other elements to confirm. These verification findings demonstrate that spring flow and base flow in the basin have a substantial association, that the water chemistry and isotope composition of distinct water bodies vary, and that the water bodies in GDEs have comparatively separate ecosystems. It is still necessary to enhance the geographical representativeness of the aforementioned results. Is it attainable to categorize and validate GDEs in space, despite the fact that they are challenging to locate and define precisely?

Answer: Thank you very much for your comment. We will reply to your questions in the following points:

The Langxi River Basin (LRB) is a typical continuous carbonate-type karst basin in northern China. Generally speaking, this kind of basin is scattered and relatively independent. The small area contains complex topography and groundwater exchange relationships. Therefore, similar research often selects basins with a small area, which is convenient for detailed investigation. The research methods have operational

commonality in similar basins around the world. For example, this study is based on previous methods and aims at the characteristics of the underlying surface of the LRB, trying to propose a more complete research framework and improved methods. In this study, we targeted the classification and identification of GDEs according to the types of GDEs in LRB. Because different types of GDEs are distributed in LRB, including karst springs and hyporheic zones, they are more typical in northern China. In other places, affected by groundwater overexploitation and high-intensity human activities, GDEs have been seriously damaged. Even though large karst springs exist in some places, they do not form an obvious ecosystem. Therefore, first of all, we believe that choosing LRB as a typical research area is representative of the karst areas in northern China.

In this study, we propose a more systematic and comprehensive method compared to current identification and mapping research. We are not simply doing GDE classification research, because the classification is relatively simple and can be identified in the wild. And our research mainly focuses on recognition and mapping.

Based on previous research, we proposed a framework for identifying, mapping and verifying the distribution range of GDEs. This system can be improved and transplanted to other regions. For example, Barron et al. (2014) used NDVI and NDWI to classify potential GDEs in Australia. This is not significantly feasible in LRB, but this does not mean that its idea is not feasible. We selected appropriate remote sensing indices NDBSI and NDVI and jointly identified potential GDEs in LRB, and the results showed that the discrimination effect was very good. Therefore, we believe that this study is more focused on proposing such a system for identifying, mapping and verifying GDEs, which can be used in specific research areas with appropriate improvements. One thing to note is that we are not yet able to accurately determine the boundaries of GDEs. We can only make a comprehensive judgment based on surface vegetation and water bodies. A more precise division requires further exploration.

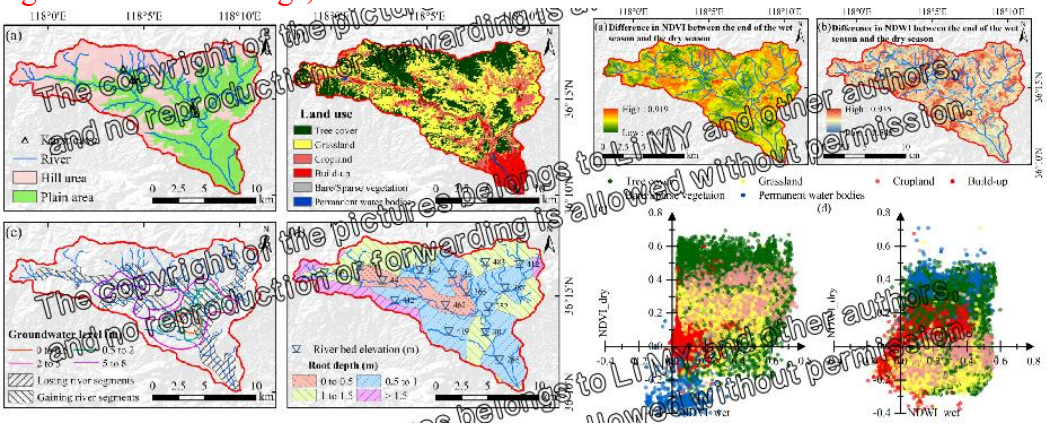
2. The author used data from 2020 to 2021 to divide the scope of GDEs in the Langxi River Basin. This seems to be because the author conducted the experiment during this period. Does this method also work at other times?

Answer: Thank you for your question. First of all, the distribution range of GDEs will change with the amount and range of groundwater recharge. The amount and extent of groundwater recharge will slowly change with the impacts of climate change and human activities. When natural disasters such as earthquakes, coal mining, or human activities cause serious changes in underground aquifers, the distribution range of GDEs may change significantly in a short period of time. During the period when the stratum does not change significantly, long-term groundwater level monitoring data shows that the changes in groundwater levels in the entire LRB and its vicinity are very weak. Therefore, we believe that the distribution range identification method of GDEs proposed in this article is representative. It should be noted that when the groundwater level fluctuates significantly or the stratigraphy changes significantly, we recommend re-evaluating the relevant indices and parameters in the study area and

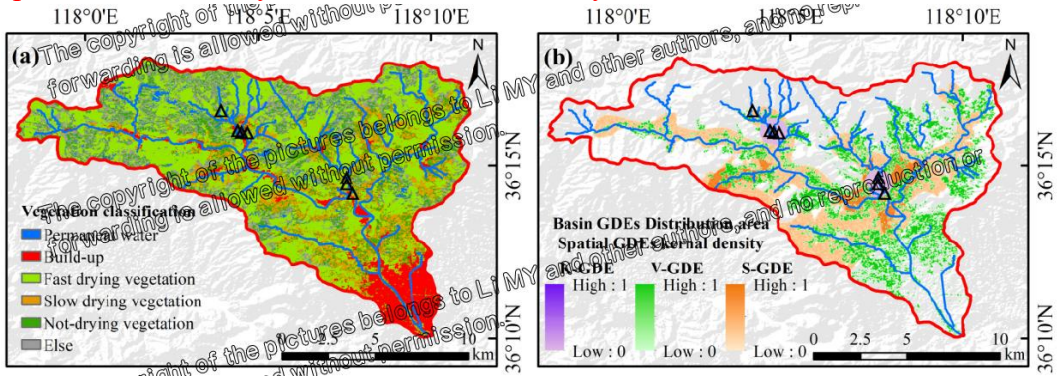
this system.
We have added relevant discussion of this situation in the Discussion section of the paper.

In the paper:
Line 532 to 540:
The quantity and range of groundwater recharge will affect the GDEs' distribution range. The effects of climate change and human activity will gradually alter the volume and scope of groundwater recharge. The distribution range of GDEs can alter dramatically in a short amount of time when major changes are made to subterranean aquifers by natural disasters like earthquakes, coal mining, or human activity. It should be noted that when the groundwater level fluctuates significantly or the stratigraphy changes significantly, we recommend re-evaluating the relevant indices and parameters in the study area and this system. Long-term groundwater level monitoring data indicates that the changes in groundwater levels in the entire LRB and its vicinity are very weak during the period when the stratum does not change significantly. For this reason, we believe that the distribution range identification method of GDEs proposed in this article is representative.

3. The Langxi River Basin is a typical study area selected by the author. Is the GDEs identification and mapping framework proposed by the author also applicable to other river basins? I think this is also an interesting question for other readers.
Answer: We understand that readers will consider whether this approach can actually be applied to other basins. We subsequently conducted relevant experiments in another Chinese karst area, the Tanglang River Basin (TRB), and used this framework to classify GDEs. We will show you some of the results here.
Since the following content may involve some of our unpublished content, we have watermarked the images. We hope you understand.
First, we collected and organized relevant data on TRB and divided plains and mountains. Land use types, groundwater levels, water gaining and losing reaches, river bed elevation, and vegetation root systems of the TRB were investigated. The vegetation index at the end of the dry season and the wet season is used to classify crops, plants that lose water quickly, plants that lose water slowly, evergreen vegetation and buildings, etc.



The GDEs distribution characteristics of TRB can be further calculated by using the spatial kernel density method used in this study.






It should be noted that the identification, drawing and verification framework we proposed has been transplanted from LRB to TRB and has also been improved accordingly. First of all, because there are a large number of population centers and cities in TRB, we added the identification of construction land to the identification framework of GDEs. Secondly, compared with LRB, TRB has more karst caves. During the verification process of water bodies, we added work such as sampling of cave fissure water and aquatic life inside and outside caves. This can make the verification more convincing. In subsequent research, by incorporating hydrological (ecological hydrological) models that consider groundwater, and conducting source analysis of water chemistry, isotopes, and sediment, a series of research accuracy such as the identification and mapping of GDEs can be improved.

Some other formatting questions or suggestions:

1. Line 275 should add relevant introduction to the base flow segmentation method.

Answer: We have added a brief introduction to baseflow segmentation at the corresponding location in the text.

In the paper:

Base flow segmentation is a method used in hydrology to separate streamflow data into its base flow and surface runoff components. Base flow generally represents the groundwater contribution to streamflow, while surface runoff comes from precipitation events and other surface sources. There are several methods for base flow segmentation, including hydrograph separation, chemical separation, hydrometric separation, et. The study utilizes the straight-line secant method, which involves horizontally dividing the peak of the flow process line using a horizontal line. It is stipulated that the contribution of surface runoff lies above the horizontal cutting line, while the contribution of base flow lies below the horizontal cutting line. The value of the horizontal line, which represents the runoff, can be determined as the minimum flow during the dry season, the minimum daily average flow during the dry season, or the minimum monthly average flow for the year. During the non-rainy season when the karst aquifer is recharged, the flow of the spring will gradually decrease in size until it matches the recharge rate of the aquifer, as there is no additional recharge from precipitation. The equation for the flow attenuation process can be written as (Rodríguez et al., 2017).

2. It is recommended to use tables to express the data part of Line 310

Answer: Thanks to your suggestion. We have added Table 1 to sort out the types, names, resolutions, sources of data sets used in this study, and the bands used for remote sensing data.

In the paper:

Line 315:

In this paper, the data mainly includes remote sensing data, and hydrogeological survey data (Table 1).

Line 766:

**Table 1: Remote sensing and hydrogeological survey data used in the research.**

| Data Type | Data Name | Resolution | Resources | Bands used in research |
|---|---|---|---|---|
| **Remote sensing Data** | USGS Landsat 8 Level 2, Collection 2, Tier 1 | 30 m | Google Earth Engine (GEE) | B2-B7 (Blue, Green, Red, Near infrared, Shortwave infrared 1 and Shortwave infrared 2) |
| | NASA SRTM Digital Elevation | 30 m | GEE | Elevation and Slope (Calculated by elevation) |
| **Hydrogeological Survey Data** | Chinese stratigraphic lithology dataset | 1:2,500,000 | China Geological Survey | Geological lithology, geological body boundary, amphibole schist, crater point, et. |
| | The maximum root depth | 1:5,000,000 | Harmonized World Soil Database | - |
| | River bed level | Point scale | Field surveys | - |
| | Groundwater level | Point scale | Field surveys | - |
| | Water hydrochemical and groundwater fauna sampling | Point scale | Field surveys | - |

Note: Please see Supplementary Table 2 for remote sensing data sources.

3. Line 495 Please adjust the font size

Answer: Thank you for your suggestion. We have adjusted the font size.

4. Line 565 In the conclusion, the author uses the full names of K-GDE, S-GDE and V-GDE. In fact, the abbreviation has been used in the previous article, and it is recommended to use the abbreviation here.

Answer: Thank you for your opinion, but we have our own considerations here. As the finishing touch of a paper, the conclusion plays the role of naming the main content and summarizing the article. In this article, we reorganize the classification of GDE based on the characteristics of the study area. Using the full names of the three GDEs at the end allows readers to accept this definition (concept) more clearly.

Therefore, we believe that the full names of K-GDE, S-GDE and V-GDE can be used here.

5. The study area map of Line 710 in Figure 1 should be redesigned. It's not pretty now.

Answer: We modified Figure 1, adjusted the layout, and replaced the more difficult-to-understand geological symbols with abbreviations.

In the paper:

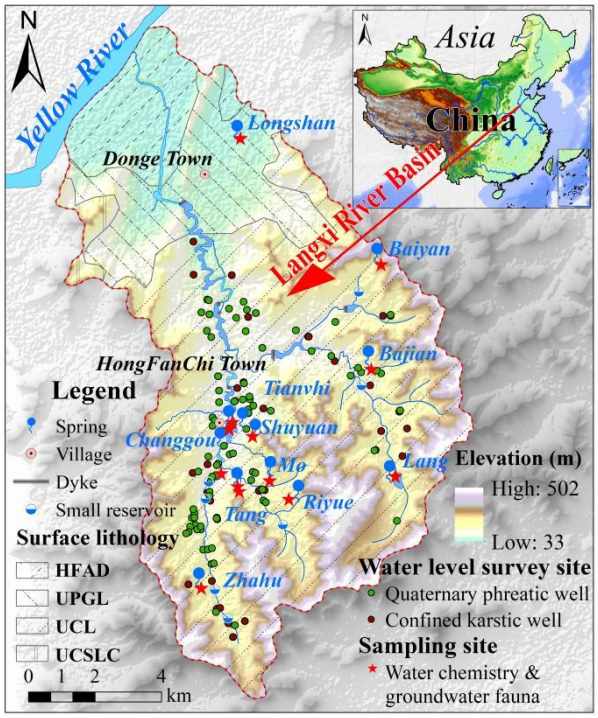



**Figure 1: The location, lithology, topography, spring water, groundwater level survey points, hydrochemical groundwater biological sampling points of the Langxi River Basin. HRAD: Holocene fluvial alluvial deposits; UPGL: Upper Pleistocene gravel layer; UCL: Upper Cambrian limestone; UCSLA: Upper Cambrian shale-limestone amalgamation.**

**Notification to the authors:**

1.Coloured or marked text in *.pdf manuscript file is not allowed. Please provide a clean version of *pdf manuscript file (with black text) with the next revision.

Answer: Thank you for your review. In the first draft, we colored citations in blue for easier reading. In accordance with journal rules, we have adjusted the text to black in the revised manuscript.

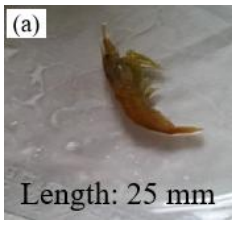
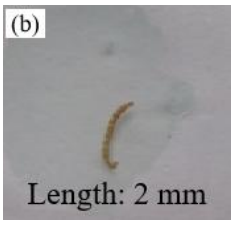
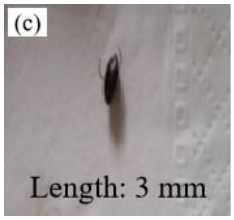
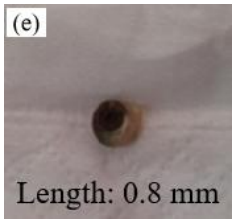
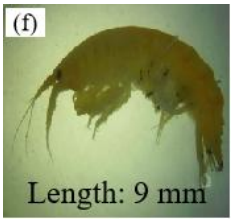
2. It seems that table is included as figure #11. If it is so, it must be re-labelled as table and the references in the manuscript text must be adjusted accordingly. A table may be inserted as an image, but still be called as a table.

Answer: As requested we have modified Figure 11 into a table, it is now Table 4.

In the paper:

**Table 4: Groundwater fauna samples. (a) *Galba.jervia.sp*; (b) *Radix lagotis Schrank*; (c) *Chironmidae*; (d)**

***Gyraulus.sp*; (e) *Dytiscidae.sp*; (f) *Anisogammarus.sp*.**

| **Neocaridina denticulata sinensis** | | | **Radix lagotis Schrank** | | |
|---|---|---|---|---|---|
|  | **Phylum:** | Arthropoda |  | **Phylum:** | Mollusca |
| | **Class:** | Malacostraca | | **Class:** | Gastropoda |
| | **Order:** | Decapoda | | **Order:** | - |
| | **Family:** | Atyidae | | **Family:** | Lymnaeidae |
| | **Genus:** | *Caridina* | | **Genus:** | *Radix* |
| **Chironmidae** | | | **Gyraulus.sp** | | |
|  | **Phylum:** | Arthropoda |  | **Phylum:** | Mollusca |
| | **Class:** | Insecta | | **Class:** | Gastropoda |
| | **Order:** | Diptera Nematocera | | **Order:** | - |
| | **Family:** | Culicomorpha | | **Family:** | Planorbidae |
| | **Genus:** | *Chironomoidea* | | **Genus:** | *Gyraulus* |
| **Dytiscidae.sp** | | | **Anisogammarus.sp** | | |
|  | **Phylum:** | Arthropoda |  | **Phylum:** | Arthropoda |
| | **Class:** | Insecta | | **Class:** | Malacostraca |
| | **Order:** | Coleoptera | | **Order:** | Amphipoda |
| | **Family:** | Dytiscidae | | **Family:** | Anisogammaridae |
| | **Genus:** | *Cybister* | | **Genus:** | *Anisogammarus* |

3.Please ensure that the colour schemes used in your maps and charts allow readers with colour vision deficiencies to correctly interpret your findings. Please check your figures using the Coblis – Color Blindness Simulator (https://www.color-blindness.com/coblis-color-blindness-simulator/) and revise the colour schemes accordingly.

Answer: All images in this article have been verified using Coblis – Color Blindness Simulator. We believe that the information in the picture can be clearly identified in the three modes of Anomalous Trichromacy, Dichromatic view, and Monochromatic view. If the editorial department believes that our color matching still does not meet the regulations, please contact us and we will redraw it in the next version. Many Thanks!

4. For the next revision, please check if your figures containing photos require a copyright statement/image credit and add it to the figures (or captions) (https://publications.copernicus.org/for_authors/manuscript_preparation.html#figurestables -> Reproduction and reuse of figures and tables). If these figures were entirely created by the authors, there is no need to add a copyright statement or credit. In that case it is important that you confirm this explicitly by email.

Answer: We have read the publication rules. We have modified one image for which reproduction rights have not been granted and certify that all images are created by us.

5. For the next revision, please make sure that information about the contribution of each of the authors of the manuscript is presented in the "Author contribution" section of the *.pdf manuscript.

Answer: As requested we have included an author contribution section in the paper.

In the paper:

**Author contribution**

Mingyang Li and Fulin Li developed the initial and final versions of this manuscript and analyzed the data. Shidong Fu, Huawei Chen, KairanWang, Xuequn Chen, and Jiwen Huang contributed their expertise and insights to oversee the analysis.