Anonymous Referee #1

This manuscript introduced a study of GDE identification, which is fundamental for understanding ecosystem functioning on maintaining local biodiversity. This study applied remote sensing observations and field measurements to identify GDEs, also validated using water table depth data and land use data.

General comments

1. Sptial resolution downscele: It needs to explain why to downscale 1km climate data (rainfall) to 30 meters. It is dangerous to use 1km rainfall data to explain vegetation water use in 30 meters pixels.

Reply: The downscaling of rainfall data from 1 km to 30 m was chosen in the study mainly to maintain the consistency with the spatial resolution of vegetation coverage data, so as to avoid misjudgment of ecological processes caused by scale mismatch. Although downscaling may introduce some errors, we can reasonably express the spatial heterogeneity of rainfall by combining topographic and vegetation-assisted data, while maintaining the original resolution may lead to information loss on a larger scale.

2. Author misused NDVI, FVC and potential ET. Firstly, NDVI links to the vegetation chlorophyll content, it can't indicate groundwater table depth. FVC is the vegetation cover. For mature GDEs, GDE FVC should be stable, and it should not change much. Lastly, the authors used PET to indicate the vegetation water use. I think this is wrong, PET indicates the maximum evapotranspiration rate, it relates to the climate (temperature, radiation, wind ...), it has no relationship with groundwater. Hence, using PET-Rainfall relationship can't explain the vegetation accessing groundwater. There are many AET data available, so authors should consider to replace PET to AET.

Reply: This study uses FVC as an indicator to identify GDEs because in arid and semi-arid areas, FVC and NDVI have a good correlation with groundwater. Meanwhile, the period selected in this study is that there is relatively little rainfall in dry years, which can be used as a suitable indicator for shallow groundwater storage conditions. In addition, NDVI and FVC are the most widely used indicators to identify GDEs in the existing research. In the article Groundwater-dependent ecosystem map exposes global dryland protection needs published in Nature by Melissa et al., NDVI has also been used as one of the important indicators for predicting GDEs. In this study, the use of PET to characterize vegetation water use does have its limitations, and the use of AET as an alternative to PET is considered

3. This manuscript used land use data, only mentioned that it was generated using randomforest model, however, I didn't see any details introducing how to train the model and what input features for model training.

Reply: We are very sorry that the training details of the random forest model are not detailed in the paper. In the actual research process, we used a series of environmental and geographical features related to Urumqi River basin and Chaiwopu Basin as input features to train the random forest model. A special section is added in the paper to introduce the training process of the random forest model in detail, including the specific names of input features, data sources and pre-processing methods.

4. KNN was used in this study to classify GDEs, but this manuscript didn't visually show the classification results. Without KNN results, I can't evaluate the performance of the methodology. Also, it needs to discuss the contributions of each input feature to GDE identification.

Reply: It is a pity that the KNN classification results are not visually presented in the paper. The KNN classification results are a key basis for evaluating the performance of the groundwater dependent ecosystem (GDEs) identification method in this study. In the actual operation, we have completed the KNN classification work and obtained relatively clear classification results. The reason for not showing the paper is that we are worried that too long will affect the overall structure and reading experience of the paper. The display part of KNN classification results will be added to the paper in the future, and the classification results will be visually presented in the form of maps and tables. The map can clearly show the spatial distribution of GDEs in Urumqi River Basin and Chaiwopu Basin, and the table can list the statistical information such as the quantity and area of each category in detail. In addition, the confusion matrix of KNN classification will be provided to evaluate the accuracy and reliability of the classification results by calculating the accuracy rate and recall rate.

5. This manuscript lacks statistical analysis. Figures in this manuscript only present spatial distribution, authors should consider using other types of figures to explain the model performance.

Reply: We fully agree on the importance of statistical analysis and error assessment for the interpretation of model performance, and plan to improve the study from the following aspects. On the basis of the existing spatial distribution map, the new error distribution heat map and scatter density map will be added to directly display the spatial correlation between the predicted value of the model and the measured data and the local error aggregation characteristics, and supplement the table containing the root mean square error (RMSE), the average absolute error (MAE) and the determination coefficient (R^2). To compare the model performance differences in different sub-regions (such as the alluvial fan in the Urumqi River basin and the Chaiwopu Lake shore zone).

Other issues:

Line 61: "To validate GDEs identification...." This sentence is hard to understand. Please clarify what's "results"? Why it has limit accuracy?

Reply: Thank the reviewer for pointing out the language defect of the original text. "To validate GDEs identification...." This sentence fully means "To verify the accuracy of GDEs identification results..." . Here "result" refers to the probability degree distribution of GDEs identified. "Precision limited" means that a single validation method is not accurate enough. The sentence on line 61 was changed to "In order to verify the accuracy of GDEs identification results, correlation and regression analysis are usually used to evaluate the relationship between the results and actual data or field validation methods. However, using these methods alone may not provide sufficient accuracy and reliability for the verified GDEs identification regions."

Line 113: Picking August as the study month may be not appropriate. Not every Augest shows dry climate. Here you need to provide the ET and rainfall data for supporting this selection. or you can pick the driest month for each year using rainfall and pet/et data.

Reply: The selection of August as the research month not only takes into account the drought situation, but also considers that the vegetation growth in this region is better from June to September. In addition, the identification of remote sensing data also needs to be taken into account. This choice is the result of our multi-consideration.

Line 116: You resampled rainfall data from 1km to 30m, how did you ensure the data accuracy? There are a lot uncertainty with remote sensing rainfall data. Normally, rainfall has the character that not spatial continue.

Reply: The downscaling of rainfall data from 1 km to 30 m was selected in the study mainly to maintain the same spatial resolution with vegetation coverage data, so as to avoid misjudgment of ecological processes caused by scale mismatch. However, changes in data accuracy during this process were indeed ignored in the application process. The combination of elevation data and machine learning model will be considered in the paper revision process, which retains the statistical characteristics of the original rainfall data and enhances the characterization ability of local terrain for rainfall redistribution.

Line 118: Why AET was hard to access? Some remote sensing AET data are avaiable, pml v2, landsat ET, modis ET

Reply: Thank you for your recommended use of AET related data sets. We have noticed PML v2, Landsat ET, MODIS ET and other AET data sets, and will replace the PET used in the study with them.

Line 120: How did you get this conclusion that vegetation using groundwater when high PET. PET is driven by climate, not groundwater.

Reply: Thank you for pointing out the limitations of PET data. The PET in this study is only a substitute for AET data, and the PET data will be replaced with AET data in the future.

Line 132: I can't link FVC to "regional ecological environment quality". FVC is a factor to indicate vegetation structure and coverage.

Reply: Thank you for pointing out this problem, this may be the original expression of the problem. We will change this sentence in line 132 of the original to "Vegetation cover (FVC) is an important indicator of regional vegetation structure and growth status", In addition, this study did not associate FVC with "regional ecological environment quality". FVC was used as one of the indicators to identify GDEs, because in arid and semi-arid areas (and this study selected dry years, excluding the influence of rainfall to a certain extent), the water consumption of plants mainly came from shallow groundwater. To a certain extent, the level of FVC can reflect the groundwater intake by vegetation in this region, so it is considered that FVC can be used as a suitable indicator of the storage conditions of shallow groundwater.

Line 138: NDVI can't indicate groundwater! at least, it can't directly indicate groundwater. You can see GDEs are sensitive to groundwater, reflecting by NDVI variations.

Reply: Thank you for your question. There may be some ambiguity in this sentence. In line 138, this sentence will be amended to read "GDEs is sensitive to groundwater changes and can feedback through NDVI changes".

Line 140: what time period did you use landsat 5 for? Landsat 5 ended in 2012. However, your study included years after 2012. And where did you obtain landsat 5 data? It needs to state in your manuscript.

Reply: Thank you for pointing out this question. Since Landsat 5 ceased operation in 2012, the data source for land use type and vegetation cover (FVC) interpretation in 2020 and 2023 in this study is Landsat 8.

Line 155: is water body NDVI value in 5th percentile?

Reply: Thank you for pointing out this question. Since Landsat 5 ceased operation in 2012, the data source for land use type and vegetation cover (FVC) interpretation in 2020 and 2023 in this study is Landsat 8.

Line 192: you have already defined GDEs.

Reply: Thanks to the expert for pointing out this problem, this duplicate content will be deleted in the original text.

Line 193-196: why these words with capital letters?

Reply: Thanks to the expert for pointing out this problem, this duplication will be removed from the original text.

Line 199: irrigation region is a typical GDE.

Reply: As the experts said, irrigation area is a typical GDEs, but the irrigation of farmland in the study area is mainly carried out by groundwater extraction or surface irrigation channels, which is greatly influenced by human beings. The natural vegetation area which is the focus of this study is not in the scope of our study, which is also explained in the article.

Line 207: How did you get the land use results from landsat? What model did you use? It needs more details.

Reply: We are very sorry that the training details of the random forest model are not detailed in the paper. In the actual research process, we used a series of environmental and geographical features related to Urumqi River basin and Chaiwopu Basin as input features to train the random forest model. A special section is added in the paper to introduce the training process of the random forest model in detail, including the specific names of input features, data sources and pre-processing methods.

Line 213: What do you mean "high vegetation quality"?

Reply: We are very sorry for the confusion caused by this expression in the article. In the original article, "high vegetation quality" mainly refers to the area with high vegetation coverage. We will make it more clear in the article.

Line 250: Please clarify the WTD source.

Reply: The groundwater depth data is derived from the groundwater level measured at 200 field well locations and further obtained through ArcGIS interpolation. The data source will be further emphasized in the original article.

Line 393: How FVC becomes negative? FVC is ranging 0-1

Reply:We are very sorry for the confusion caused by this expression in the article. FVC is not negative, the expression of the article may have insurrection. The original intended to indicate the change of FVC. the original content of line 293 will also be revised to read "Since 2000, the mean FVC in the Urumqi River Basin had a slow upward trend, with an average growth rate of less than 10%"

Line 397: Does this ET indicate potential ET or actual ET?

Reply: We apologize for any confusion caused by this expression. The ET in line 397 refers to potential evapotranspiration (PET).

Anonymous Referee #2

This manuscript utilized geospatial technological analysis and field verification methods to identify and map the GDEs in the Urumqi River and Chai Wo-pu Basins, obtaining the distribution of potential GDEs, which holds scientific value. The methods employed are generally feasible, and the conclusions drawn are credible. However, the following points require further modification and enhancement:

1. The title of the manuscript only includes mapping, but does not include identification and verification, which is included in the content of the paper, so the title did not reflect the contents of the paper clearly.

Reply: Thank you for bringing up this important point, The manuscript title will be considered for revision as "Groundwater ecosystem identification in Urumqi River and Chaiwopu Basin based on geospatial techniques and field data "

2. The abstract does not provide a concise and complete summary. For example, what indicators are used to identify the GDEs, what methods are used to map, and what methods are used to verify it, which cannot be clearly reflectedin the manuscript.

Reply: Thank you for asking this question, but the specific indicators, mapping methods and verification methods in the abstract of this article have been more clear. the relevant summary content is "This study selected the final year of a prolonged drought period and the current year for analysis. Key indicators, including vegetation cover (FVC), the difference between evapotranspiration and precipitation (ET-P), Terrain Wetness Index (TWI) and the vegetation groundwater uptake index (VGUI), were employed. The K-means clustering algorithm was applied for classification, and spatial overlay analysis was performed in the Urumqi River and Chai Wo-pu Basin in Xinjiang, China, to assess the spatial distribution and temporal variations of GDEs. Additionally, the results were validated through the integration of wetland distribution and field investigations."

3. The keyword of Integrated Mapping is not adequately reflected in the paper, and the details of Geospatial Technologies are not thoroughly explained. Therefore, the selection of keywords requires further consideration.
Reply: Thank you for your question. After re-refining the keywords, "Integrated Mapping" will be replaced with "Analysis of identification", and "Geospatial Technologies" with "GIS".

4. In lines 61-63 on page 2 of the the introduction chapter, concerning the verification methods of GDES, the author referenced relevant literature and stated that the accuracy and reliability of the results would be limited. In fact, the opposite is true; employing various methods, including field hydrogeological surveys to verify the distribution of GDEs, would enhance the accuracy and reliability of GDE identification.

Reply: Thank you for raising this statement question, the original meaning is actually to point out that the use of a single method will limit the accuracy and reliability of the results, and then further point out that multiple methods can improve the validation accuracy.

5. The paper suggests that the impact of human irrigation should be eliminated when identifying GDES. In fact, GDEs may still be present if minimal groundwater irrigation does not lead to a significant drop in groundwater levels, allowing plant roots to continue absorbing groundwater. A specific analysis is necessary and at the very least, the groundwater depth in the irrigation area should be considered in this study area. So in the introduction chapter for study area, it is essential not only to reflect on the hydrological characteristics of rivers and reservoirs but also to describe the hydrogeological conditions, including the characteristics of groundwater recharge, and discharge, groundwater exploitation, and the depth of groundwater in the study area.

Reply: Thank you for raising this question, but the study object of this paper did not consider the non-natural vegetation area which is greatly affected by human factors. We will pay attention to this issue in the follow-up study, but it is not the focus of this study.

6. Based on low annual precipitation and ongoing drought, and considering the principle of temporal proximity, this paper selects 2001, 2006, 2014, 2020, and 2023 as the identification years for GDE. However, no time series data on precipitation is available, and the selection of typical years should also take into account the impact of regional groundwater development. It is advisable to briefly outline the reasons and rationale for this choice.

Reply: Thank you for asking this question. Based on low annual precipitation and persistent drought, 2001, 2006, 2014, 2020 and 2023 are selected as GDEs recognition years. Precipitation data from 1998 to 2023 will be supplemented in the original article. The selection of typical years is mainly concerned with reducing the potential impact of precipitation on vegetation ecosystems, so as to ensure that surface vegetation is more dependent on groundwater, and regional groundwater extraction does not directly affect the dependence of vegetation on groundwater.

7. In section 1.2 Data Collection and Processing, why is Fractional Vegetation Cover (FVC) chosen instead of using the NDVI data index directly? What impact does selecting the indexes of Terrain Wetness Index (TWI) and the ET-P deference in the process of GDEs identification?In particular, TWI is a physical indicator used to measure the influence of regional topography on runoff direction and runoff accumulation, How is it applied for GDEs identification?

Reply: Thank you for asking this question. Vegetation coverage (FVC) is calculated by NDVI, and there is no obvious difference in the information expressed, but FVC

can more intuitively characterize the structure and distribution of vegetation. Topographic humidity Index (TWI) is a physical index used to measure the influence of regional topography on runoff direction and accumulation. The area with high TWI value is usually located in the lower part of the landscape and is closely related to groundwater. One of the key ways to assess how dependent plants are on groundwater is through water balance calculations. Water use by plants that exceeds the availability of rainfall, soil water, and surrounding surface water sources indicates dependence on groundwater, so the difference between evapotranspiration and precipitation, ET-P, can characterize the likely use of groundwater in the area.

8. In the Section 1.3 Methods, the logical description of the identification, mapping, and validation of GDEs needs to be strengthened.

Reply: Thank you for asking this question. We will re-sort and summarize the logical relationship and corresponding content of GDEs identification, mapping and verification in the original text.

9. Is The K-means algorithm used for GDEs identification or classification or mapping? Figure 2 seems to be used for layer processing and mapping.

Reply: Thank you for asking this question. It is confirmed that K-means algorithm is used for classification mapping of GDEs, which will be explained in the article.

10. The Vegetation Groundwater Utilization Index (VGUI) selected by validation of GDEs is literally understood as the amount or ratio of groundwater absorbed by vegetation, reflecting a concept that vegetation partially or completely accepts groundwater recharge. However, this paper shows a difference between the root depth of vegetation plus the height of capillary rise and the depth of groundwater burial. Further clarification is needed.

Reply: We are very sorry for the confusion caused by this expression in the article. "Vegetation groundwater utilization index (VGUI)" refers to the degree of vegetation contact and absorption of groundwater, which is specifically expressed as the difference between vegetation root depth plus capillary rise height and groundwater buried depth. Its definition will be redefined in the original article.

11. When using the capillary rise height values (Hc) corresponding to different types of soil, the paper references data from the literature(Li, X., Chang, S. X., and Salifu, K. F.: Soil texture and layering effects on water and salt dynamics in the presence of a water table: a review, Environmental Reviews, 22, 41-50) and presents it in the table 1. Please verify whether the literature data is based on theoretical calculations, column experiments, numerical simulations, or actual monitoring results, as these values can vary significantly! As a general rule of thumb, the Hc value for fine sand ranges from 0.25 to 0.5 m, while the Hc value for silty sand and sandy clay falls between 1 and 2 m.

Reply: Thank you for raising this question. The original article will further state the source of data (theoretical calculation, column experiment, numerical simulation or actual monitoring) based on the literature content

12. The methods for GDEs verificationused in this paper are categorized into wetland verification and field verification in typical areas. Notably, whether wetland verification is conducted through specific investigation or remote sensing interpretation, if the latter is employed, the results derived from one uncertain method are validated by another uncertain method, which appears to lack credibility.

Reply: Thank you for asking this question. The verification method used in this paper has been applied in the study of Iongel et al in Chile and Olga et al in the Ellen Brook region of Western Australia. Although there are some uncertainties in the method used, However, we believe that combining the verification results of these two methods can also reduce the contingency and improve the reliability.

13. In the conclusion of the potential GDEs distribution mapping, particularly as represented in Figure 3, the area excluding the bedrock distribution reflects the potential GDEs distribution based solely on the topography and lithology map. This result merits further discussion. Since potential GDEs may be found in the distribution areas of Quaternary pore water and bedrock fracture water, additional hydrogeological maps, profiles, aquifer distributions, and groundwater types are necessary to accurately identify and determine the potential GDEs distribution.

Reply: Thanks to the experts for pointing out the lack of research in this part, will be added in the original discussion.

14. It appears that the paper only presents the results of GDEs distribution over many years, yet it does not address the correlation between the size or range of the GDEs distribution area and factors such as precipitation, groundwater depth, and human groundwater exploitation activities in the discussion section, nor is a rationale provided.

Reply: Thanks to the experts for pointing out the lack of research in this part, will be added in the original discussion.

Anonymous Referee #3

Proposing reliable approaches to identify groundwater-dependent ecosystems (GDEs) and to assess their dependence on groundwater can be useful for hydrology. In this paper, remote sensing, meteorological and topographic data were used to calculate key indicators and then clustering analysis was used to identify GDEs. The method was further validated with field measurements.

However, in my opinion, this manuscript needs many improvements and its novelty is not clear. Some grammatical errors, confusing sentences and redundant vocabulary may hinder the message the authors want to convey.

General comments

1. The structure of the manuscript is suggested to be modified. Usually, Section I is the introduction. Besides, the section of Materials and Method is too long, and it could be better to separate them into different sections.

Introduction - To improve readability, consider organizing the content into more paragraphs, e.g., the definition of groundwater-dependent ecosystems (GDEs), the importance of identifying GDEs, current approaches to identifying GDEs, current gaps, and the purpose of the study. The general significance of the study in hydrology should be emphasized.

Data Collection and Processing - Since this section is not the main focus of the study, I suggest removing some of the unnecessary descriptions or moving some details to the Supplementary Material.

Reply: Thank you for raising this issue. We will reorganize and summarize the "introduction" and "Materials and methods" of the article according to the expert opinions, and move the non-core content to the appendix.

2. Methods - The logic seems strange. As I understand it, (1) you select potential areas based on hydrogeological zones and land use types; (2) three indicators, i.e., FVC, ET-P (ET or PET?), and TWI, are used to cluster the pixels and thus obtain the map of probability levels; (3) wetland ecosystem and some field measurements are used for validation; (4) the indicator of VGUI is included in the clustering operation to further identify the GDEs in typical areas (or for validation?). I am confused about the main purpose and main innovation of this study. Please clarify further. If your aim is to propose a new method, I think you should focus more on how to identify the GDEs via the selected indicators using clustering operation, and then thoroughly discuss the advantages of your method by comparison (more accurate identification results? Or improved operational efficiency? etc.).

Reply: Thank you for raising this question. We will further adjust

the "Materials and methods" narrative order and manner, according to the GDEs identification process description. We will further summarize and clarify the research objectives and innovation points in the abstract and introduction. The goal and innovation of this research is to propose a GDEs geospatial recognition method based on multi-source data fusion and VGUI modification, and to coordinate classification of FVC, ET-P, WTI and VGUI layers by integrating K-means algorithm. It effectively solves the problem of low credibility caused by human interference and index coupling imbalance in traditional GDEs recognition. At the same time, long series remote sensing data is used to realize the dynamic recognition on the time scale, which provides a possibility for analyzing the trend of regional GDEs.

3. Results and Analysis - There are too many qualitative analyses with only a few quantitative descriptions of changes in areas.

Reply: Thank you for raising this question. We will add the content of GDEs area change quantitative analysis and convert the picture information into quantitative figures

Specific comments:

Lines 52-54: The reference should appear after the author's name which is mentioned for the first time.

Reply: Thank you for raising this issue and a uniform change will be made to the original references.

Line 66: What does “periodic identification” mean?

Reply: We are very sorry for the confusion caused by this expression in the text. "Periodic identification" refers to the periodic evaluation of the status of GDEs changes, with a frequency of 1-5 years, which will be further explained in the text.

Lines 110-114: Could you provide some evidence to support this? It can be included as the Supplementary Material.

Reply: Thank you for asking this question. 2001, 2006, 2014, 2020 and 2023 are selected as GDE recognition years based on low annual precipitation and persistent drought. Precipitation data from 1998 to 2023 will be supplemented in the original article.

Lines 118-119: Actual evapotranspiration data with high resolution is not difficult to obtain (e.g. MOD16 products).

Reply: Thank you for asking this question, the PET data will be replaced and re-analyzed using AET data.

Lines 120-121: “Higher potential evapotranspiration values suggest that vegetation may be utilizing groundwater.” Based on hydrological principles, potential evapotranspiration is controlled by many other factors, so your point is not really convincing.

Reply: Thank you for pointing out the limitations of the PET data. The PET in this study is only a substitute for AET, and the PET data will be replaced later.

Lines 138-139: “Additionally, NDVI shows a good correlation with groundwater, making it a suitable indicator for shallow groundwater storage conditions…” Although the authors cite a reference here, I don't think this is reasonable, as it may only apply to specific regions and may not be generalizable to other areas.

Reply: Thank you for raising this question, the expression of this sentence does have some limitations, stating it as "GDEs is sensitive to groundwater, reflected by NDVI changes". The sentence in line 138 of the original will be amended to read "GDEs is sensitive to groundwater changes and can feedback through NDVI changes"

Lines 221-222: It is important to know how to identify GDEs. Could you explain this in more details? Why is the k-value 5? Have you checked the optimal clusters using the performance metrics?

Reply: Thank you for asking this question, k=5 was actually determined artificially during the research, which will be further discussed and described in the original article

Line 241: There are two 1.3.4 sections.

Reply: Thank you for pointing out the mistake. It has been revised in the original text

Lines 393-394: “Since 2000, the average FVC in the Urumqi River Basin has shown a slow upward trend, ranging from -10% to +10%.” I am a bit confused about this sentence.

Reply: We are very sorry for the confusion caused by this expression in the article. The expression of the article may be ambiguous, and the original content has been modified. the original content of line 393 will also be revised to read "Since 2000, the mean FVC in the Urumqi River Basin had a slow upward trend, with an average growth rate of less than 10%”

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