Revision Notes

Dear Editor and Reviewers:

Thank you for your letter and for the reviewers' comments concerning our manuscript entitled "Evaporation, infiltration and storage of soil water in different vegetation zones in Qilian mountains: From a perspective of stable isotopes" (Manuscript Number: Hess-2021-376).

According to the reviewers' comments, we have revised our manuscript carefully. The revised portions have been marked in red in the revised version of the manuscript. The main corrections and the response to the reviewers' comments are as follows.

Responses to the reviewer's comments:

Response to Reviewer #2

Reviewer#2: This a potentially interesting paper, but one that needs major attention before it is suitable for publication. The paper is poorly written in places. While I have sympathy with authors having to write in a second language, which is something that I cannot do, some sections of the paper are very difficult to follow. More importantly, the sections of the paper are not well linked. It is not clear from the Introduction how the paper addresses the important issues. The same can be said about the Discussion where it is not clear how the data in this paper inform the issues being discussed. For example, runoff generation is mentioned in the introduction and appears in the general conclusions, but there is no discussion as to how the data in the paper help us understand it (there are several similar examples as well). The sections describing the data tend to be very generalised and the data description needs to be more informative. Moreover, the data need to be presented in the paper or as a supplement.

Overall, the paper needs to be rewritten so that the data are discussed in a more rigorous manner that help understand the aims. I am not convinced that it actually addresses important issues or that the aims of understanding the memory effect or runoff generation are advanced by this study.

Thanks for your comments.

Specific comments

Title

Comment 1: Having a title that is grammatically incorrect is not a good way to promote your research. Something like: "Evaporation, infiltration and storage of soil water in different vegetation zones in the Qilian mountains: a stable isotope perspective" would be better.

Response: Based on the suggestions of the two reviewers, I have revised the title of the manuscript.

L1-3: Evaporation, infiltration and storage of soil water in different vegetation zones in the Qilian mountains: a stable isotope perspective

Abstract

The abstract needs improvement. Abstracts are important as they are what convince the readers to look at the rest of the paper. They should convey not only what has been studied and why, but should also contain enough details so that the main conclusions are evident. This abstract needs improving, specifically:

Comment 1: Be specific: "different water bodies in different vegetation zones" does not convey what you have done.

Response: I have explained this point in detail.

L13-17: In order to further understand the process of soil water movement and runoff generation in different vegetation zones (Alpine Meadow, Coniferous Forest, Mountain Grassland and Deciduous Forest) in mountain areas, this study monitored the temporal and spatial dynamics of hydrogen and oxygen stable isotopes in the precipitation and soil water of the Xiying River.

Comment 2: Avoid qualitative terms such as "weak"

Response: The article carried out a more quantitative expression, such as "The evaporation intensity of the four vegetation zones was: Mountain Grassland > Deciduous Forest > Coniferous Forest > Alpine Meadow.".

Comment 3: Some of the sentences are unclear. I am not sure what "The water storage capacity of surface soil was weak in vegetation zones" really means as surely all the catchment is vegetated?)

Response: In our results, the soil water storage capacity of 0-10 cm is less than that of other soil layers, and we have clarified the soil depth here. Here, we want to show the water storage of different soil layers. In our sampling site, the soil is covered by dominant species.

L23-27: The soil water storage capacity order in each vegetation zone was: Alpine Meadow > Deciduous Forest > Coniferous Forest > Mountain Grassland. In addition, the water storage capacity of 0-10 cm soil was weak, and the water storage capacity of 10-40 cm was strong.

Comment 4: There are several grammatical and spelling errors (Nvertheless) that detract from the work

Response: We carefully checked and revised the grammar and spelling of the manuscript.

Introduction

The introduction is also not very clear. Some of this reflects the writing style and occasional poor grammar. As well, there needs to be a much clearer explanation of the background. The explanations are vague and would not convey much meaning to anyone not working in the field. There needs to be clearer explanations and more precise terminology.

Comment 1: L31-33. Not very clear what you mean here.

Response: For readers to better understand, I re-narrate this sentence.

L31-34: In arid inland river basins, changes in climate and vegetation will affect the hydrological cycle process, which is essential for assessing regional water balance and future changes in water resources (Wang et al., 2012; Tetzlaff et al., 2013; Ning et al., 2020; Sharma et al., 2021).

Comment 2: L48. "Storage" is not a transport mechanism.

Response: I agree with your comment, this problem has been corrected.

L49-50: The water seepage in the unsaturated soil zone and the evaporation of water at the air-soil interface are the main forms of soil water transport.

Comment 3: L50. Do you mean on the ground surface or in the near-surface part of the soils?

Response: We rewrite this sentence.

L63-65: The evaporation of liquid water produces water vapor enriched in ^{1}H and ^{16}O, while the remaining water is enriched in ^{2}H and ^{18}O (Ferretti et al., 2003).

Comment 4: L48-75. This would not be readily understandable to many readers who had not worked with these types of data. It is too generally worded and needs details. This paragraph is important as it sets the framework for using the stable isotopes to understand processes.

(1) Define that you are discussing ^{18}O and ^{2}H data (there are lots of stable isotopes!).

(2) Terms such as "makes soil water isotopes enriched" are vague. Specifically, evaporation enriches the residual water in ^{18}O or ^{2}H (or increases the $\delta^{18}O$ and $\delta^{2}H$ values)

(3) Likewise, "soil moisture fractionation is positively correlated with evapotranspiration but negatively correlated with precipitation". Are you talking about the magnitude or sign?

(4) How significant?

(5) Define the d-excess (briefly)

(6) L63-70. Lacks detail and is unclear.

Response: According to the suggestions of three reviewers, this part was rewritten to solve the above problems: (1) We identified stable isotopes of hydrogen and oxygen; (2) According to your suggestion, the expression has been changed; (3) and (4) According to the reviewer's suggestion, we introduced the evaporation process more and deleted the influencing factors of evaporation; (5) We defined "d-excess"; (6) I gave a detailed description of this part to make it more expressive of the status quo of the research.

L49-98: The water seepage in the unsaturated soil zone and the evaporation of water at the air-soil interface are the main forms of soil water transport. Seasonal variations of precipitation isotopes are often used to track the process of soil water leakage (Stumpp et al., 2012). During the piston infiltration process, the precipitation with different $\delta^{2}H$ and $\delta^{18}O$ peaks retained in the soil profile and gradually disappears as the infiltration depth increases (Sprenger et al., 2016a), while the preferential flow will keep these peaks until the deep soil layer (Peralta-Tapia et al., 2015). During a precipitation event, the response of water isotope in surface soil to precipitation is more obvious, showing a changing trend similar to that of stable isotope of precipitation. With the deepening of the soil layer, the seasonal variation of precipitation isotope signals is rapidly attenuated, and the influence of precipitation on soil water gradually weakens (Sprenger et al., 2017). Evapotranspiration is the main form of soil water dissipation. Because the mass of hydrogen and oxygen atoms that make up water molecules are related to their thermodynamic properties, isotope fractionation of water will occur in the process of the water cycle. The evaporation of liquid water produces water vapor enriched in ^{1}H and ^{16}O, while the remaining water is enriched in ^{2}H and ^{18}O (Ferretti et al., 2003). Dansgaard (1964) proposed the concept of d-excess (d-excess=$\delta^{2}H-8\delta^{18}O$) to illustrate the intensity of evaporative fractionation. In the state of isotopic equilibrium, the value of the d-excess is 10. Compared with d-excess, lc-excess can explain the evaporative fractionation process better. The main reason is that lc-excess in precipitation and soil water changes smoothly and has relatively small seasonal changes (Landwehr et al., 2014). The dynamic changes of isotopes record the signal of soil water evaporation. This enrichment from dynamic fractionation exists in soil water isotopes in different climatic regions. Compared with temperate regions, the signals of evaporation in arid and Mediterranean environments penetrate deeper into the soil (Sprenger et al., 2016b). Some water will be stored in the soil after evaporation and seepage processes. The water storage capacity of humid areas is higher than that of arid areas, the water storage capacity of forests is higher than that of grassland, and the water storage capacity of middle and lower soil layers with higher clay content is higher than that of surface soil layer (Heinrich et al., 2019; Sprenger et al., 2019; Kleine et al., 2020; Snelgrove et al., 2021).

In alpine mountains, climate warming will accelerate the melting of glaciers and frozen soil, and the dynamic interaction between water bodies stored in different media will become the main focus of the water cycle (Penna et al., 2018). Previous studies on evaporation, infiltration and storage of soil water mostly focused on different climatic regions or vegetation types under the same climatic region. Understanding the climatic and hydrological conditions of different vertical vegetation zones and clarifying the regulating role of vegetation in the water cycle process can help to better adapt to the influence of climate change on the hydrological process in the source area. In this study, the stable isotope composition of precipitation and soil water, and soil water storage's spatiotemporal dynamics were monitored in four vegetation zones (Alpine Meadow, Coniferous Forest, Mountain Grassland and Deciduous Forest) with different hydrothermal conditions in the Xiying River Basin. In order to explore the differences in soil water evaporation, infiltration and storage processes in these four different climates, vegetation and terrain regions, the following research objectives are proposed: (1) Exploring the evolution of isotope evaporation signals and the "memory effects" of precipitation input, mixing and rewetting; (2) Understand the soil water storage capacity and influencing factors of four vegetation areas in the mountain areas.

Comment 5: L76-78. Not clear what you mean by this. Are the water resources more unstable or are they transitioning?

Response: I have reinterpreted this sentence for the sake of understanding.

L81-83: In alpine mountains, climate warming will accelerate the melting of glaciers and frozen soil, and the dynamic interaction between water bodies stored in different media will become the main focus of the water cycle (Penna et al., 2018).

Comment 6: L84. "Heat conditions" do you mean temperatures?

Response: We want to express the vegetation zone under different moisture and temperature conditions. Based on this, I re-narrate this sentence.

L89-93: In this study, the stable isotope composition of precipitation and soil water, and soil water storage's spatiotemporal dynamics were monitored in four vegetation zones (Alpine Meadow, Coniferous Forest, Mountain Grassland and Deciduous Forest) with different hydrothermal conditions in the Xiying River Basin.

Comment 7: L82-90. These are fine as general aims, but can you explain (briefly) why this is important (i.e. what are you doing that is new, what are the broader implications?). There is a disconnect here between the broad general themes in the rest of the introduction and your specific study. Also, runoff generation and the memory effect are not explicitly discussed in any depth in the paper (need to make sure that your aims are actually what you discuss).

Response: Previous studies on soil moisture evaporation, infiltration and storage have mostly focused on different climatic regions or vegetation types under the same climatic region, and there are few uses of isotope technology to trace the hydrological processes in the mountain vegetation vertical zone.

Comment 8: L88. If it is important, define the memory effect and explain why we need to understand it.

Response: The "memory effect" means that the temporal and spatial changes of the stable isotope profile of soil water can reflect and characterize the input, mixing, and rewetting process of precipitation. Understanding the "memory effect" helps us trace the dynamic changes of climate and soil hydrology.

Study Area

This section needs referencing. Also a few more details as to the spatial variation of rainfall and temperature (I presume that the highest rainfall and lowest mean temperatures are in the mountains?)

Response: I added a reference. Table 1 shows the spatial variation of precipitation and temperature.

Table 1 Basic data of each Vegetation zone (*Long*-Longitude, *Lat*-Latitude, *Alt*-Altitude, *T*-Air Temperature, *P*-Precipitation Amount, *h*-Relative Humidity)

Vegetation zone	Geographical parameter			Meteorological parametes			Number of samples	
	Long(° E)	*Lat*(° N)	*Alt*(m)	*T*(℃)	*P*(mm)	*h*(%)	Precipitation	Soil
Alpine Meadow	101°51'16"	37°33'28"	3637	-0.19	595.1	69.2	72	47
Coniferous Forest	101°53'23"	37°41'50"	2721	3.34	431.9	66.6	42	41
Mountain Grassland	102°00'25"	37°50'23"	2390	6.6	363.5	60.4	37	54
Deciduous Forest	102°10'56"	37°53'27"	2097	7.9	262.5	59.8	40	53

Comment 1: L94. What is a "first-class tributary"?

Response: I changed the description of this sentence.

L101-104: As the largest tributary of the Shiyang River, it is formed by Shuiguan River, Ningchang River, Xiangshui River and, Tatu River converging from southwest to northeast, and finally flowing into Xiying Reservoir.

Comment 2: L98-101. Probably worth reporting the Koppen Zones.

Response: We used the Köppen climate zone.

L106-113: The basin' elevation is between 2000 m and 5000 m, which belongs to a temperate semi-arid climate with strong solar radiation, long sunshine time, and a large temperature difference between day and night. The average annual temperature of the basin is 6℃, the annual average evaporation is 1133 mm, the annual average precipitation is 400 mm, and the precipitation from June to September accounts for 69% of the annual precipitation. The precipitation increases with the elevation, while temperature decreases with the elevation (Table 1) (Ma et al., 2018).

Comment 3: L103-106. Refer to Fig. 1.

Response: Figure 1 has been referenced here.

L113-116: The zonal differentiation of vegetation in the basin is dominated by Deciduous Forest, Mountain Grassland, Cold Temperate Coniferous Forest, and Alpine Meadows. The soils mainly include lime, chestnut, alpine shrub meadow, and desert soil (Fig.1).

Comment 4: Fig. 1. What is the inset on the left-hand map?

Response: The complete nine-dotted line is shown here.

Data and Methods

The methods used here are standard and suitable for the project. As with much of the rest of the paper, there are a few details lacking and the explanations are not very clear.

Comment 1: L111-113. It would be helpful here or in Section 2 to outline what 2017 was like in terms of rainfall and temperature as these vary year-by-year. In particular, distinguish between long-term averages and values in the sampling year.

Response: I have outlined precipitation and temperature.

L123-127: In 2017, the precipitation in Alpine Meadow, Coniferous Forest, Mountain Grassland and Deciduous Forest were 595.1mm, 431.9mm, 363.5mm and 262.5mm, respectively. The average daily values of Alpine Meadow, Coniferous Forest, Mountain Grassland and Deciduous Forest are -0.19℃, 3.34℃, 6.6℃ and 7.9℃, respectively (Table 1).

Comment 2: L116-122. This is rather a clunky description (not sure that you need to specify explicitly that you wrote dates on bottles). What do you mean by "four parallel samples" being also collected?

Response: I re-narrate the soil sampling process.

L130-134: Three duplicate samples were collected for each soil layer. The collected soil sample was placed into a 50 mL glass bottle, the bottle mouth was sealed with Parafilm marked with the sampling dates, and then frozen for storage until experimental analysis. Each sample was collected separately in an aluminium box.

Comment 3: L143. It's "permil" not "thousands". As written, "thousandths of the Vienna Standard Mean Ocean Water (VSMOW)" is meaningless.

Response: This error has been corrected.

L155-157: The analysis results were expressed in peril of the Vienna Standard Mean Ocean Water (VSMOW):

Comment 4: Section 3.2. The analysis is only part of the uncertainty. Did you perform multiple extractions on the same sample to test the uncertainty associated with that. This will undoubtedly be higher and needs to be considered.

Response: During the sampling process, we collected duplicate samples to improve the accuracy of the experiment.

Comment 5: Section 3.3.1 The line-conditioned excess is less used than the d-excess (but is potentially more informative). You should explain what it is (and define the term). The explanation "The physical meaning of lc-excess is expressed as the deviation degree between isotopic values in samples and LMWL, which indicates the non-equilibrium dynamic fractionation process caused by evaporation (Landwehr et al., 2014; Sprenger et al., 2017)" is not very clear.

Response: Based on your suggestion, we described lc-excess in detail.

L163-177: The linear relationship between δ^2H and δ^{18}O in precipitation and soil water is defined as the LMWL (local meteoric water line) and SWL (soil waterline), respectively, which is of great significance for studying the evaporative fractionation of stable isotopes during the water cycle. We further calculated the line-conditioned excess for each soil water and precipitation sample. The lc-excess in different water bodies can characterize the evaporation index of different water bodies relative to local precipitation (Landwehr and Coplen, 2006).

$$\mathrm{lc-excess} = \delta^2\mathrm{H} - a \times \delta^2\mathrm{H} - b \tag{2}$$

Where a and b are the slope and intercept of LMWL, respectively, and δ^2H and δ^{18}O are the isotopic values of hydrogen and oxygen in the sample. The physical meaning of lc-excess is expressed as the degree of deviation of the isotope value in the sample from the LMWL, indicating the non-equilibrium dynamic fractionation process caused by evaporation. Generally, the change of lc-excess in local precipitation is mainly affected by different water vapor sources, and the annual average is 0. Since the stable isotopes in soil water are enriched by evaporation, the average lc-excess is usually negative (Landwehr et al., 2014; Sprenger et al., 2017).

Comment 6: Section 3.3.2. More details are needed as to where these data are derived from. Are they local data measured at the field site or interpolated estimates? Application of the Penman-Monteath equation is very data sensitive. What do you think the errors are here?

Response: These data are from nearby weather stations. According to the literature, we revised the formula.

L179-186: Calculation of potential evapotranspiration based on Penman-Monteath equation (Allen et al., 1998):

$$\text{PET} = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u^2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u^2)} \quad (3)$$

Where PET is the daily potential evapotranspiration (mm day^{-1}), R_n is net radiation (MJ m^2 day^{-1}), G is soil heat flux density (MJ m^2 day^{-1}), γ is psychrometric constant (kPa℃$^{-1}$), u_2 is the wind speed at 2 m height (m s^{-1}), T is mean daily air temperature at 2 m height (℃), Δ is slope vapor pressure curve (kPa℃$^{-1}$), e_a is actual vapor pressure (kPa) and e_s is saturated vapor pressure (kPa). These data come from nearby weather stations.

Comment 7: Section 3.3.3. These are based on your measurements, yes? Again, do you have estimates of uncertainties. Also, some of the techniques (eg moisture content) need more detail.

Response: This data comes from our actual measurement, which is constant, and we added the calculation of soil moisture.

L191-194: W is gravimetric water content, which is expressed by formula as follows:

$$W = \frac{M_1 - M_2}{M_2} \times 100\% \quad (5)$$

In the formula: M_1 is the gravimetric of the wet soil (g), and M_2 is gravimetric of the dry soil (g).

Results

This section suffers from the shortcomings of the rest of the paper. The explanations are not very clear and are often overly general. Also, I cannot see where the raw data are (no Table or Appendix); presenting the actual data is required.

Comment 1: L175-178. How precise are these values (i.e. is the 1dp precision warranted)? What was the rainfall during those times?

Response: We use FAO Penman-Monteith to calculate the potential daily evapotranspiration (possible evapotranspiration) in the study area (the software calculation results are kept to three decimal places, and we keep one decimal place in the study). This illustrates the date when the maximum and minimum values appear, and there may be no rainfall on that day.

Comment 2: L180-182. Not very clearly worded.

Response: I restated this sentence.

L201-203: The input of summer precipitation and ice-snow meltwater increases the runoff, resulting in a trend similar to PET.

Comment 3: L213-220. The ranges in stable isotope values are probably more useful. Suggest that you report the range and the mean (you can omit the SD as that is less useful). Also report the number of observations, so we get an idea of how much data there is. Ideally the mean should be weighted by precipitation amount (it is not clear that that is the case, but you should be clear whether it is).

Response: We describe the average value and variation range of the isotope, preserve the SD, and add the number of observations according to the recommendations. The average amount of isotopes is based on the weighted average of precipitation or soil water content.

L235-244: The mean values of δ^2H and δ^{18}O in Alpine Meadow (Number of samples: 72) were -73.1‰±36.3‰ (-163.9‰~13.7‰) and -10.0‰±4.3‰ (-23.1‰~-1.3‰), respectively. The average values of δ^2H and δ^{18}O of Coniferous Forest (Number of samples: 42) were -42.0‰±37.2‰ (-117.8‰~13.0‰) and -7.1‰±4.7‰ (-17.4‰~-0.1‰), respectively. The average values of δ^2H and δ^{18}O of Mountain Grassland (Number of samples: 37) were -37.4‰±30.5‰ (-103.1‰~4.2‰) and -5.9‰±3.9‰ (-15.1‰~-0.9‰), respectively. The average values of δ^2H and δ^{18}O of Deciduous Forest (Number of samples: 40) were -31.8‰±42.8‰ (-110.2‰~23.2‰) and -5.8‰±5.5‰ (-15.2‰~3.2‰), respectively (Table 2).

Comment 4: L220-224. Poorly worded.

Response: I restated this sentence.

L244-250: The maximum isotopic values of the four vegetation zones appeared on August 4 (Alpine Meadow: 13.7‰, δ^2H; -1.3‰, δ^{18}O), August 10 (Coniferous Forest: 13.0‰, δ^2H; -0.1‰, δ^{18}O), August 7 (Mountain Grassland: 4.2‰, δ^2H; -0.9‰, δ^{18}O) and August 13 (Deciduous Forest: 23.2‰, δ^2H; 3.2‰, δ^{18}O), respectively. The highest temperature in each vegetation zone appeared on July 27. The high temperature caused the precipitation to undergo strong below-cloud evaporation during the fall, leading to the enrichment of isotopes.

Comment 5: L224-227. This isn't really that obvious from Fig. 3. Can you report the magnitudes in the text?

Response: Here, we have shown the seasonal variation trend of precipitation isotope and added the maximum value of each vegetation zone and the time of its appearance in the previous analysis.

L244-250: The maximum isotopic values of the four vegetation zones appeared on August 4 (Alpine Meadow: 13.7‰, δ^2H; -1.3‰, δ^{18}O), August 10 (Coniferous Forest: 13.0‰, δ^2H; -0.1‰, δ^{18}O), August 7 (Mountain Grassland: 4.2‰, δ^2H; -0.9‰, δ^{18}O) and August 13 (Deciduous Forest: 23.2‰, δ^2H; 3.2‰, δ^{18}O), respectively. The highest temperature in each vegetation zone appeared on July 27. The high temperature caused the precipitation to undergo strong below-cloud evaporation during the fall, leading to the enrichment of isotopes.

Comment 6: L232-260. This section has too little detail in it to follow. You need to explain the data more specifically (avoid vague terms such as "depletion" or "enrichment" and report some values). More importantly where are the data? Fig. 4 is labelled as a "heat map" but seems to be the values (I think) and they are on Fig. 5. However, these also need to be in a Table somewhere.

Response: According to your suggestion, I plot the data into a table and use the data for analysis.

L262-298: The low-temperature environment and abundant precipitation events in alpine meadows make the monthly average of δ^2H and δ^{18}O of soil water more depleted than other vegetation zones (-69.4‰~-51.6‰, δ^2H; -7.5‰~-10.3‰, δ^2H). Despite this, SWlc-excess of most samples in this station was still negative, and there were different degrees of evaporation in the process of precipitation penetrating the soil and mixing with original pore water, among which evaporation fractionation was stronger in July (-11.9‰, lc-excess) and October (-14.5‰, lc-excess). Soil water isotopes of Coniferous Forest gradually changed seasonally. From April to July, precipitation was scarce, the temperature rose, and the isotopes of soil water were gradually enriched on the surface (-52.7‰~-29.5‰, δ^2H; -7.0‰~-2.1‰, δ^2H), reaching the peak value of the observation period in July (-29.5‰, δ^2H; -2.1‰, δ^{18}O), and continuous rainfall input from late July to mid-August resulted in soil water isotopes depletion (-57.0‰, δ^2H; -8.1‰, δ^{18}O). SWlc-excess was an obvious fractionation signal opposite to the trend of isotope change, reaching the lowest value (-26.3‰) in the sampling period in July, and the change of air temperature and precipitation controlled the evaporation intensity. From April to July, the isotopic value of surface soil water in Mountain Grassland was higher (δ^{18}O was greater than zero), and SWlc-excess was lower than -30‰. During this period, evaporation and fractionation of shallow soil water were intense. Similar to the Coniferous Forest, the input of heavy precipitation from late July to mid-August led to the depletion of soil water isotopes. There was only sporadic rainfall in Deciduous Forest from April to July, and the soil water isotopes were gradually enriched on the surface (-46.1‰~-18.2‰, δ^2H; -4.7‰~0.2‰, δ^2H) and reached its peak in June when there was no rainfall event (-18.2‰, δ^2H; 0.2‰, δ^{18}O), and then became depleted (-53.2‰, δ^2H; -5.2‰, δ^{18}O). In addition, due to the influence of Xiying Reservoir and vegetation coverage, the isotopic enrichment degree of soil water in this vegetation zone was lower than that in Mountain Grassland. As the most intuitive form of water change, GWC (gravimetric water content) was always at a low value in July (AM: 21.0; CF: 14.8; MG: 11.9; DF: 14.9), when the evaporation was the strongest, and it was most obvious in shallow soil (Table 3) (Fig. 4).

Table 3 General characteristics of soil water δ^2H, δ^{18}O, lc-excess and GWC in different vegetation areas from April to October 2017

Month	Vegetation zone	δ^2H/‰			δ^{18}O/‰			lc-excess/‰			GWC/%		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
4	AM	-55.2	-70.7	-65.6	-8.5	-10.8	-10.1	-2.7	-7.1	-4.7	25.9	23.0.0.	24.7
	CF	-52.7	-72.2	-63.9	-7.0	-9.9	-8.9	-4.0	-12.0	-8.4	27.6	14.9	20.0
	MG	-7.32	-50.6	-41.0	2.8	-5.8	-3.9	-8.8	-36.8	-19.4	21.7	6.5	14.7
	DF	-46.1	-69.4	-62.1	-4.7	-9.9	-8.5	-2.5	-23.2	-9.7	27.7	19.4	21.8
5	AM	-46.1	-76.5	-66.4	-7.4	-12.2	-10.1	-2.6	-7.7	-4.9	32.6	23.2	28.9
	CF	-45.8	-61.9	-53.5	-5.3	-8.4	-7.0	-9.3	-17.7	-13.0	22.6	9.0	16.1
	MG	-6.7	-47.3	-39.2	2.9	-6.5	-4.3	-4.5	-36.2	-14.4	15.7	7.6	11.2
	DF	-30.8	-63.5	-53.8	-1.9	-9.4	-6.9	-3.2	-30.1	-13.6	26.0	11.7	17.7
6	AM	-62.5	-83.9	-69.4	-8.9	-12.6	-10.3	-1.5	-8.4	-5.8	33.3	21.9	26.0
	CF	-45.8	-78.4	-58.7	-5.1	-12.0	-7.8	5.5	-26.6	-8.5	32.1	10.0	21.3
	MG	-19.7	-74.9	-46.9	0.8	-11.8	-5.8	13.0	-33.7	-11.0	19.3	7.5	14.2
	DF	-18.2	-64.9	-51.7	0.2	-9.0	-5.9	-4.6	-38.2	-19.4	13.5	8.4	11.1
7	AM	-47.3	-60.1	-51.6	-6.9	-8.4	-7.5	-8.8	-14.8	-11.9	25.4	19.0	21.0
	CF	-29.5	-51.4	-41.6	-2.1	-7.9	-5.6	-2.6	-26.3	-11.2	24.3	7.2	14.8
	MG	-10.6	-48.4	-39.2	2.3	-6.4	-4.1	-5.8	-35.8	-16.1	18.7	6.3	11.9
	DF	-35.1	-69.0	-54.1	-1.7	-8.7	-5.5	-14.8	-35.3	-24.5	18.2	11.8	14.4
8	AM	-58.5	-80.3	-66.6	-8.4	-11.6	-9.6	-6.1	-15.4	-9.7	28.1	19.5	25.1
	CF	-57.0	-75.5	-66.4	-8.1	-9.8	-9.2	-2.5	-13.1	-8.3	21.4	8.7	16.3
	MG	-34.2	-53.8	-44.0	-3.2	-5.5	-4.4	-14.7	-22.6	-18.7	11.3	9.5	10.4

	DF	-53.2	-84.3	-67.6	-5.2	-13.5	-9.2	6.8	-26.1	-9.6	23.6	14.7	20.6
9	AM	-48.0	-79.2	-61.0	-7.8	-11.1	-9.2	-4.3	-10.4	-7.2	29.9	20.3	25.3
	CF	-52.5	-67.7	-60.7	-7.8	-10.1	-8.8	-0.1	-11.3	-6.0	31.3	9.3	20.5
	MG	-32.3	-45.3	-38.8	-3.5	-4.4	-4.0	-9.1	-23.8	-16.5	15.3	9.1	13.0
	DF	-30.5	-77.0	-59.8	-3.1	-11.4	-8.2	-1.8	-19.3	-9.3	25.8	14.7	19.1
10	AM	-42.4	-73.5	-58.9	-6.1	-9.8	-7.9	-12.2	-18.2	-14.5	36.2	25.4	29.5
	CF	-59.1	-66.3	-61.7	-8.8	-10.5	-9.5	5.1	-5.3	-1.5	30.0	16.8	23.1
	MG	-50.3	-66.7	-58.3	-5.6	-8.3	-7.1	-5.5	-18.4	-11.9	18.3	11.4	15.8
	DF	-38.0	-61.8	-48.3	-2.7	-8.2	-4.9	-11.9	-34.8	-23.9	25.5	8.9	17.2

Comment 7: L266-269. Speculative, can you provide a reference to show that these processes cause secondary evaporation.

Response: I have included references here. In addition, based on other reviewers ' suggestions, this part was moved to the discussion.

L373-376: In Alpine Meadow, due to low atmospheric temperature, low cloud base height, and low air-saturated water vapor loss, it is weakly affected by secondary evaporation during precipitation. The slope of LMWL (8.4) is even higher than that of GMWL (Zhang et al., 2012).

Comment 8: L270-275. A reference would also help here

Response: I have added references here. In addition, based on the suggestions of other reviewers, this part was moved to the discussion.

L376-378: As the altitude decreases, the secondary evaporation under the cloud strengthens, and the slope of the LMWL of each vegetation zone decreases (Pang et al., 2011) (Fig 5).

Comment 9: L275-276. Seems redundant as I'm not sure where else the moisture could come from.

Response: This part was deleted.

Comment 10: L288-295. Again, lacks detail. It is difficult to follow these arguments when the data is discussed in very vague terms.

Response: I used data to describe this part of the content.

L320-327: During the study period, compared with other vegetation belts, the surface isotopic value of soil water in Mountain Grassland was relatively enriched (-24.3‰, δ^2H; -0.8‰, δ^{18}O), the lc-excess was smaller and deeper into the middle and lower soil layers (-25.8‰), and the GWC was relatively low (8.4%). Because of the difference in vegetation types and the influence of reservoirs, this change did not have the elevation effect completely. Although the elevation was low, the soil water of Deciduous Forest had more depleted isotopic characteristics and higher soil moisture than Mountain Grassland in most samples.

Comment 11: L298. What is "dynamic fractionation"?

Response: Here should be "evaporation".

L328-331: The low-temperature natural environment made Alpine Meadow soil-less affected by evaporation (lc-excess > -20 ‰), and GWC was at a high value (GWC > 20%) during the whole study period.

Comment 12: L296-309. As with much of the rest of this section, I struggled to follow the details. The explanations are not clear, there are a fair number of general statements that lack detail, and a number of findings that are not obvious. For example, "Evaporation signal can easily penetrate deep soil, which made the GWC value of all sampling activities at this site lower than 20% (Fig.6)" which seems to be at odds with "With the increase of soil depth, the fractionation signal gradually weakened".

Response: I used data to describe this part of the content.

L327-339: Soil profiles obtained from different vegetation zones can reflect the evaporation signals of water. The low-temperature natural environment made Alpine Meadow soil-less affected by evaporation (lc-excess > -20 ‰), and GWC was at a high value (GWC > 20%) during the whole study period. The surface soil water of Coniferous Forest was easily affected by climate and had higher isotopic composition (-29.5‰, δ^2H; -2.1‰, δ^{18}O) and lower lc-excess (-26.3‰). Due to evaporation, soil water isotopes in Mountain Grassland and Deciduous Forest were enriched in the surface soil layer. Especially in the Mountain Grassland, the average values of δ^2H and δ^{18}O in 0-10cm soil layer were as high as -24.4‰ and -1.2‰, respectively, and SWlc-excess was lower than -25‰, even close to -40‰ in some samples. Evaporation signal can easily penetrate deep soil, which made the GWC value of all sampling activities at this site lower than 20% (Fig. 4) (Fig. 6).

Discussion

This section has some interesting ideas in it but it is not well linked to the data in the study. You need to show how the data that you collected informs our understanding. Some of the later part of this section is written more like an introductory literature review.

Section 5.1

L325-354. Some of this section describes the data (the observations on soil moisture) and that material belongs in the results.

Response: We reanalyzed Figure 7 in the results.

L343-365:**4.4 Variation of water storage capacity of 0-40cm soil layer in different vegetation areas**

This study used soil water to calculate the water storage of the 0-40cm soil layer in the four vegetation zones during the observation period (Fig 7). The water storage capacity of the Alpine Meadow gradually decreases from April to July (209.7 mm~167.2 mm), and the water storage capacity increases after July (167.2 mm~201.8 mm). The monthly average water storage capacity is the least for 0-10 cm (43.0 mm) and the most for 30-40 cm (51.7 mm). The water storage capacity of the Coniferous Forest gradually decreases from April to July (150.1 mm~101.2 mm), and the water storage capacity increases after July (101.2 mm~160.0 mm). The monthly average water storage capacity is the least for 0-10 cm (28.0 mm) and the most for 30-40 cm (40.0 mm). The water storage capacity of the Mountain Grassland gradually decreases from April to July (80.3 mm~64.0 mm), and the water storage capacity increases after July (64.0 mm~104.6 mm). The monthly average water storage capacity is the least for 0-10 cm (17.5 mm) and the most for 20-30 cm (22.0 mm). The water storage capacity of the Deciduous Forest gradually decreases from April to June (159.3 mm~104.0 mm), the water storage capacity increases from June to August (104.0 mm~154.0 mm), and there is a decrease from August to October (154.0 mm~111.8 mm).The monthly average water storage capacity is the least for 0-10 cm (29.1 mm) and the most for 20-30 cm (35.0 mm). In general, the soil water storage capacity of the 0-10 cm soil layer is less than that of other soil layers. The order of the water storage capacity of the 0-40 cm soil layer in the four vegetation zones is AM > DF > CF > MG.

Section 5.2

This section does not link well with the results. It is difficult to follow how your data help you make these conclusions. More justification and explanations are required. Moreover, there is little discussion of processes here – how does the data help understand how processes operate? You have concentrated on discussing the isotopic variability, without using it to understand what is going on.

This is the section where you should discuss aspects such as the memory effect and runoff generation, but you do not do so.

Response: According to your suggestion, I improved the discussion of this part.

Section 5.3.

This section reads more like an introduction. It is not clear how what you have done in this study relates to these broad general findings. As with the Introduction, you need to make a clearer link between your study and these general statements. This are all important issues, but there needs to be linkages.

Climate change in mentioned several times, but it is not clear how your study informs our understanding of its impacts. Those types of links need to be made clearer if they exist. Likewise, there are comments about groundwater recharge and runoff but no indication of how your results help understand those processes. Runoff generation was not actually discussed in the body of the paper (it appears in the introduction and the end of the discussion, but not in the discussion of the specific results).

Same comments apply to: subsurface runoff (presume that you mean interflow?); the management practices; human activities. These are topics that all appear in this section with no real link to the data in the rest of the paper.

There are also a number of superfluous details here. For example, why is mining waste (L426-428) relevant to this study.

Response: We logically sorted out the full text based on the reviewers' comments. The discussion on runoff generation in the watershed does not match the theme of this manuscript (Evaporation, infiltration and storage of soil water in different vegetation zones in the Qilian mountains: a stable isotope perspective). Therefore, the manuscript focused on soil moisture's evaporation, infiltration, and storage mechanism in the study area. Based on this, we reorganized this part of the content. Your comments have further improved the logic of the article.

L370-494: **5.1 Evaporation of soil moisture in different vegetation zones**

In the arid river source area, the replenishment of soil moisture mainly comes from precipitation. The slope of the regional atmospheric precipitation line can reflect the strength of local evaporation. In Alpine Meadow, due to low atmospheric temperature, low cloud base height, and low air-saturated water vapor loss, it is weakly affected by secondary evaporation during precipitation. The slope of LMWL (8.4) is even higher than that of GMWL (Zhang et al., 2012). As the altitude decreases, the secondary evaporation under the cloud strengthens, and the slope of the LMWL of each vegetation zone decreases (Pang et al., 2011) (Fig 5). The dynamic changes of lc-excess of soil profiles in different vegetation areas reflect the process of soil water evaporation caused by drought during the study period. The monthly average value of SWlc-excess in Alpine Meadow was less than 0, and the minimum value was -11.9‰ (July). Although the vegetation belt is subject to different degrees of evaporation each month, it is less affected by drought and it is difficult for evaporation to penetrate into the middle and lower soils. The SWlc-excess of the Coniferous Forest belt is greater than that of the alpine meadow from April to June. The evaporation is the strongest in July (-11.2‰, lc-excess). Similar to alpine meadows, evaporation mainly occurs in the top soil. The vegetation coverage of Mountain Grassland is low, and the arid environment makes the isotopes of the surface soil produce strong evaporation signals (lc-excess is close to -40‰). In most samples, the SWlc-excess of the 60-80 cm soil layer is negative. The evaporation signal moves to the lower layer of the soil. (Zimmermann et al., 1966; Barnes and Allison, 1988). Similar evaporation signals have been found in the Mediterranean and arid climate regions (Sprenger et al., 2016b; McCutcheon et al., 2017). Evaporation signal only exists in the surface soil in humid areas, and there is no difference between lc-excess and 0 in the soil layer below 20cm (Sprenger et al., 2017). The monthly surface soil evaporation of Deciduous Forest is less than that of Mountain Grassland from April to June, and it is greater than mountain grassland after July, which is mainly due to the influence of vegetation and reservoirs. There were commonalities in soil moisture changes in different vegetation zones characterized by more enriched isotopes, stronger evaporation signals, and lower moisture content in shallow soil. With the increase of soil depth, the isotope was gradually depleted, and the evaporation signal was gradually weakened until it disappeared. The evolution of isotopes, lc-excess, and GWC in unsaturated soil showed the differences among different vegetation zones. From high altitude to low altitude, the isotopic value of the surface gradually enriched, and the evaporation signal increased (Fig 4) (Fig 6).

5.2 "Memory effects" of precipitation input, mixing and rewetting

The changes of soil water isotope and soil moisture can evaluate the input, mixing and rewetting process of precipitation in different vegetation areas. The main methods of precipitation input are plug flow and preferential flow. Plug flow is the complete mixing of water through the soil matrix with shallow free water. Under the action of the plug flow, precipitation infiltrates along the hydraulic gradient, pushing the original soil water downward. Preferential flow means that precipitation uses soil macropores to quickly penetrate shallow soil to form deep leakage (Tang and Feng, 2001). After precipitation, the variability of isotope signals at a certain soil depth can identify the seepage way of water (Peralta-Tapia et al., 2015). During the study period, the soils of Alpine Meadow and Coniferous Forest were seasonally frozen and thawed all year-round, and the isotope difference of soil isotope profile was small. The soil moisture profile showed a trend of water increase from top to bottom, indicating that this period was caused by the influence of the previous precipitation. The soil is humid, so the replenishment of soil water by precipitation has the characteristics of top-down piston replenishment. Preferential infiltration showed high variability of isotopic signal (Brodersen et al., 2000), and rainwater in Mountain Grassland and Deciduous Forest flowed into deep soil rapidly through soil matrix through exposed soil fissures and roots. It is manifested by the sudden depletion of soil isotopes at a depth of 60-100 cm. This may be due to the recent relatively depleted precipitation that quickly reached this depth along with the preferential passage in the soil. Water movement and mixing in the unsaturated zone can be observed in the space-time variation of isotope within 1 meter of the soil profile, Alpine Meadow and Coniferous Forest zone were rich in rainfall. After a short period of weak evaporation, the soil will be rewetted by the next rainfall. Especially in Alpine Meadow, the soil moisture is kept above 20% each month. The Mountain Grassland and Deciduous Forest zone had only sporadic precipitation from mid-May to late July, and the soil moisture evaporates rapidly. With the decrease of air temperature and the occurrence of continuous precipitation after July, the soil was re-wetted after two months of drought, and both vegetation zones showed the replacement and mixing of soil water isotope and precipitation. The results showed that the soil water storage capacity of the alpine grassland was seriously insufficient, reflecting the incomplete rewetting of the soil by precipitation at the end of the study. In addition, low soil water storage capacity will enrich the remaining soil water isotope (Zimmermann et al., 1966; Barnes and Allison, 1988). We observed the "memory" effect of soil re-wetting caused by precipitation input and the mixing of different vegetation areas during the entire study period. The changes in soil moisture in each vegetation area reflect different climatic and hydrological characteristics (Fig. 4) (Fig. 6).

5.3 Influencing factors of soil water storage capacity in arid headwaters areas

As the temperature decreases rapidly with the increase of height, precipitation and humidity increase to a certain extent, and the vegetation shows a strip-like alternation approximately parallel to the contour line, forming zonal vegetation with obvious differentiation (Yin et al., 2020). The dry-wet conditions of different vegetation zones restrict the soil water storage capacity in the basin. In the process of low-altitudes vegetation zones replacement, precipitation decreased, temperature rose, the groundwater level dropped, and the soil water storage capacity was weak (Coussement et al., 2018; Kleine et al., 2020). The soil water storage capacity of Alpine Meadow with low temperature and rainy weather was higher than that of other vegetation zones (value of 0-40cm soil layers from April to October: AM: 187.8 mm; CF: 128.4 mm; MG: 81.2 mm; DF: 132.1 mm). During the study period, the soil water storage capacity (0-40 cm) exceeded 165 mm in each month, with little difference between months and no obvious change between months. With the decrease of altitude, the monthly difference of dry-wet conditions in each vegetation zone gradually became obvious. With the increase of temperatuer in summer, the environment became dry, and the soil water storage capacity weakened (Sprenger et al., 2017). The soil water storage capacity of Coniferous Forest began to decrease in April, and the water storage capacity of 0-40 cm reached the minimum value (101.2 mm) in July. The variation of temperature and precipitation was the main reason for the monthly difference (Dubber and Werner, 2019). Although there was a certain water storage capacity in Coniferous Forest with some water transpiration loss, the soil water storage capacity in this vegetation zone was not strong. The water storage capacity of Mountain Grassland soil was lower than that of other vegetation zones. The continuous dry and warm weather in spring and summer led to the water storage capacity of 0-40 cm soil being lower than that of 100 mm every month. Particularly, drought stress leads to insufficient soil moisture, making it difficult to maintain plant demand, resulting in sparse vegetation and large-scale exposed surface soil, which further accelerates surface water loss. The continuous precipitation from the end of July prevented further drought development, and the water input gradually restored the soil water storage capacity (Kleine et al., 2020). Deciduous Forest had similar hydrothermal conditions with Mountain Grassland, but the soil porosity of forest land is obviously larger than that of barren land, and its permeability was better than that of barren land. Precipitation was sent to the ground through roots and turned into groundwater. The forest was a reservoir with strong water storage and soil conservation capacity (Sprenger et al., 2019). The water storage capacity of 0-40 cm soil in Deciduous Forest was higher than 100 mm at each sampling time. In addition, the water content of the 0-40 cm soil layer in each vegetation zone increased with the deepening of the soil layer, and the water storage capacity of surface soil was weak. The difference in soil properties will also lead to more water storage in the middle and lower soil with higher clay content (Heinrich et al., 2019) (Fig. 7). Climate warming and the Spatio-temporal imbalance of water resources have disturbed the ecological-water balance of different vegetation zones in inland river source areas (Liu et al., 2015). Plants growth mainly depends on the water stored in shallow soil layers (Amin et al., 2020). Drought reduced soil water storage and inhibited the plants growth (Li et al., 2020). In order to effectively improve and manage water resources in arid water source areas, it is necessary to explore the heterogeneity among different vegetation zones. According to the current situation of climate, hydrology and social economy in the basin, scientific and reasonable management policies should be formulated according to local conditions for different ecological-hydrological contradictions and extended to more areas.

Conclusions

As with the discussion, the links to the study are not well made. In some ways this material is less general than some of the latter parts of the Discussion (Section 5.3) and it would be worth reordering so that you have the more general ideas at the end.

Response: Based on the opinions of the three reviewers, we re-summarized the conclusions of the manuscript.

L496-522: This work provides further insights into the movement and mixing of soil water in different vegetation zones in arid source regions. During the study period, the dynamic changes of lc-excess in soil profiles of different vegetation zones reflected the evaporation signals caused by drought. Soil water evaporation in spring and summer and insufficient precipitation during the drought period were the main driving forces leading to isotopic enrichment in surface soil. The results show that: The evaporation intensity of the four vegetation zones was: Mountain Grassland > Deciduous Forest > Coniferous Forest > Alpine Meadow. In the Mountain Grassland and Deciduous Forest zone, drought caused the evaporation signal to penetrate deep into the middle and lower soils. The SWlc-excess below 70 cm of the ground surface was still negative. Soil water isotopes and GWC record the process of soil rewetting caused by precipitation input and mixing. Alpine Meadow and

Coniferous Forest zones were enriched in precipitation. After a short period of weak evaporation, the soil will be rewetted by the next precipitation. There was only sporadic precipitation in Mountainous Grassland and Deciduous Forest belt from mid-May to late July. After July, the temperature dropped and continuous precipitation made the soil wet again after two months of drought. The Mountain Grassland and Deciduous Forest zone had only sporadic precipitation from mid-May to late July. With the decrease of air temperature and continuous precipitation after July, the soil was re-wetted after two months of drought. Moisture and temperature conditions were the key factors that restrict the soil water storage capacity in different vegetation zones. Each vegetation area's soil water storage capacity is: Alpine Meadow > Deciduous Forest > Coniferous Forest > Mountainous Grassland. The water storage capacity of the surface soil in each vegetation zone was weak, and more water was stored in the middle and lower soil with higher clay content. This research is helpful to understand the hydrological process in different vegetation areas and to provide theoretical support for the realization of regional ecological hydrological balance.