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 manuscript. The main corrections and the response to the reviewers' comments are as follows.

Responses to the reviewer's comments:

Response to Reviewer #3

Reviewer#3: This paper presents an interesting hydrological and runoff study from the Qilian region where water and soil water samples were obtained across different climatic, topographical and vegetative conditions in order to understand the infiltration, evaporation and storage processes. The paper is well structured, but major issues need fixing as also suggested by the other referees. Overall, the English language needs to be proofread and words such as "obvious" should be avoided. The Abstract needs substantial work to emphasize the purpose/objectives of the study, describe the methods used, and to relate quantifiable results. Further discussion of the results themselves is required as well as linking the results obtained (what are the observations withdrawn from the data) to previous research. Please see additional comments below.

Thanks for your comments.

Abstract

Comment 1: L11-12: Is this really true? That in arid areas most of the water comes from mountains? How about low lands? And groundwater? I think this sentence is not needed.

Response: Based on your suggestion, we have deleted it.

Comment 2: L12: should be the "processes" not "process".

Response: This spelling error has been corrected.

Comment 3: L13: "have" instead of "has".

Response: This spelling error has been corrected.

L10-13: The processes of water storage and runoff generation have not been fully understood in different vegetation zones in mountainous areas, which is the main obstacle blocking human cognition of hydrological processes and water resources assessment.

Comment 4: L15: instead of "In current study" use "In this study"

Response: We corrected this.

Comment 5: L15-17: This is an important sentence that summarizes the work done. I would suggest to rewrite it being more specific to which isotopes, which types of vegetation zones and why this is needed.

Response: Based on suggestions from you and other reviewers, we rewrite this part.

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 6: L17: Weak compared to what? Results should be quantified instead of using "weak" and "save up".

Response: We have clarified the evaporation intensity through the SWlc-excess of each vegetation zone and verified it through meteorological data.

L17-23: The evaporation intensity of the four vegetation zones was: Mountain Grassland > Deciduous Forest > Coniferous Forest > Alpine Meadow. Alpine meadows and coniferous forests only had evaporation in the topsoil, and the rainfall input was fully mixed with each layer of soil. Evaporation signals of mountain grasslands and deciduous forests could penetrate deep into the middle and lower layers of the soil, and precipitation quickly flows into the deep soil rapidly through the soil matrix.

Comment 7: L19-21: What is the result in the paper that lead to this hypothesis? The authors need to add evidence of this instead of speculating.

Response: This part of the result has been changed, we have added data and information.

L17-27: The results show that: The evaporation intensity of the four vegetation zones was: Mountain Grassland > Deciduous Forest > Coniferous Forest > Alpine Meadow. Alpine meadows and coniferous forests only had evaporation in the topsoil, and the rainfall input was fully mixed with each layer of soil. Evaporation signals of mountain grasslands and deciduous forests could penetrate deep into the middle and lower layers of the soil, and precipitation quickly flows into the deep soil rapidly through the soil matrix. 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 8: L22: What is evaporate strongly? How much?

Response: We have clarified the evaporation intensity through the SWlc-excess of each vegetation zone and verified it through meteorological data.

L17-19: The results show that: The evaporation intensity of the four vegetation zones was: Mountain Grassland > Deciduous Forest > Coniferous Forest > Alpine Meadow.

Comment 9: L21-22: The lower elevation vegetation zones within the Mountain Grassland and Deciduous forest? Aren't these areas at high altitude?

Response: This sentence was restated. Previously, it was to express that Mountain Grassland (2390 m) and Deciduous Forest (2097 m) are relatively low-altitude areas compared to Alpine Meadow (3637 m) and Coniferous Forest (2721 m).

Comment 10: L25: Delete word "reasonably"

Response:"Reasonably" has been deleted.

L27-28: This work will provide a new reference for the process of soil hydrology in the arid headwaters area.

Introduction

Comment 1: L39-40: Soil water in the unsaturated zone from precipitation can transform into water vapour or groundwater recharge.

Response: I have modified this sentence according to your suggestion.

L39-40: Soil water in the unsaturated zone can be converted to steam or groundwater recharge from precipitation.

Comment 2: Line 40: Delete "Its".

Response: "Its" has been deleted.

Comment 3: Line 41: Delete "very".

Response: This word "very" has been deleted.

Comment 4: Line 48: 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 5: Line 54: is it soil water profiles?

Response: This part of the content has been deleted.

Comment 6: Line 56: Delete "In addition,".

Response: This part of the content has been deleted.

Comment 7: Line 58: Describe what the d-excess is.

Response: "d-excess" has been introduced in detail.

L65-67: Dansgaard (1964) proposed the concept of d-excess (d-excess=$\delta^2H-8\delta^{18}O$) to illustrate the intensity of evaporative fractionation. In the state of isotopic equilibrium, the value of the d-excess is 10.

Comment 8: Line 66-70: Delete ",and" and rewrite following sentence. It is not clear at the moment.

Response: This part of the content has been deleted.

Comment 9: Line 71: Do not use "Generally speaking" in a scientific publication

Response: "Generally speaking" has been deleted.

Comment 10: Line 71: Do "wet" areas refer to tropical regions?

Response: This should be a "humid area", which refers to an area with humid air and abundant rainfall.

Comment 11: Line 80: can better help adapt.

Response: This place has been corrected.

L86-89: 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.

Comment 12: Line 82: "In this study" instead of "In current study".

Response: This place has been corrected.

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 13: Line 82: "," after soil water.

Response: This place has been corrected.

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 14: Line 83: Is it in four regions of different climate, vegetation and topographical conditions? As opposed to vegetation zones?

Response: Our research objects are four typical vertical vegetation belts in mountainous areas, and their climatic conditions, topography and dominant species are different.

Comment 15: Line 85: Then, it can be clarified that this study explores how evaporation, infiltration and storage processes differ within these four regions according to the climate, vegetation and topography.

Response: Yes, this was confirmed in the follow-up discussion.

L93-98: 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.

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Comment 16: Line 89: similarly to the previous comment, are the authors restricting the analysis to only vegetation zones? I would argue that the study compares regions with varying climatic, topographic and vegetative conditions.

Response: The climatic conditions, topography and dominant species of the vegetation zone are different. I think the description of the vegetation zone already contains the similarities and differences of these natural conditions.

Study Area

Comment 1: Line 99: ranges between 2000m and 5000m above sea level

Response: I revised this sentence.

L106-109: 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.

Data and Methods

Comment 1: L110: Delete "and determination"

Response: This words "and determination" have been deleted.

Comment 2: L116: What does "parallel" mean here?

Response: This is a spelling error, it should be "duplicate samples". Collect duplicate samples to improve the accuracy of the experiment.

Comment 3: L170-172: Equation before line 170 needs reference.

Response: References have been added.

L188-189: Soil water storage is the thickness of water layer formed by all water in a certain soil layer (Milly, 1994)

Results and Analysis

Comment 1: L175: "PET" should be written Potential evapotranspiration (PET), then the authors can use PET but it needs complete spelling the first time it is used.

Response: Full spelling is used for the first time.

L178: **3.3.2 PET (Potential evapotranspiration)**

Comment 2: L177: I assume it is also the daily evapotranspiration? Need to make it explicit which type of evaporation.

Response: I double-checked the usage of the text. We calculated the daily potential evapotranspiration during the study period, and obtained the potential evapotranspiration for each month and the entire observation period by summing.

Comment 3: L184: Delete "generally speaking".

Response: This words "generally speaking" has been deleted.

Comment 4: L191: "temperature" instead of heat

Response: I have modified this.

L210-212: To explore the differences of the natural environment in different vegetation zones, air temperature, atmospheric humidity and precipitation were used to indicate each research site's temperature and moisture conditions.

Comment 5: L194: 72 precipitation events? Make it explicit, where all these rainfall?

Response: I have explained in detail here.

L215-217: During the observation period, there were 72 precipitation events in the Alpine Meadow zone, the total precipitation was 534.3 mm, which was relatively evenly distributed in each month.

Comment 6: L207: Rewrite sentence to "The temperature of the studied regions was ordered as follow:"

Response: According to your suggestion, this part has been rewritten.

L228-231: The temperature of the studied regions was ordered as follow: AM (Alpine Meadow) < CF (Coniferous Forest) < MG (Mountain Grassland) < DF (Deciduous Forest), and the humidity of the studied regions was ordered as follow: AM > CF > MG > DF (Fig. 2).

Comment 7: L208: Define first what AM, CF, MG, and DF mean

Response: Full spelling is used for the first time.

L228-231: The temperature of the studied regions was ordered as follow: AM (Alpine Meadow) < CF (Coniferous Forest) < MG (Mountain Grassland) < DF (Deciduous Forest), and the humidity of the studied regions was ordered as follow: AM > CF > MG > DF (Fig. 2).

Comment 8: L213: Do not use obviously in scientific publications, you can say what it was significantly different? Did you do any statistical analysis to conclude this? If so what please mention it in the results

Response: This has been rewritten, and the difference is analyzed in the subsequent results.

L233-235: Influenced by different water sources and complex weather conditions in the precipitation process, the isotopic composition of precipitation in four vegetation zones was different during the study period.

Comment 9: L211-220. This info would be better in a table

Response: Based on your suggestion, we have drawn a table.

L254-256: **Table 2** General characteristics of precipitation δ^2H and $\delta^{18}O$ in different vegetation areas from April to October 2017

Vegetation zone	δ^2H/‰				$\delta^{18}O$/‰			
	Max	Min	mean	SD	Max	Min	mean	SD
AM	13.7	-163.9	-73.1	36.3	-1.3	-23.1	-10.0	4.3
CF	13.0	-117.8	-42.0	37.2	-0.1	-17.4	-7.1	4.7
MG	4.2	-103.1	-37.4	30.5	-0.9	-15.1	-5.9	3.9
DF	23.2	-110.2	-31.8	42.8	3.2	-15.2	-5.8	5.5

Comment 10: L235: "The low temperature environment of Alpine Meadow and abundant and uniform precipitation events made the monthly mean values of δ 2H and δ 18O change little" how much?

Response: Based on the opinions reviewer, this part' content has been revised.

L262-265: The low-temperature environment and abundant precipitation events in alpine meadows make the monthly average of δ^2H and $\delta^{18}O$ of soil water more depleted than other vegetation zones (-69.4‰~-51.6‰, δ^2H; -7.5‰~-10.3‰, δ^2H).

Comment 11: L239: "Evaporation fractionation of soil water isotopes in Coniferous Forests was more intense." More intense than what? These kind of statements need quantification.

Response: According to the opinions of the three reviewers, this sentence is meaningless here. This part mainly analyzes the temporal changes of soil water isotopes in different vegetation zones. Therefore, I deleted this part of the content.

Comment 12: L277-278: "With the decrease of altitude, the soil water evaporation became stronger and stronger, except soil in Deciduous Forest". This sentence does not make sense, please rewrite and quantify stronger.

Response: Based on your suggestion, I have changed and explained it here.

L308-312: With the decrease in altitude, the slope of the soil waterline in all vegetation zones except for the Deciduous Forest soil waterline decreases (Alpine Meadow: 6.4; Coniferous Forest: 4.7; Mountain Grassland:3.4; Deciduous Forest:4.1), indicating that the evaporation of soil moisture is getting stronger.

Discussion

I am in agreement with the comments of Referee 1 and Referee 2 concerning the discussion. It feels more like a summary of previous studies. The authors need to refer to the results and put them in context of previous work and how their study is contributes to that pool of knowledge.

Comment 1: L323-325: "The soil water storage capacity of Alpine Meadow with low temperature and rainy weather was obviously higher than that of other vegetation zones." The authors need to explain how this conclusion is evident from their data without using words such as "obviously" referred to figure 7 for discussion.

Response: **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 Spatiotemporal 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.

Comment 2: L440-442. Fix this sentence grammatically

Response: This part of the content has been replaced by new content.

Conclusion

Comment 1:L457: Storage capacity decreased (instead of weakened)

Response: This problem has been corrected.

L515-520: 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.

Comment 2:L461: Soil "water" evaporation in spring…

Response: This problem has been corrected.

L499-501: 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.

Comment 3:L463: Is it "isotopic" instead of "isotopci"?

Response: This problem has been corrected.

L499-501: 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.

Comment 4:L463-465. This sentence needs fixing. I could not understand what it conveys.

Response: I have revised this sentence.

L503-506: 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.