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Human activities determine vegetation water use in the middle and lower reaches of arid areas

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Abstract: In the middle and lower reaches of inland river basins of arid regions, human-intensive exploitation directly determines the distribution patterns of plants in arid areas and further determines the patterns of water use and the water cycle in arid regions. However, human activities on vegetation water utilization and the influence of the water cycle process and mechanism are not clear. In this study, seven observation systems were set up to collect samples in the mountainous, oasis and desert areas of the Shiyang River Basin, an arid inland river in central Asia. In order to quantitatively assess the contribution of different potential water sources to plants, stable isotopes of various water bodies in different geomorphic units of the basin were analyzed. The results showed that precipitation and soil water were the main sources

of forest trees in mountainous areas, and the farmland vegetation in the middle and lower reaches of the oasis mainly absorbed soil water supplied by irrigation. The desert area forms vegetation in the ecological water transport area, and vegetation mainly absorbs soil water, lake water and groundwater formed by ecological water transport. On the whole, the water use patterns of plants in mountainous areas are not affected by human activities fundamentally, the oasis area is mainly affected by irrigation activities, and the inland river terminal lake area is mainly affected by ecological water transport. Human activities determine the water use patterns in the middle and lower reaches of inland rivers in arid areas.

Keywords: Arid areas;Stable isotope; MixSIAR model; Plant water use

1 Introduction

Water availability is one of the most important factors for the growth of individual plants in terrestrial ecosystems (Boyer et al., 1982). Plant survival and activities, as well as ecosystem stability is closely related to water availability (Zhou et al., 2019). In arid and semi-arid areas, water is the main limiting factor for vegetation development (Porporato et al., 2004). Due to water shortage, plant growth is limited, but plants have strategies to prevent water loss and resist drought (Gupta et al., 2020). Precipitation is one of the main sources of water (Zhao et al., 2018) and an important climatic factor of vegetation change (Roca et al., 2004), which controls plant community structure, composition and vegetation type (Weltzin et al., 2003). The uneven distribution of precipitation leads to the extreme spatial and temporal variability of soil moisture (Antunes et al., 2018). Under different precipitation

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conditions, the water use strategies of vegetation will be different (Miller et al., 2001). The distribution of precipitation and the depth of groundwater level control the spatial pattern of soil moisture availability. This plays a crucial role in plant adaptation and vegetation composition (Zhou et al., 2019). In addition, human beings have been influencing the hydrological cycle since the beginning of civilization (Zhao et al., 2020), and in recent years, human activities have changed the global and regional environment and sustaining making influence (Yang et al., 2011). Human activities are key factors affecting vegetation growth, which are manifested as affecting vegetation types and vegetation degradation, etc. (Klein., 2012; Jiang et al., 2017). Therefore, it is of great significance for ecological restoration and water resources management to study the effects of human activities on vegetation water use patterns under natural precipitation gradients in arid inland river basins.

Stable isotopes are natural traces widely distributed in natural water bodies and have been widely used in plant water research (Ehleringer and Dawson., 1992). The stable hydrogen and oxygen isotope characteristics of terrestrial ecosystems can provide clear trace information for hydrological cycles in terrestrial ecosystems (Pan et al.,2020). Generally, there is no stable isotope fractionation in the process of plant water absorption. Thus, xylem water can reflect the isotopic composition of water sources used by most plant species (Wershaw et al., 1966). Previous studies have found that in arid areas, plants mainly absorb shallow soil water supplemented by precipitation or deep groundwater supplemented by groundwater (Zeng et al., 2013), and the water source used by individual plants will change over time (Nie et al., 2012).

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Under water stress conditions, A steady, long-term source of water is essential for plant survival. In addition, the utilization of rainwater by desert plants in arid and semi-arid ecosystems is related to precipitation intensity. In areas with high annual precipitation, growing artemisia ordosica and white thorn, have higher utilization efficiency of shallow soil water, while in areas with low annual precipitation, they mainly utilize deep soil water and groundwater (zhou et al., 2011). In addition, plant water use behaviour can be linked to broader drought resistance strategies (Antunes et al., 2018).

Although many studies have been conducted on plant water use in arid and semi-arid environments, in the face of the strong impact of global change and human activities, it is necessary to further clarify the change of vegetation water utilization in mountainous areas, oases and deserts in arid areas and the impact of human activities on vegetation water use patterns in arid areas. This study (1) determined the water sources of different vegetation in mountainous areas, oases and deserts; (2) analyzed the impact of human activities on vegetation water use patterns in arid areas; (3) discussed the implications of vegetation water use strategies for water resources management in arid areas.

2 Materials and methods

2.1 Study area

Shiyang River Basin (36°29′ - 39°27′ N, 101°41′ - 104°16′E) is located in the arid region of northwest China, which is a typical temperate arid inland basin in China. Shiyang River Basin is a temperate continental arid climate, which is controlled by

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several atmospheric circulations of the westerly belt, eastern monsoon and plateau monsoon (Zhang et al., 2008). The average annual temperature is 8.1℃, and the average annual precipitation ranges from 82 to 692mm, 80% of which is concentrated in summer. Annual evaporation ranges from 2000 to 2600mm (Wan et al., 2019). Shiyang River is a typical inland water system with a total length of 250 kilometres. From south to north, Shiyang River mainly includes Qilian mountain area in the south, oasis area in the middle and a desert area in the north. Studies have found that the water vapour transport track in this region is transported from the desert area in the south to the mountainous area in the north through the oasis area (Zhu et al., 2019). In addition, the annual precipitation in the three regions is 124-698mm, 83-124mm and 54-82mm from south to north, respectively (Ma et al., 2009), so the soil and vegetation have obvious zonal characteristics (Wang et al., 2012). The main vegetation in the mountainous area is Picea crassifolia, willow and ice grass, Vegetation in the oasis area is mainly corn and other farmland vegetation and some shrubs and the main vegetation in the desert area is a white thorn and Haloxylon ammodendron.

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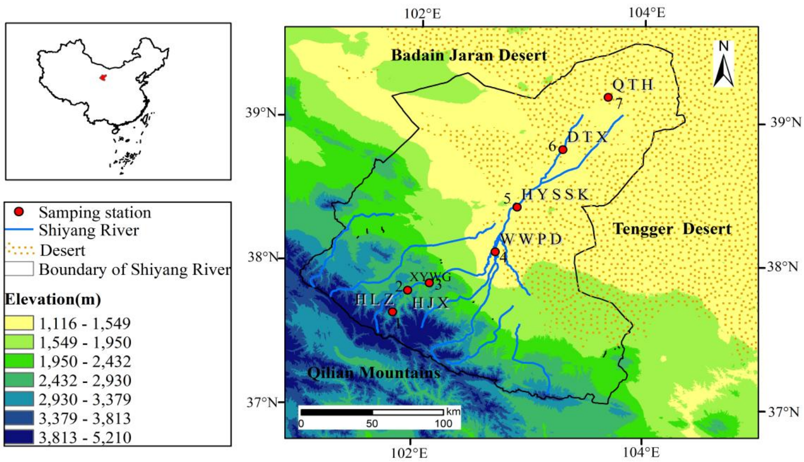

Fig. 1. Overview of the study area.

2.2 Sample collection and measurement

From 2017 to 2019, we collected samples of precipitation, soil, vegetation, and groundwater from seven stations in the Shiyang River Basin during the plant-growing season (April to November). Table 1 shows the summary data of the sample points. The selected sampling points are respectively distributed in the mountainous area, oasis area and desert area of Shiyang River Basin. There are three stations in the mountainous area (Hulinzhan(HLZ),Huajianxiang(HJX),Xiyingwugou(XYWG), three stations in the oasis area (Wuweipendi(WWPD)， Hongyashanshuiku(HYSSK)， Datanxiang(DTX))， and one station in the desert area (Qingtuhu(QTH)). Soil, vegetation and groundwater were sampled once a month. Rainwater samples were collected according to precipitation events by means of a rainwater gauge cylinder installed at the sampling point. Precipitation samples were collected immediately after the precipitation process. For continuous precipitation, we collect precipitation once a day. For plant collection, we selected stems more than 2 years old, took branches

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about 0.35-0.5cm in diameter and 3-5cm in length, quickly stripped the epidermis and phloem of the branches, retained the xylem, and immediately placed them into sampling bottles for sealing. For groundwater collection, we collected groundwater near the sampling point. In the vicinity of the plant sampling site, soil samples were collected every 10cm of the soil using a soil drill, up to 100cm depth if conditions permit. The collected soil samples were divided into two parts. The first part was sealed in 10ml glass bottles with sealing film and stored at -18℃ for subsequent analysis of δD and $\delta^{18}O$ in the soil. The second part was placed in aluminium boxes and dried in the laboratory to determine soil water content.

Table 1. Basic information about sampling points.

Sample station	Longitude	Latitude	Elevation	Mean annual temperature (°C)	Annual precipitation (mm)
Hulinzhan（HLZ）	101°50’	37°41'	2721	3.2	370
Huajianxiang(HJX)	102°00'	37°50'	2323	6.6	363.5
Xiyingwugou(XYWG)	102°11’	37°53'	2097	7.9	262.5
Wuweipendi(WWPD)	102°40'	37°55'	1531	10.2	186.5
Hongyashanshuiku(HYSSK)			1475		113
Datanxiang(DTX)	103°13'	38°47'			113.2
Qingtuhu(QTH)	103°35’	39°05'	1300	7.8	110

2.3 Isotopic composition and analysis of hydrogen and oxygen

All samples were analyzed for δ2H and δ18O at the Stable Isotope Laboratory of Northwest Normal University using a Liquid Water analyzer (DLT-100, Los Gatos Research, USA). Soil water and vegetation water were extracted and analyzed by a vacuum low-distillation device (LI-2100, LICA United Technology Limited, China). The extraction accuracy of the low-temperature and low-pressure distillation device was up to 98%. The measured values of isotopes are denoted by the symbol "δ" and expressed as one-thousandth of the Vienna standard means sea water:

$$\delta = [\frac{R_{sample}}{R_{standard}} - 1] \times 1000\% \quad (1)$$

Where, R_{sample} represents the ratio of $^{18}O/^{16}O$ or $D/^{1}H$ in the precipitation sample, and $R_{standard}$ is the ratio of $^{18}O/^{16}O$ or $D/^{1}H$ in V-SMOW.

2.4 Data analysis

The MixSIAR isotope mixing model based on Bayesian theory was used to identify soil water sources and quantitatively analyze the contribution ratio of different water sources (Stock and Semmens., 2013). Bayesian mixed models have advantages over simple linear mixed models in estimating the probability distribution of source contributions (Zhu et al., 2021). In the MixSIAR model, the input of xylem water and soil water isotope values in each soil layer were all original data, TDF data was set as 0, and isotope fractionation did not occur by default. The operating length of the Markov chain Monte Carlo (MCMC) was set as "extreme", and the error structure was set as Rm. Soil water in different soil layers was considered the potential water source for vegetation in arid areas. The classification of potential water sources was based on the isotopic composition of soil water and soil water content. The shallow layer (0-20 cm) was greatly affected by precipitation, irrigation water and evaporation, and the soil water content and isotopic composition of soil water changed greatly. The changes in soil water content and soil water isotopic composition in the middle layer (20-60 cm) were relatively small. The variation of soil water content in the deep layer (60-100cm) was the least, and the isotopic composition of soil water was stable. The δ18O values of each potential water source were brought into the MixSIAR model to determine the contribution ratio of each potential water source.

3 Results and analysis

3.1 Isotopic values of different water bodies

3.1.1 Precipitation isotope

Precipitation gradually decreased from mountainous to desert areas, with significant differences between δD and $\delta^{18}O$ (Fig. 2). The annual precipitation of the seven sampling sites was ranked as follows: HLZ > HJX > XYWG > WWPD > HYSSK > DTX > QTH (Table 1). Because the Shiyang River Basin is located in the inland region, it is difficult for warm and wet water vapor from the western Pacific Ocean to reach it, and it is affected by secondary evaporation during the precipitation process, which leads to the enrichment of precipitation isotopes in summer. In September, the stable isotope values of precipitation begin to decrease. In the growing season from April to November, the d-excess ranking of the seven sampling sites was in the following order: HLZ (14.8‰) > HJX (12.5‰) > XYWG (12.4‰) > HYSSK (8.8‰) > WWPD (8.7‰) > DTX (7.6‰) > QTH (5.7‰). The reason for these results

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may be the intense evaporation of raindrops as they fall.

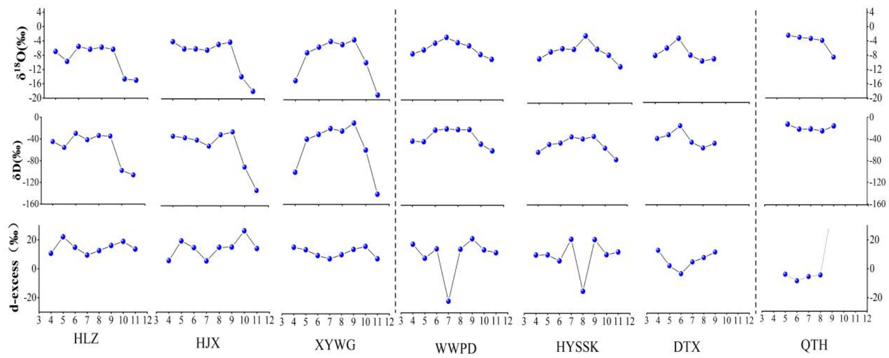

Fig. 2. Variation of δD(‰), δ18O(‰) and d-excess in vegetation growth season (April-November) in mountainous, oasis and desert areas of the arid region. HLZ, HJX, XYWG, WWPD, HYSSK and DTX, respectively, represent the Hulinzhan, Huajianxiang, Xiyingwugou, Wuweipendi, Hongyashanshuiku, Datanxiang and Qingtuhu.

3.1.2 Isotopic composition of soil water, groundwater and xylem water

A linear relationship was established between δD and δ^{18}O in precipitation, soil water, xylem water and groundwater samples at seven stations (Fig. 3). The slope and intercept of LMWL at seven sampling points were all smaller than GMWL, because Shiyang River Basin was located in the arid region of Northwest China, where evaporation was intense. The slope ranking of LMWL of the seven sampling points was QTH < DTX < HLZ < HYSSK < XYWG < WWPD< HLZ, indicating that the evaporation in the desert area of Shiyang River Basin was the strongest, followed by the oasis area, and mountain area was the weakest. The isotopic values of soil water in mountainous areas (HLZ, HJX, XYWG) and oasis areas (WWPD, HYSSK) were consistent with LMWL, indicating that precipitation in these areas may be the potential water source for soil water recharge. However, the soil water isotopes in the oasis area (DTX) and the desert area (QTH) were inconsistent with the LMWL, indicating that the precipitation had less soil water recharge in these two areas.

With the increase of soil depth, the deviation of the soil water isotope from LMWL gradually decreased. There were significant differences in the utilization of soil water in different soil layers by vegetation in different locations with precipitation. The $\delta^{18}O$ values of xylem water from the mountainous area to the oasis area to the desert area（The $\delta^{18}O$ values of xyloxyme water from Qinghai spruce in HLZ, willow in HJX, white poplar in XYWG, corn in WWPD, poplar in HYSSK, corn in DTX and white prickly tree in QTH were -5.02‰, -4.64‰, -5.51‰, -7.60‰, -5.64‰, -5.45‰, -1.59‰, respectively)are similar to the $\delta^{18}O$ values of soil water in the surface layer, and the middle layer, respectively. The $\delta^{18}O$ values of xylem water were the highest in the desert area (QTH) and the lowest in the oasis area (WWPD). These results indicated that vegetation gradually used deep soil water with a decrease in precipitation.

The $\delta^{18}O$ value of soil water decreased with the increase of soil depth in mountainous and oasis areas of arid regions, and the maximum value appeared in the soil surface layer (Fig. 4). In the three regions, the $\delta^{18}O$ of soil water in the mountainous area varied greatly from 0 to 30cm (in the HLZ and XYWG) and from 0 to 40cm (in HJX), with the variation range from -4.62 to -7.05 in the HLZ and XYWG, and from -7.04 to -9.69 in the HJX. Soil $\delta^{18}O$ of the two sampling sites in the oasis area also varied greatly from 0 to 30cm (WWPD) and 0 to 40cm (HYSSK), with

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a variation range of -4.98 to -8.79 in WWPD and -1.80 to -5.88 in HYSSK. In the desert area (QTH), the $\delta^{18}O$ of soil water in the 0-20cm soil layer changed greatly, ranging from -3.07 to -2.39, indicating that the soil layer in other stations except DTX had undergone drastic evaporation.

The $\delta^{18}O$ values of groundwater in the oasis area (WWPD and DTX) were similar to the $\delta^{18}O$ values of soil water in 50cm and 90cm, respectively, indicating that groundwater could replenish soil water in these two locations, while the $\delta^{18}O$ values of soil water in other locations were significantly different from those of groundwater, indicating that groundwater did not replenish soil water in these locations. In addition, the $\delta^{18}O$ values of xylem water at seven sampling sites were close to the $\delta^{18}O$ values of soil water at different depths. the mountain area is 10~20cm (HLZ, XYWG) and 30~40cm (XJX); The oasis area is 10-20cm (WWPD)) and 30-40cm (HYSSK), respectively. The desert area is 40~50cm (QTH); These results indicate that soil water is a potential source of water for vegetation at these sites, and that vegetation gradually uses deep soil water as precipitation decreases. In addition, the $\delta^{18}O$ value of xylem water of maize in the oasis area (DTX) was significantly different from that of soil water, which may be because irrigation water was the main water source for farmland in the oasis area (DTX).

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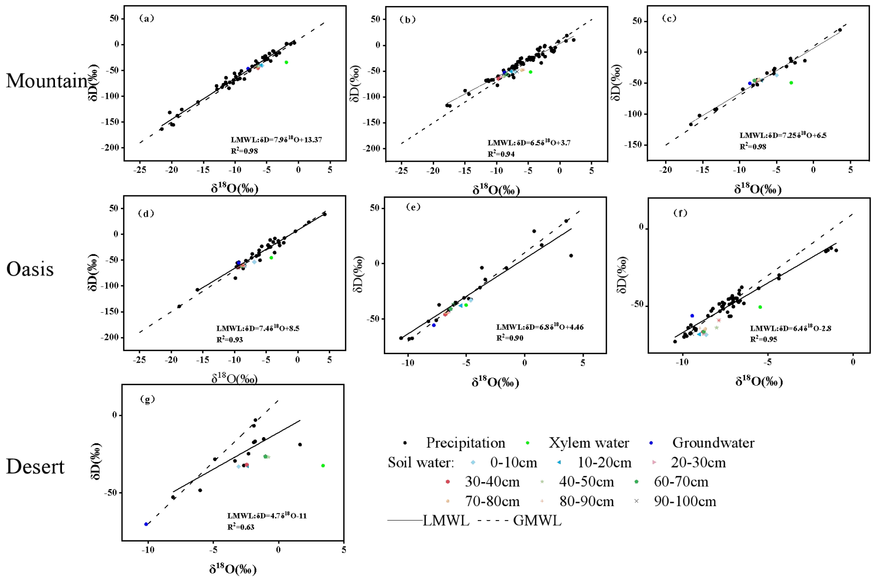

Fig. 3. Stable isotopes (δ18O(‰), δD(‰)) of soil water, plant xylem water and groundwater at different depths in mountainous, oasis and desert areas of arid regions. LMWL represents the local atmospheric water line (solid line), and GMWL represents the global atmospheric water line (δH=8δ18O+10). (a)~(f)respectively represent the Hulinzhan, Huajianxiang, Xiyingwugou, Wuweipendi, Hongyashanshuiku, Datanxiang and Qingt uhu.

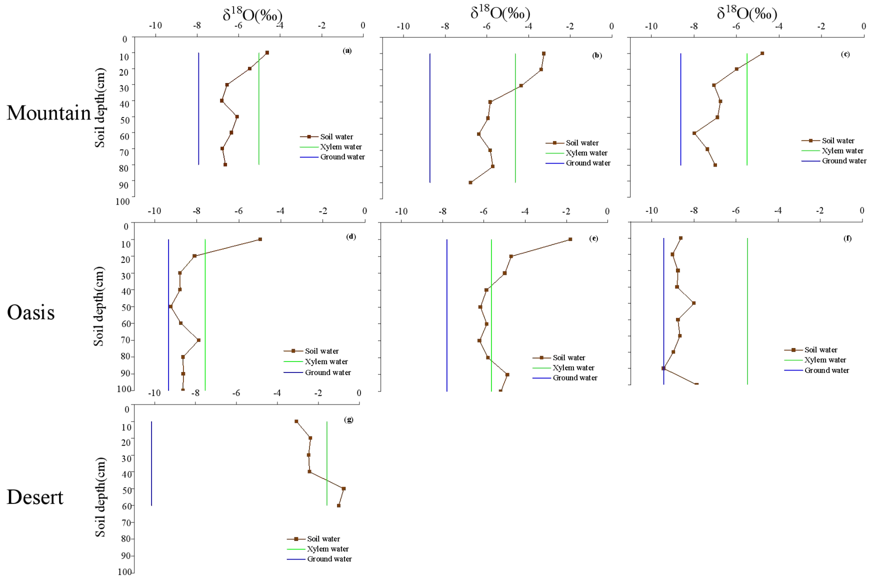

Fig. 4. $\delta^{18}O$ values of xylem water, soil water and groundwater in different soil layers of mountainous, oasis and desert areas in the arid region. (a) ~ (f) respectively represent the Hulinzhan, Huajianxiang, Xiyingwugou, Wuweipendi, Hongyashanshuiku, Datanxiang and Qingtuhu.

3.2 Calculation of vegetation water sources

The relative contributions of potential water sources to vegetation in seven sites of the mountainous area, oasis and deserts were calculated (FIG. 5). In the mountaious area(HLZ, HJX and XYWG), the vegetation utilization rate of precipitation is 23.1%, 12% and 16.8% respectively, while the utilization rate of soil water is 65.5%, 74.5% and 65% respectively. Because precipitation is the main source of soil water in mountainous areas, 85.6% of vegetation water comes directly or indirectly from precipitation.

Vegetation in the oasis area (WWPD, HYSSK and DTX) uses soil water at 65%,

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65.8% and 45.8%, respectively, and groundwater at 18%, 17.7% and 18.1%, respectively. Surface and underground irrigation water are the main sources of water for crops in the oasis area (DTX). The reason for the low utilization rate of soil water by the vegetation in DTX is that the vegetation in this area directly uses river water and groundwater at a ratio of 37.6%. Therefore, irrigation water directly or indirectly contributes 83.4% of the water at this sampling point.

Vegetation in the desert area (QTH) uses soil water at a rate of 46.1%, and directly uses lake water and groundwater at a rate of 37.7%. Around the QTH, vegetation was formed in the affected area of artificial ecological water transport, and the ecological water transport directly or indirectly contributed 83.8% of the water content of the plants.

With the decrease in precipitation, the highest soil water use efficiency of vegetation in seven sites in mountainous, oasis and desert areas of arid region gradually shifted from shallow soil layer to deep soil layer. Vegetation in a mountainous area (HLZ, HJX, XYWG) mainly uses shallow soil water, while vegetation in an oasis area(HYSSK, DTX) and desert area (QTH) mainly uses middle and deep soil water.

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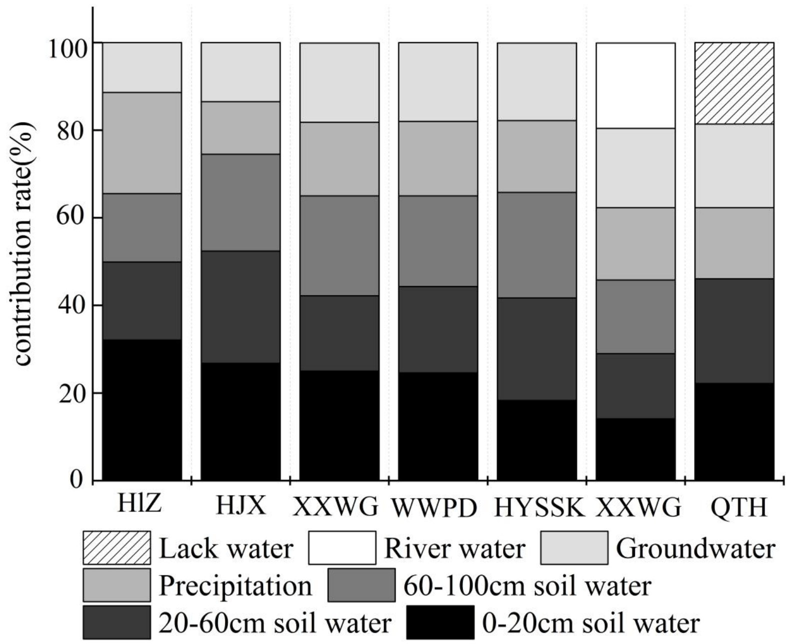

Figure. 5. The relative contribution of different potential water sources (soil water, precipitation, groundwater, river water, lake water) to the vegetation of mountainous, oasis and desert areas in arid region. HLZ, HJX, XYWG, WWPD, HYSSK, and DTX represent the Hulinzhan, Huajianxiang, Xiyingwugou, Wuweipendi, Hongyashanshuiku, Datanxiang and Qingt uhu.

4 Discussion

4.1 Effects of precipitation on plant water use strategies

As one of the main sources of water (Zhao et al., 2018), precipitation is the main factor limiting the growth and development of vegetation in arid and semi-arid areas (Jiang et al., 2017). Moreover, effective precipitation and physiological characteristics of vegetation affect the rate of precipitation utilization by vegetation (Poorter et al., 2019; Sankaran and Staver et al., 2019). Under different precipitation conditions, the

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main water sources of vegetation are different. When precipitation is high, the surface soil water replenished by rain increases, and plants increase their use of shallow soil water (Lin et al., 1996; Williams & Ehleringer., 2000; Duan et al., 2008). However, when precipitation decreases, the soil water content decreases significantly, and shallow soil water cannot meet the needs of vegetation, so deep soil water is sought to sustain life activities, thus improving the utilization efficiency of deep soil water by plants (Groisman et al., 1999). The precipitation isotope values at each sampling point in this study differed due to the influence of precipitation, evaporation source, and topography. The isotope values of precipitation generally indicated a tendency of gradual increase from mountainous areas to oasis areas to desert areas. In the 7 sampling points, precipitation decreases from south to north. Although the study area is located in an arid area, due to the high altitude in the mountainous area, precipitation can reach 124-698mm, while the precipitation in the oasis area is 83-124mm, and the precipitation in the downstream desert area is 54-82mm (Ma et al., 2009), thus forming three precipitation gradients. The results showed that the utilization rate of Qinghai spruce in the mountain forest station was the highest (23.1%), and the utilization rate of vegetation in other sampling sites was lower than that in the forest station and similar, with a ratio of about 16%-17%.

Precipitation is an important factor controlling soil water isotopes (Wang et al., 2017). In arid and semi-arid areas, plants mainly absorb shallow soil water supplemented by precipitation or deep soil water supplemented by groundwater (Dodd et al., 1998; Zeng et al., 2013). Under the conditions of rare precipitation, deep

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underground water depth or unstable soil water, herbage plants and deep-rooted plants can provide water through hydraulic uplift to meet the water demand of the formation (Tang et al., 2018). When the precipitation recharge of soil water cannot meet the water demand, Water absorption shifts from shallow soil to deep soil (Yang et al., 2015), and local water cannot meet the growing demand of vegetation, which will suffer from water stress (Tang et al., 2018). Deeper soil water is generally more deficient in heavy isotopes than shallow soil water collected at the same location (Zhou et al., 2019), partly due to the capillary movement of groundwater containing light isotopes (Rezzoug et al., 2004). In this study, soil water was the main water source for vegetation in the arid area. With the increase of soil depth, the variation range of δ18O value of soil water gradually decreased and tended to be stable. The vegetation utilization rate of soil water in the study area ranged from 45.8 to 74.5%. In the whole arid region, the soil water content of the mountainous area, oasis and desert showed a great difference in space. The soil water content of the three regions was ranked as follows: mountainous area, oasis area and desert area. Soil moisture content in the region with the altitude of the down trend is obvious, mainly because of shiyang river basin upstream of high altitude mountainous area precipitation more, is the recharge area of water resources of the region, and the oasis and desert rely mainly on the mountains of ice and snow melt water supply, but the condition of oasis area is better than in the desert region.

In the three regions, along the precipitation gradient, from the mountain area to the oasis area and then to the desert area, the use of soil water by vegetation gradually

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shifted from the shallow layer to the deep layer. Picea crassifolia in the mountain (HLZ) used 0~20cm of shallow soil water at a ratio of 32.1%, while willow in HJX in the mountain area, poplar in XYWG in the mountain area and corn in WWPD in the oasis area slightly reduced the use rate of shallow soil water compared with the HLZ, which was 26.8%, 25% 24.6%.In the HYSSK in the oasis area, the utilization rate of shallow soil water by poplar trees in this location is lower (18.3%), but the utilization rate of medium and deep soil water is increased, with values of 23.4% and 24.1%, respectively. In DTX of the oasis area, under the conditions of less precipitation and strong evaporation, irrigation water becomes the main water source for local farmland vegetation. Therefore, the utilization rate of soil water by local vegetation is lower than that of other places, and the utilization of deep soil water is slightly higher than that of shallow and middle soil water. In the QTH in the desert area, the utilization ratio of the vegetation in this area to the middle and shallow soil water is relatively average.

4.2 Effects of human activities on plant water use strategies

Human activities have an important impact on plant water use patterns in arid areas, and the impacts mainly occur in the middle and lower reaches. With the further strengthening of human factors on hydrological control, the water use strategies of vegetation around the water body of Shiyang River Basin are also affected. Through the calculation of vegetation water sources at various stations and previous studies on vegetation water use strategies in arid areas, the influence of human activities on vegetation water use patterns in the middle and lower reaches of arid areas is

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discussed.

Reservoirs are a transitional link between terrestrial and aquatic ecosystems, and their hydrological changes are vulnerable to local human activities (Naiman and Décamps et al., 1997; Newman et al., 2006; Tonkin et al., 2018), and the seepage from reservoirs can have an impact on the water use strategies of vegetation around reservoirs. The impact is mainly that the reservoir recharges the surrounding soil water through seepage, which affects the water use strategy of vegetation around the reservoir, and results showed that the construction of reservoirs had an important impact on the water consumption strategy of riparian trees in the arid region, and the influence range of reservoirs on vegetation water absorption pattern was within 2Km. In the study area of Oasis Hongyashan Reservoir, with the increase in distance, vegetation increased the utilization of soil water and decreased the utilization of groundwater.In addition, irrigation has a significant impact on the agricultural water cycle in arid areas with low precipitation and high evaporation, and in areas with extreme water scarcity, agricultural water resources account for 80% of total water resources (Zhu et al., 2021). The sampling site in the oasis area, DTX, has low precipitation, and agricultural irrigation is a key factor in the existence of the oasis. Due to anthropogenic irrigation, agricultural vegetation such as maize in the area is used for irrigation, in addition to precipitation and soil water, and river water and groundwater are used as the main water source for vegetation in the area. The vegetation absorbs soil water supplemented by past irrigation water in addition to the direct use of current irrigation water, and the utilization rate of current irrigation water

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is larger at 37.6%. In some terminal lake areas of arid regions, artificial ecological water transfer is carried out to protect the ecological environment and in these areas, ecological water is an important water source used by plants, and the water use strategy of desert plants adapts when the hydrological environment such as precipitation and groundwater changes (Chen et al., 2017). The ecological water transfer project launched in 2007 has changed the hydrological conditions in the surrounding areas of Qingtu Lake in the desert region, which resulted in the changes in vegetation water use strategies in the catchment area of Qingtu Lake. The study showed that spatially, the water use of white spurge in this area gradually shifted from topsoil water to deep soil water as the distance between the sample site and the lake catchment increased(Jiang et al.,2019). Therefore, we conclude that human activities control the water use pattern of mid- and downstream vegetation in the arid zone to some extent.

4.3 Implications of vegetation water use strategies in different geomorphic units for water resources management

Water resources in arid and semi-arid areas of social and economic development and ecological protection play an important role, and space-time distribution of the heterogeneity of water shortages in arid regions of the northwest means that the fragile ecological system of the region and the interior of the shiyang river basin has a unique water cycle, and water resources have significant characteristics, main show is mountain is forming region, Oases and deserts are dissipation zones (Chen et al., 2016). In order to meet regional water demand, local water resources can be

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supplemented by external water sources, such as inter-regional rivers and long-distance water transmission channels. When regional water resources are greater than the maximum demand, no additional water supply is needed (Wang et al., 2008). The water resources management system based on administrative management should be established to strengthen the management of Shiyang River basin, so as to promote the orderly development, effective distribution and rational utilization of water resources in Shiyang River Basin. The isotopic composition reflects how plants respond to drought and water scarcity: At the ingestion point (root system), differences in isotope ratios between plant species are clearly caused by species-dependent strategies of plants to cope with water stress, through different utilization of suitable water along the soil profile (shallow or deep) (Yakir and Yechieli., 1995). This is mainly due to the differences in soil water absorption depth and the time of stomatal opening in the daily cycle (Gat et al., 2007). The results of MixSIAR model showed that the vegetation of different geomorphic units in Shiyang River Basin had different potential water sources, and the utilization ratio of main water sources was different. In the mountainous area, vegetation has higher utilization of precipitation and surface soil water and less utilization of groundwater, while the mountainous area has abundant water resources and provides a continuous water source for the oasis in the basin, so it is necessary to improve the water connotation function in the mountainous area and strengthen the construction of water connotation forest, in addition, in order to reduce evaporation, mountain reservoirs can be built to abandon the plain reservoirs to reduce the evaporation loss in a large area of the plain.

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In the oasis area, agriculture irrigation consumes a large number of water resources. The main use of irrigation water and farmland vegetation water in deep soil layers, so it can optimize the structure of planting crops, and using advanced water-saving irrigation technology, combined with the crop growing period, reasonable arrangement of irrigation depth and quantity so as to improve the efficiency of management, to meet the appropriate management of water resources, realize the sustainable development of agriculture. In the desert area, precipitation is scarce and evaporation is strong. The decline of groundwater level in this area will speed up the process of ecological degradation and desertification, especially the vegetation growth in the lake catchment area is affected by the ecological water transfer. In order to protect the ecological environment, we can continue to do artificial ecological water transport, rationally plan the spatial distribution of sand-fixing plants, and improve the vegetation structure in order to preserve the ecological environment and promote ecological restoration.

5 Conclusion

In this study, δD and $\delta^{18}O$ stable isotope methods were used to study the water use characteristics of vegetation in mountainous, oasis and desert areas of Shiyang River basin in arid northwest China. Precipitation and soil water are the main sources of forest trees in mountainous areas, and the proportion of irrigation water replenishment for woodland and farmland vegetation in the middle and lower reaches of the oasis region is high. The desert area forms vegetation in the ecological water transport area, and the vegetation mainly absorbs the groundwater, soil water and lake water formed by the ecological water transport. On the whole, plant water use patterns in mountainous areas are basically not affected by human activities, oasis areas are mainly affected by irrigation activities and leakage of water conservancy facilities, and the inland river terminal lake areas are mainly affected by ecological water transport. As precipitation decreased from mountainous areas to desert areas, the utilization of soil water by vegetation at different sampling sites gradually shifted from shallow to deep layers. In addition to the important impact of precipitation on the growth and development of vegetation in arid areas, human activities also determine the vegetation water use patterns in the middle and lower reaches of arid areas through irrigation and artificial ecological water transport. Therefore, basin management should be strengthened in Shiyang River Basin to promote the orderly development, effective distribution and rational utilization of water resources in the basin.

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Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author, stable isotope data are not publicly available due to privacy or ethical restrictions.

Conflict of Interest Statement

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The authors declare no conflicts of interest.

Contributions

Siyu Lu: Writing-Original draft preparation; Guofeng Zhu: Writing-Reviewing and Editing; Rui Li: Data curation; Yinying Jiao: Methodology; Gaojia Meng: Visualization; Dongdong Qiu: Investigation; Yuwei Liu: Supervision; Lei Wang: Software; Xinrui Lin: Software; Yuanxiao Xu: Validation; Qinqing Wang: Software; Longhu Chen: Software.

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