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**Revision notes:**

We would like to thank the editor and reviewers for the valuable and comments, which were very helpful for the further improvement of the manuscript. We have looked through each comment the editor and reviewers raised and responded and incorporate it in the revised manuscript. For your review, we have attached the revised PDF manuscript at the end. The following is the detailed response:

**Reviewer #2:**

hess-2023-96 “Effects of urbanization on the water cycle in the Shiyang River Basin: Based on stable isotope method” Rui Li, Guofeng Zhu, Siyu Lu, Liyuan Sang, Gaojia Meng, Longhu Chen, Yinying Jiao, Qinqin Wang

**1. The organisation of the paper, particularly section and sub-section numbering, is an issue. The title of “Section 2. Systems, Data, and Methods of Observation” implies many things yet we have just 2 paragraphs of site description and Figure 1, which should be “S2.1 Site Description”. The first occurrence of Section 3 (p7 line 139), that should be S2.2, lists the data sample names and an equation for isotope difference, while the second occurrence of Section 3 (p9 line 168), that should be S2.3, lists the actual analyses to be performed on the isotope measurements. There is something to be said for the old-fashioned format of 1-Introduction, 2-Methods and Materials, 3-Results, 4-Discussion and 5-Conclusion.**

**Response:** We have changed the numbering of the chapters based on your comments, here are the details of the changes:

1 Introduction

2 Observation Systems and Data

2.1 Study Area

2.2 Sampling and data analysis

3 Methods

3.1 Calculation and indication of *d-excess*

3.2 Calculation of evaporation losses of surface water

3.3 Periodic regression analysis and the mean residence time (MRT)

## 4 Results

4.1 Spatiotemporal distribution of isotopes in different water bodies

4.2 The Relationship between  $\delta D$  and  $\delta^{18}O$  values

4.3 Impact of urbanization on groundwater

4.4 Temporal and spatial variation of surface water evaporation losses in the urban area of

Wuwei

## 5 Discussion

5.1 Effects of Urbanization on the Rainfall-Runoff Process

5.2 Effects of Water Conservancy Projects in Urban Areas on Isotope Dynamics

5.3 Effects of Urbanization on the Water Cycle of basins

## 6 Conclusions

**2. The way the data is presented it seems that S1 to S10 are sequential and cascading along the same reach which does not appear to be the case. Looking at Table 2, the obvious outlier is S6, which appears to be on a south-eastern tributary of the main channel. If this is not downstream of the urban dams, and therefore may not be affected by their isotopic concentration, its inclusion in the overall sequence is misleading. In fact, looking at all the sites in Figure 1, S1 and S2 are on a different tributary to S3, S4 and S5 in the urban dam area, and different again to S6. This leads to only S7 to S10 being sequential on the same channel reach, with the major reservoir between S9 and S10. What you have are three groups: (1) unimpaired river water (S1, S2, S6), (2) urban dam affected river water (S3, S4, S5), and (3) downstream mixed river water (S7, S8, S9, S10) with S10 also affected by the major reservoir.**

**Response:** We have explained the key issue you mentioned. The detailed explanation is as follows.

Due to our drawing error, Figure 1 is presented in an incorrect form. We have modified Figure 1. The specific modification information is as follows.

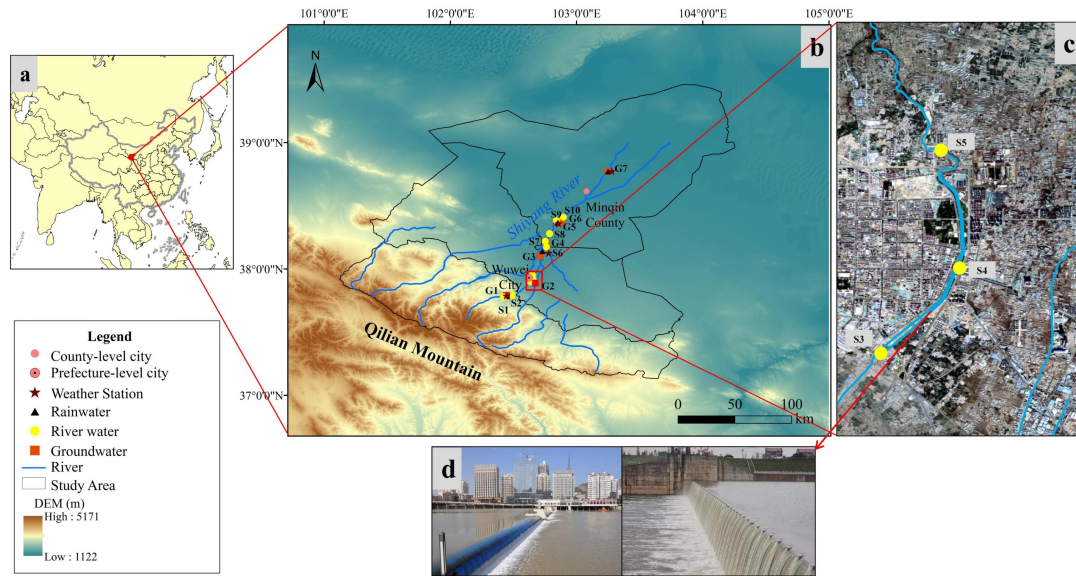


Figure 1 (a) The location of the study area, (b) Comprehensive observation system for the study area, (c) Urban surface water sampling points (from Google Maps), (d) Common urban landscape dams in SYR Basin.

The Shiyang River Basin is an inland river basin in the arid region of Central Asia. It is mainly composed of eight rivers from east to west, including the Dajing River, Gulang River, Huangyang River, Zamu River, Jinta River, and Xiying River. In addition to the Dajing River, six rivers in the central part merge into the Shiyang River near Wuwei, flow into the Hongyashan Reservoir, and then enter the Minqin Basin.

We chose the Xiying River Basin located in its upper reaches as the upstream runoff area. Since the Xiying River Basin is one of the areas with the richest rainfall in the Shiyang River Basin, and there are glaciers at its source, the Xiying River Basin has become a typical runoff-producing area in the Shiyang River Basin, so two sampling points S1 and S1 were set up. . The three sampling points S2, S3, S4 and S5 are located in the urban landscape dam area and are most obviously affected by urbanization. The value is mainly affected by the tributaries, resulting in a more depleted S6 isotope value. Moreover, S6 is far away from the urban area and is basically not affected by the river water in the upstream city. S7, S8, S9, and S10 are all located in the downstream mainstream, while s10 is located in the Hongyashan Reservoir, which also results in a longer residence time. Therefore, S10 also represents the isotope composition characteristics of the reservoir water. After S10, the Shiyang River is mainly transported downstream in the form of main water pipes.

At the watershed scale, S1-S10 are located on continuous rivers whose connectivity is changed by reservoirs, dams and other water facilities, which is a result of urbanization and is one of the main causes of changes in the water cycle of the watershed and is our main study content.

Referencece:

Sang, L., Zhu, G., Qiu, D., Zhang, Z., Liu, Y., Zhao, K., Wang, L., and Sun, Z.: Spatial variability of runoff recharge sources and influence mechanisms in an arid mountain flow-producing zone, *Hydrological Processes*, 36, <https://doi.org/10.1002/hyp.14642>, 2022.

Sang, L., Zhu, G., Xu, Y., Sun, Z., Zhang, Z., and Tong, H.: Effects of Agricultural Large-And Medium-Sized Reservoirs on Hydrologic Processes in the Arid Shiyang River Basin, Northwest China, *Water Resources Research*, 59, e2022WR033519, <https://doi.org/10.1029/2022WR033519>, 2023.

Zhang, G., Su, X., Ayantobo, O. O., Feng, K., and Guo, J.: Remote-sensing precipitation and temperature evaluation using soil and water assessment tool with multiobjective calibration in the Shiyang River Basin, Northwest China, *Journal of Hydrology*, 590, 125416, <https://doi.org/10.1016/j.jhydrol.2020.125416>, 2020.

Zhu, G., Sang, L., Zhang, Z., Sun, Z., Ma, H., Liu, Y., Zhao, K., Wang, L., and Guo, H.: Impact of landscape dams on river water cycle in urban and peri-urban areas in the Shiyang River Basin: Evidence obtained from hydrogen and oxygen isotopes, *Journal of Hydrology*, 602, 126779, <https://doi.org/10.1016/j.jhydrol.2021.126779>, 2021.

**3. Figure 3 has three panels that are made up of three smaller graphs, and all panels need to be labelled to fit with the caption. The two panels in Figure 6 need the same vertical scale, so that the data are visually different.**

**Response:** Due to our negligence that caused this error, based on your suggestion, we have modified Figures 3 and 6 to make them easier for the reader to understand, and the following is the specific change information.

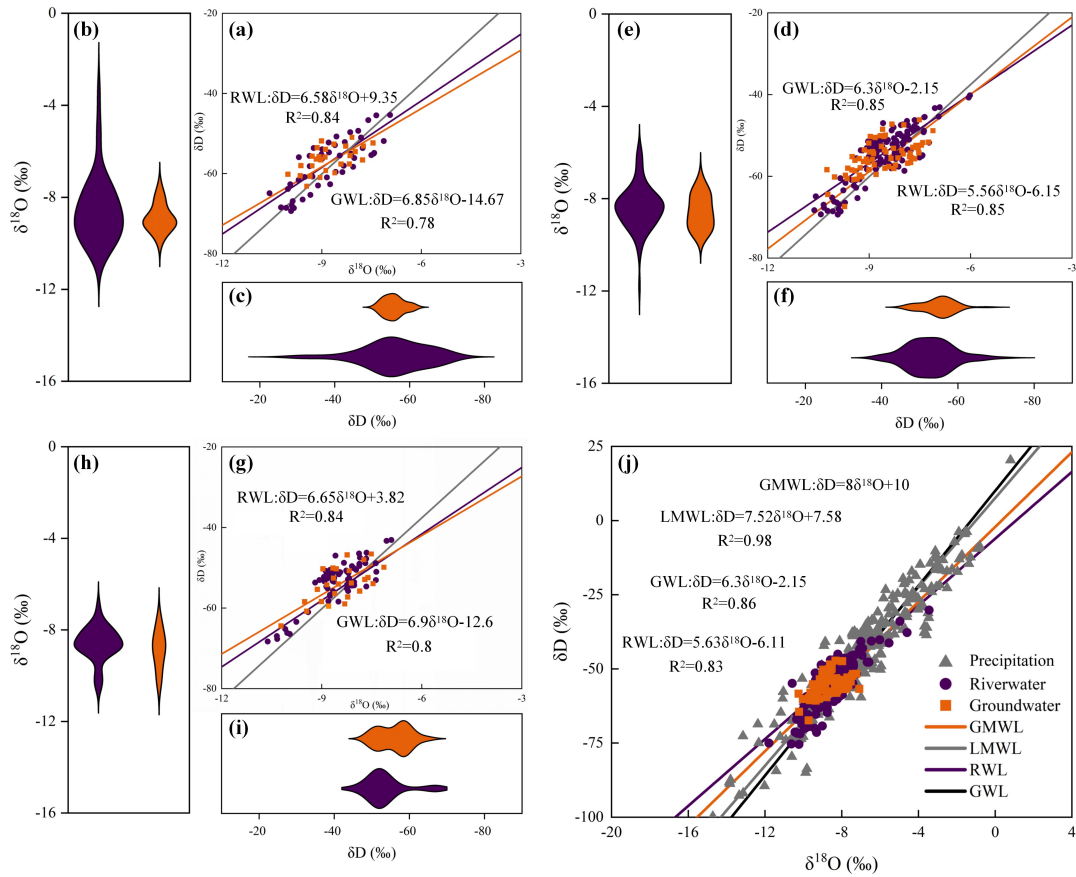


Figure 3 Relationship between  $\delta D$  and  $\delta^{18}O$  in various water bodies in the SYR Basin during different seasons (a,d,g represent spring, summer, autumn; j represent the comparison of RWL, GWL, LMWL and GMWL during the entire sampling period;b-c, e-f, h-i represent the distribution of  $\delta D$  and  $\delta^{18}O$  in river water and groundwater in spring, summer and autumn).

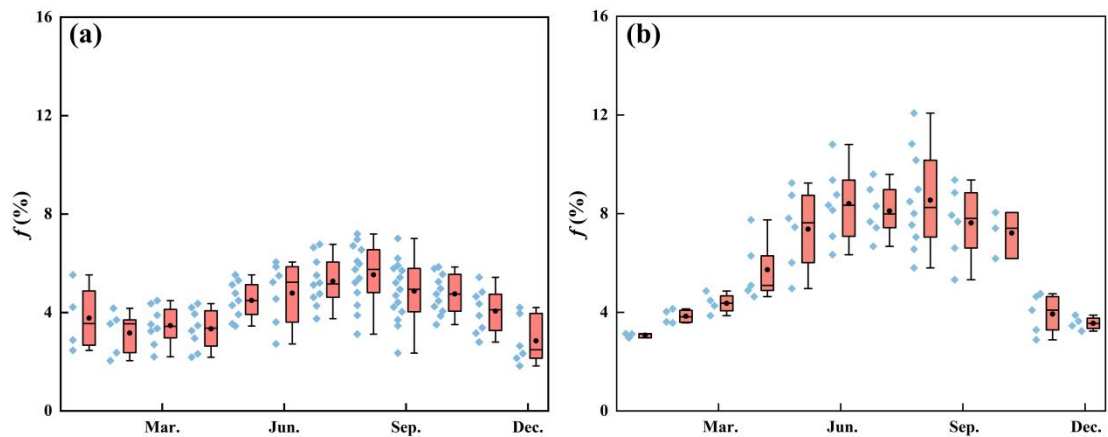


Figure 6 Evaporation losses from surface water in different areas of the SYR (a) Upper reaches mountainous area, (b) Middle reaches urban areas.

4. The caption for Figure 8 needs to be worded in a more standard way:

**“Correlation between MRT and (a) mean slope of the basin, (b) catchment area, (c) sand clay loam ratio, and (d) percentage area of residential and industrial use in the basin, with 95% Confidence and Prediction bands.”**

**Response:** In response to your suggestion, we have modified the title of Figure 8 as follows:

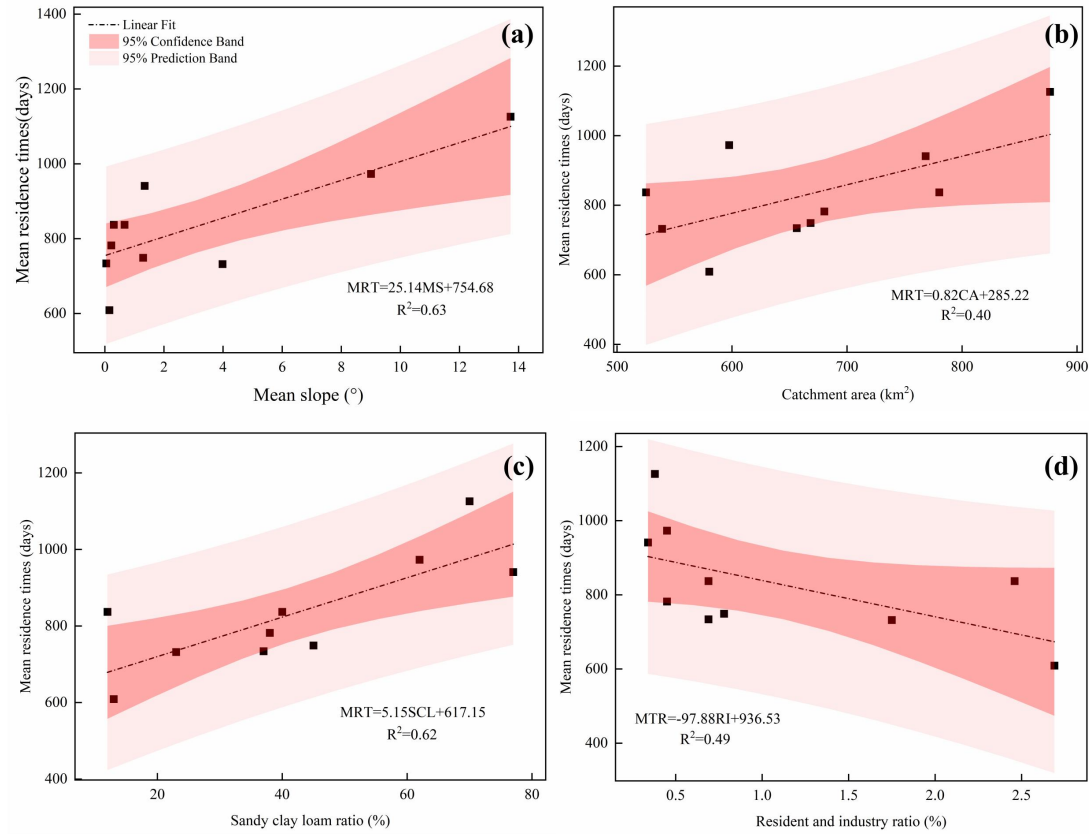


Figure 8 Correlation between MRT and (a) mean slope of the basin, (b) catchment area, (c) sand clay loam ratio, and (d) percentage area of residential and industrial use in the basin, with 95% Confidence and Prediction bands.

**5. Figure 10 does not add to the text provided, and can be omitted.**

**Response:** Based on your suggestion, we have removed Figure 10, thank you for your help.

# 1 **Effects of Urbanization on the water cycle in the Shiyang River**

## 2 **Basin: Based on stable isotope method**

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11 **Abstract:** In water-scarce arid areas, the water cycle is affected by urban  
12 development and natural surface changes, and urbanization has a profound impact on  
13 the hydrological system of the basin. Through an ecohydrological observation system  
14 established in the Shiyang River basin in the inland arid zone, we studied the impact of  
15 urbanization on the water cycle of the basin using isotope methods. The results  
16 showed that urbanization significantly changed the water cycle process in the basin,  
17 and accelerated the rainfall-runoff process due to the increase of urban land area, and  
18 the mean residence time (MRT) of river water showed a fluctuating downward trend  
19 from upstream to downstream, and was shortest in the urban area in the middle  
20 reaches, and the MRT was mainly controlled by the landscape characteristics of the  
21 basin. In addition, our study showed that river water and groundwater isotope data  
22 were progressively enriched from upstream to downstream due to the construction of  
23 metropolitan landscape dams, which exacerbated evaporative losses of river water, and

24 also strengthened the hydraulic connection between groundwater and river water  
25 around the city. Our findings have important implications for local water resource  
26 management and urban planning and provide important insights into the hydrologic  
27 dynamics of urban areas.

28 **Keywords:** Urbanization; Water cycle; Stable isotopes; River Connectivity

## 29 **1 Introduction**

30 According to the "2020 Global Cities Report," urban areas are currently home to  
31 more than half of the worldwide people, which amounts to 56.2%. This pattern is  
32 expected to continue over the course of the next decade, culminating in an  
33 urbanization rate of 60.4% by the year 2030. In addition, the study forecasts that by  
34 the year 2050, approximately seventy percent of the world's population would reside  
35 in urban areas (Chen et al., 2020; UN, 2019; UN-Habitat, 2020). Unlike other regions,  
36 urban regions have a substantial influence on the hydrological system, resulting in  
37 significant consequences on water balance and the water cycle (Gillefalk et al., 2021).  
38 To meet the diverse household and industrial requirements in metropolitan areas,  
39 where the population is concentrated and water demands are high, a complex  
40 interplay between natural and manmade components of the water cycle is required.  
41 These components include both natural features such as streams and groundwater, as  
42 well as human-made systems like drinking water and drainage networks (Gessner et  
43 al., 2014). Urbanization exacerbates water depletion and has far-reaching impacts on  
44 groundwater (Flörke et al., 2018; McDonough et al., 2020), affecting the environment  
45 and water availability (Bhaskar and Welty, 2015). Rapid urbanization will seriously



46 pressure the structure, function and water quality degradation of basin ecosystems  
47 (Grimm et al., 2008; Sun and Lockaby, 2012; Sun et al., 2015).

48 Urbanization's effects on basin hydrology and the related processes have  
49 complex and varying consequences (Caldwell et al., 2012; Martin et al., 2017). In the  
50 past few decades, with the continuous acceleration of urbanization, human activities  
51 in urban areas have become more frequent, and the hydrological effects of  
52 urbanization have become more intense, attracting widespread attention worldwide  
53 (Salvadore et al., 2015). The rise of impervious surfaces in urbanized regions  
54 increases the rate of urban water runoff, which raises the danger of urban floods  
55 (Wing et al., 2018). In addition, high-intensity human activities have led to increased  
56 discharge of domestic sewage and industrial wastewater, deteriorating water quality  
57 and ecological environment (Pickett et al., 2011). Meanwhile, basin water cycle  
58 processes are influenced by a combination of meteorological and subsurface factors. It  
59 has been found that urbanization has led to significant increases in runoff and peak  
60 flows in rivers (Liu et al., 2018; Han et al., 2022) and has resulted in shorter runoff  
61 response times (Anderson et al., 2022), which also exacerbates the intensity and  
62 frequency of flooding in basins (De Niel and Willems, 2019; Blum et al., 2020). On  
63 the other hand, the urbanization process leads to an increase in the amount of rainfall  
64 in the basin as well as an increase in the frequency of extreme rainfall events (Shastri  
65 et al., 2015; Fu et al., 2019; Yang et al., 2021), whereas in dryland inland river basins  
66 in arid zones that are dependent on water resources for development, the impacts of  
67 urbanization on the water cycle processes of the basins are still not clear, and they

68 need to be explored in depth the effects of urbanization on basin water cycle processes.  
69 Hence, study into how human activities alter the features of river runoff and the water  
70 cycle within a basin is essential for the prudent use and sustainable development of  
71 water resources.

72 Isotopes that are stable of hydrogen and oxygen are very useful tools for  
73 investigating hydrological issues that are connected to surface water and groundwater  
74 sources (Fekete et al., 2006; Förstel and Hützen, 1983; Vystavna et al., 2021).  
75 Researchers have been conducting studies using stable isotopes as tracers over the  
76 course of the past few years in order to explore the impact that urbanization has had  
77 on the water cycle. Urbanization has the potential to trigger and intensify convective  
78 activity and warm-season rainfall in both urban areas and their surrounding regions  
79 (Burian and Shepherd, 2005). Researchers generally agree that urbanization reduces  
80 depressions on the underlying surface, weakens water permeability and increases  
81 runoff. At the same time, the lower roughness of the underlying surface shortens the  
82 confluence time (Guan et al., 2015; Oudin et al., 2018). Moreover, against the  
83 backdrop of swift urbanization, the swift proliferation of urban regions has resulted in  
84 a sharp surge in impermeable areas, alterations to regional microclimates, and the  
85 erection of a vast number of infrastructures (including overpasses, subways, and so  
86 on), all of which have significantly impacted the water cycle process in urban areas  
87 (Jacobson, 2011; Westra et al., 2014). The complex connection between the permeable  
88 and impermeable zones influences the surface confluence processes (Bruwier et al.,  
89 2020). The construction of urban water conservation projects, such as rubber dams

90 and pumping stations, also affects the confluence process of urban areas to a certain  
91 extent (Zhu et al., 2021). Limited long-term and continuous monitoring has hampered  
92 accurate depiction of urbanization's spatiotemporal effects on basin hydrology.  
93 Furthermore, the scientific research till lacks sufficient research on arid regions that  
94 heavily depend on mountain river runoff for sustenance and development.

95       Against the background of increasing urbanization, it is particularly important to  
96 study the hydrological impacts of urbanization on basins and their corresponding  
97 countermeasures, especially in arid inland river basins, where the impacts of human  
98 activities in urban areas on rivers may be more prominent. Therefore, the Shiyang  
99 River Basin (SYR), located in the inland arid zone of Northwest China, was used as  
100 an example to study the impact of urbanization on the hydrology of the basin using  
101 the stable isotope method. The following problems are proposed to be solved: (1) An  
102 examination of the mechanisms underlying evaporation and infiltration of surface  
103 water within urban aquatic ecosystems; (2) Assessing the effects of urbanization on  
104 water body connectivity through a comprehensive analysis; (3) The influence of  
105 urbanization on the precipitation-runoff process is analyzed. This provides us with  
106 essential information on how to maintain and manage the water resources found in  
107 inland river basins, which is especially useful in light of the fact that the rate of  
108 urbanization is growing.

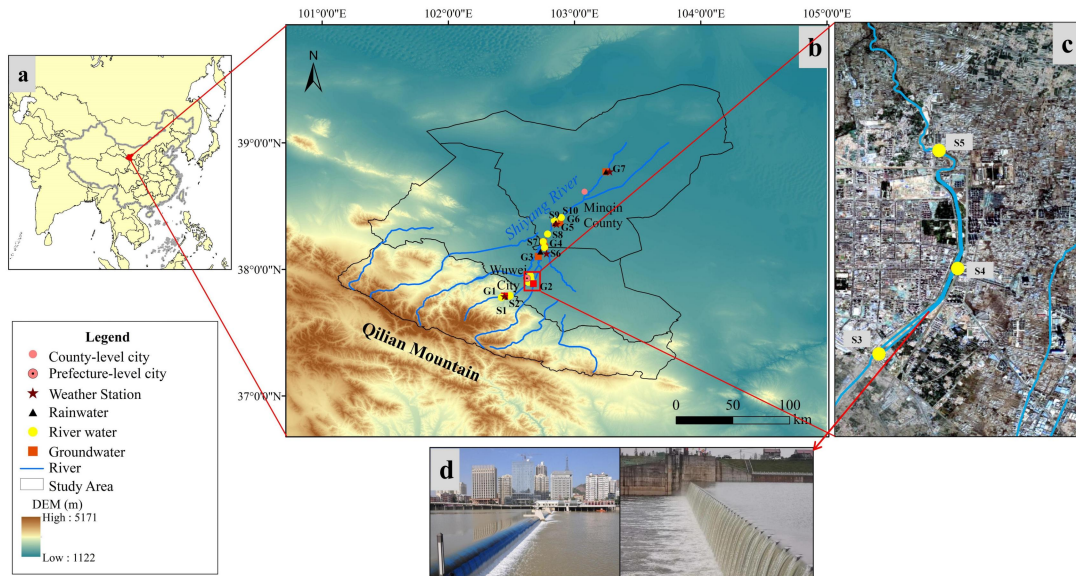
## 109 **2 Observation Systems and Data**

### 110 **2.1 Study Area**

111 The SYR Basin is located in Gansu Province, China, to the east of the He-xi  
112 Corridor. Its coordinates are 101°22' ~ 104°16' E and 36°29' ~ 39°27' N. The SYR  
113 Basin is bounded to the west by the Wushaoling Mountain and to the north by the  
114 foothills of the Qilian Mountain (Zhu et al., 2019). The basin in question is situated  
115 within the continental temperate belt, characterized by a parched climate and diverse  
116 topography. Annual precipitation hovers within the range of 100 to 600 mm, while  
117 pan evaporation levels exhibit greater variability, ranging from 700 to 2600 mm  
118 annually. The majesty of the Qilian Mountains is where the SYR begins its journey,  
119 and the Qilian Mountains are the source of its eight main tributaries. The SYR is  
120 principally supported by the convergence of precipitation, snowmelt, and glacier  
121 runoff (Wei et al., 2013).

122 The Wuwei City is crossed by four important rivers, namely the Xiyang, Zamu,  
123 Huangyang and Jinta, which cover a catchment area of 3986 km<sup>2</sup>. As the principal  
124 water source for the entire region, the SYR Basin is one of the most highly utilized  
125 inland river basins in terms of water resource development and consumption  
126 worldwide. The dams in the SYR basin are predominantly situated in close proximity  
127 to the urbanized regions of Liangzhou District, located within Wuwei City. Liangzhou  
128 District, situated in the middle of the basin, boasts of a relatively high population  
129 density and a notable commercial concentration. At the turn of the millennium,  
130 Wuwei City only boasted a paltry five landscape dams positioned on its rivers. As of  
131 2019, this figure has surged dramatically, with a staggering total of 51 urban  
132 landscape dams now gracing both urban and peri-urban areas of the city. These dams

133 are primarily composed of man-made landscape waterfalls and rubber dams, fulfilling  
134 their core function of creating public landscape water bodies within the urban expanse.  
135 (Zhu et al ., 2021).



136  
137 **Figure 1 (a) The location of the study area, (b) Comprehensive observation system for the study**  
138 **area, (c) Urban surface water sampling points (from Google Maps), (d) Common urban landscape**  
139 **dams in SYR Basin.**

## 140 2.2 Sampling and data analysis

141 Since 2017, a comprehensive observation system has been established in the  
142 SYR Basin, and stable isotope observations and hydrometeorological observations  
143 have been carried out on surface water, shallow groundwater and rainfall. Continuous  
144 sampling in the SYR Basin was carried out from April 2017 to March 2021, different  
145 water bodies were sampled, and we collected a total of 943 samples from 24 sampling  
146 points (Table 1). The river sampling location ought to be selected such that it is  
147 physically possible to go as close to the middle of the river as possible, with the goal  
148 of minimizing the impact of areas with standing water and sewage. Artesian well

149 water was collected as groundwater samples at 7 sampling locations around the basin.  
 150 The automated weather station was used to measure meteorological factors such as  
 151 temperature and relative humidity while collecting precipitation samples. Water  
 152 samples were sealed in high-density polyethylene bottles to avoid evaporation and  
 153 leakage during transit and storage, precipitation samples were collected using weather  
 154 station standard rain gauges. These samples were then frozen and wrapped with  
 155 plastic tape.

156 Table 1 Basic information on precipitation, surface water and groundwater sampling sites

<b>Parameter</b>	<b>Sampling Point</b>	<b>Number</b>	<b>Sampling period</b>	<b>Collection Channels</b>
Precipitation	P1, P2, P3, P4, P5,P6, P7,	387	Precipitation events	Rain tube collection
Surface Water	S1,S2,S3,S4,S5,S6, S7, S8, S9, S10	270	Monthly	Sampling in river water
Groundwater	G1, G2, G3, G4, G5, G6, G7	189	Monthly	Sampling from wells

157 Analysis of the water samples is conducted through liquid water isotope  
 158 analysis utilizing the DLT-100 (Los Gatos Research) in the Stable Isotope Laboratory  
 159 at Northwest Normal University. Each water sample and isotope standard are injected  
 160 six times in succession to assure reliable findings, with the first two injection values  
 161 eliminated and the average of the last four injections used for final analysis, thereby  
 162 avoiding any potential isotope analysis memory effect. The isotope measurements  
 163 were denoted by the symbol " $\delta$ ," which indicates the deviation in thousandths from  
 164 the Vienna Standard Mean Ocean Water:

165 
$$\delta_{\text{sample}}(\text{‰}) = \left[ \left( \frac{R_s}{R_{v\text{-}smow}} \right) - 1 \right] \times 1000 \quad (1)$$

166 where  $R_s$  is the ratio of  $^{18}\text{O}/^{16}\text{O}$  or  $^2\text{H}/^1\text{H}$  in the collected sample,  $R_{v\text{-}smow}$  is the  
167 ratio of  $^{18}\text{O}/^{16}\text{O}$  or  $^2\text{H}/^1\text{H}$  of the Vienna standard sample, and the analytical accuracy  
168 of  $\delta\text{D}$  and  $\delta^{18}\text{O}$  is  $\pm 0.6\text{‰}$  and  $\pm 0.2\text{‰}$ , respectively.

### 169 **3 Methods**

#### 170 **3.1 Calculation and indication of *d-excess***

171 Dansgaard (1964) introduced the concept of deuterium excess (*d-excess*) as the  
172 difference in isotopic composition between global precipitation and the Vienna  
173 Standard Mean Ocean Water ( $V_{SMOW}$ ) reference water, which corresponds to a value of  
174 10‰. This parameter reflects the average isotopic composition of air masses  
175 associated with precipitation and is widely used to identify atmospheric source  
176 regions (Deng et al., 2016). *d-excess* was proposed by Dansgaard (Dansgaard, 1964)  
177 and is defined as:

178 
$$d\text{-excess} = \delta\text{D} - 8\delta^{18}\text{O} \quad (2)$$

#### 179 **3.2 Calculation of evaporation losses of surface water**

180 The losses of surface water through evaporation and the resulting fluctuations in  
181 water levels of rivers, lakes, and wetlands are key aspects of the terrestrial water cycle  
182 that merit significant attention (Gammons et al., 2006; Hamilton et al., 2005).  
183 Evaporation is the primary mechanism of water losses in the water cycle. For river  
184 water in dry regions and urban river water that flows slowly due to manmade  
185 constraints, evaporation cannot be ignored. Thus, it is vital to address the alteration of  
186 urban landscape dam water caused by non-equilibrium isotope fractionation during

187 evaporation. The provided formula (3) can be used to estimate the rate of evaporative  
188 water losses from the body of water in question (Skrzypek et al., 2015):

$$f = 1 - \left[ \frac{(\delta - \delta^*)}{(\delta_0 - \delta^*)} \right]^{\frac{1}{m}} \quad (3)$$

189  
190 The variables in the equation are as follows:  $f$  represents the ratio of water lost to  
191 evaporation,  $\delta$  denotes the measured values of the water body located in the urban  
192 dam area of Wuwei City, situated in the middle reaches of the SYR and  $\delta_0$  represents  
193 the initial value of the hydrogen and oxygen stable isotope of the water body. It is  
194 widely assumed that the point of intersection between the local meteoric water line  
195 (LMWL) and the local evaporation line (LEL) represents the average isotopic  
196 composition of the input water body within the basin (Gibson et al., 2005). In the  
197 current investigation, the intersection point marked by  $\delta^{18}\text{O} = -7.24\text{‰}$  and  $\delta\text{D} =$   
198  $-46.9\text{‰}$  has been designated as the  $\delta_0$  value, while  $\delta^*$  denotes the maximum isotope  
199 enrichment factor and  $m$  corresponds to the enrichment slope. The calculation of the  
200 above parameters in this paper is realized in Hydrocalculator software (Skrzypek et al.,  
201 2015) (<http://hydrocalculator.gskrzypek.com>). According to studies (Qian et al., 2007),  
202 it is more accurate to use  $\delta^{18}\text{O}$  when calculating the evaporation losses ratio, so this  
203 study calculates the  $f$  value of SYR water using  $\delta^{18}\text{O}$  value.

### 204 **3.3 Periodic regression analysis and the mean residence time (MRT)**

205 Seasonal fluctuations in  $\delta^{18}\text{O}$  values were analyzed using periodic regression  
206 analysis to determine how these values changed over time. This method entailed  
207 fitting seasonal sine wave curves to annual  $\delta^{18}\text{O}$  variations using least squares



208 optimization (Rodgers et al.,2005):

$$209 \quad \delta^{18}O = \delta^{18}O_{ave} + A \cdot [\cos(c \cdot t - \theta)] \quad (4)$$

210 The modelled  $\delta^{18}O$  values and the mean weighted annual measured  $\delta^{18}O_{ave}$   
211 values were both utilized in the analysis of seasonal fluctuations in  $\delta^{18}O$  levels.  
212 Additionally, the measured  $\delta^{18}O$  annual amplitude ( $A$ ), the radial frequency of annual  
213 fluctuations ( $c$ ), and the time in days after the start of the sampling period ( $t$ ) were  
214 also considered in this analysis. Furthermore, the phase lag or time of the annual peak  
215  $\delta^{18}O$  in radians ( $\theta$ ) was determined through this approach.

216 An exponential model was used for the purpose of estimating the mean residence  
217 time (MRT). This model operates on the presumption that precipitation inputs quickly  
218 mix with resident water. In order to do this, the following equation was used  
219 (Maloszewski et al., 1983; Rodgers et al., 2005):

$$220 \quad MRT = c^{-1} \cdot [(A_{Z2} / A_{Z1})^{-2} - 1]^{0.5} \quad (5)$$

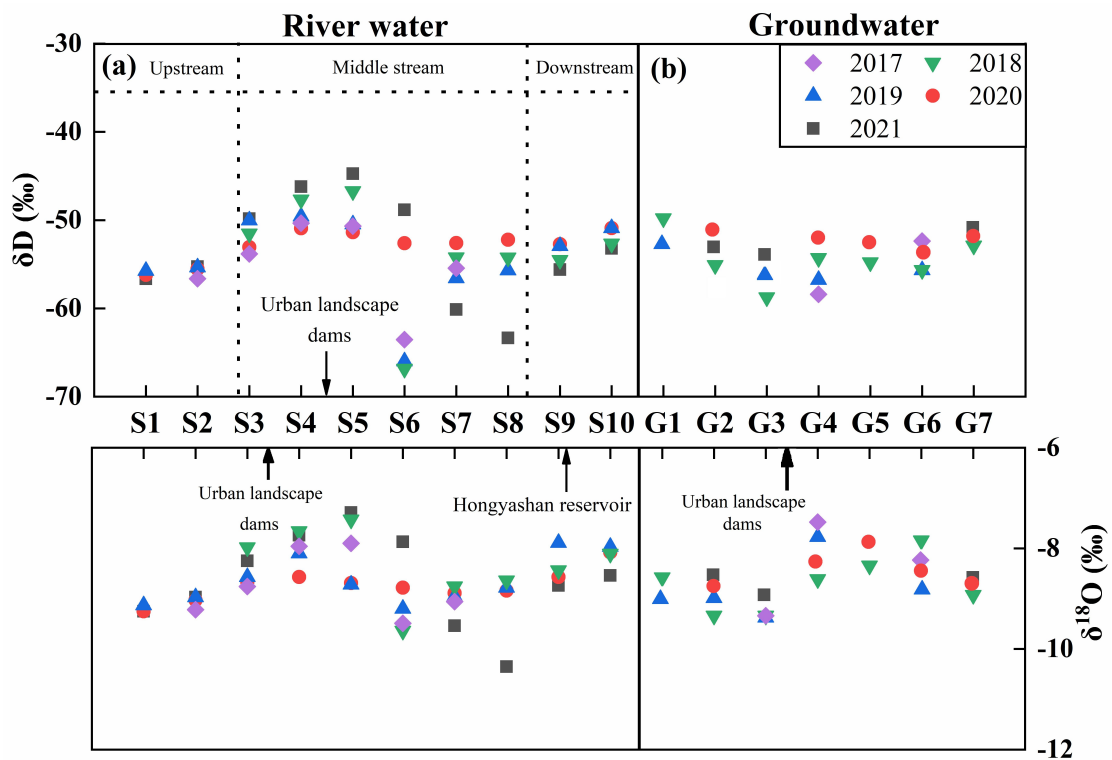
221 The amplitude of precipitation ( $A_{Z1}$ ), the amplitude of the surface water outputs  
222 ( $A_{Z2}$ ), and the radial frequency of the annual fluctuation ( $c$ ) as defined in Eq. (4) were  
223 taken into consideration to estimate the mean residence time (MRT).

## 224 **4 Results**

### 225 **4.1 Spatiotemporal distribution of isotopes in different water bodies**

226 The isotopes values of the surface water in the SYR Basin show a clear  
227 enrichment from upstream to downstream when viewed from space. It is worth noting  
228 that landscape dams and reservoirs in urban areas alter this pattern significantly,  
229 producing markedly higher isotopic compositions of surface water around such  
230 structures (Fig. 2). To be more specific, the surface water throughout the entire basin

231 had average isotope values that were lower than those of the sampling points in the  
 232 dams region, which had values that were greater (Table 2). In addition, the dams  
 233 slowed the flow of the river, this resulted in isotope enrichment of the river water.  
 234 Notably, these values exhibit spatial and temporal variability, with the largest  $\delta D$  and  
 235  $\delta^{18}O$  values observed in river water, and the lowest in groundwater.



236  
 237 Figure 2 Longitudinal variation of  $\delta D$  and  $\delta^{18}O$  in river water and groundwater in the SYR Basin.

238 To be more specific, over the course of time, these values shift seasonally from  
 239 spring to autumn (Table 2, Fig. 3). There was a range of values from -75.43‰ to  
 240 -40.62‰ for the  $\delta D$  values of surface water, with an average of -53.53‰. The  $\delta^{18}O$   
 241 values display a varied range, from -10.43‰ to -5.53‰, with an average of -8.54‰,  
 242 whereas the *d-excess* values demonstrate variability ranging from 10.26‰ to 29.72‰,  
 243 with 15.28‰ as the average value. A broad spectrum of  $\delta D$  values are observed  
 244 during the summer season, ranging from -61.27‰ to -31.16‰, with an average

245 -48.90‰. Meanwhile,  $\delta^{18}\text{O}$  values fluctuate between -9.52‰ and -3.41‰, with an  
 246 average -8.12‰. The phenomenon that was observed can be traced back primarily to  
 247 the aftereffects of the Hongyashan Reservoir built downstream. Because the reservoir  
 248 has such a large capacity for water retention, it causes significant amounts of river  
 249 water to evaporate in summer, which ultimately results in a discernible enrichment of  
 250 the isotopic composition. In both surface water and groundwater,  $\delta\text{D}$  and  $\delta^{18}\text{O}$  showed  
 251 significant seasonal variations (Fig. 3). Seasonal variations were more pronounced in  
 252 surface water than in groundwater, with surface water showing the largest amplitude  
 253 in spring and the smallest amplitude in fall, while groundwater showed closer  
 254 amplitudes in all seasons, which also indicates that groundwater is less disturbed.

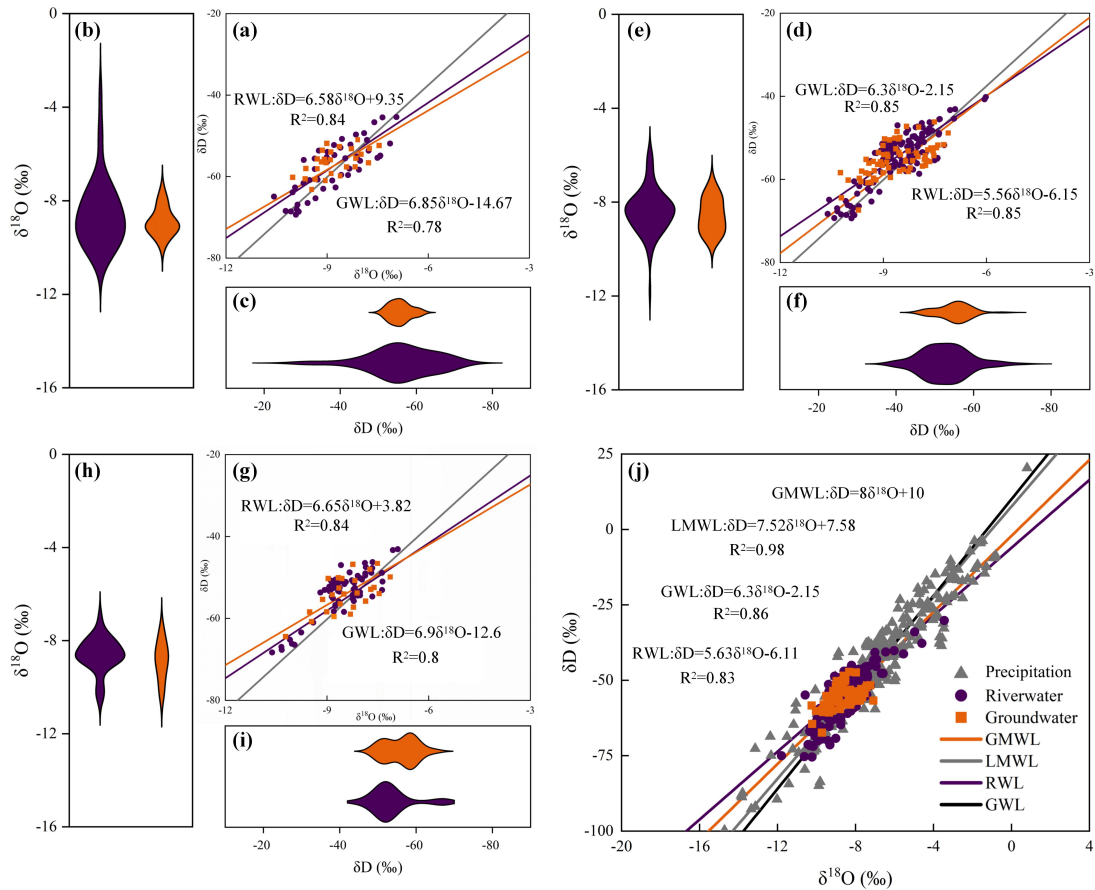
255 Table 2 Isotopic composition statistics of surface water in SYR Basin

Sampling Point	$\delta^{18}\text{O}$			$\delta\text{D}$			<i>d-excess</i>		
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
S1	-9.35	-9.86	-9.06	-57.16	-59.46	-52.47	17.2	12.33	23.91
S2	-9.22	-10.02	-8.78	-56.62	-63.85	-10.02	16.46	15.53	19.28
S3	-7.74	-9.03	-7.75	-49.84	-50.76	-46.66	15.42	13.59	19.48
S4	-7.29	-8.79	-7.65	-46.22	-53.29	-46.26	14.9	11.01	18.03
S5	-7.43	-9.11	-5.53	-48.84	-56.66	-40.62	14.29	14.21	29.72
S6	-9.54	-10.43	-8.29	-60.14	-75.43	-54.40	14.31	10.26	17.62
S7	-9.04	-9.54	-8.21	-54.23	-70.04	-48.03	16.54	12.81	21.16
S8	-9.15	-10.35	-8.64	-56.37	-63.35	-52.22	16.84	14.56	19.54
S9	-8.41	-9.70	-6.02	-53.95	-65.33	-45.54	13.33	12.31	19.50
S10	-8.18	-8.84	-6.58	-51.92	-58.05	-45.39	13.48	12.21	21.72

#### 257 4.2 The Relationship between $\delta\text{D}$ and $\delta^{18}\text{O}$ values

258 As shown by the linear fitting equation  $\delta\text{D} = 7.52\delta^{18}\text{O} + 7.58$ , there is a significant  
 259 linear positive correlation ( $R^2 = 0.96$ ) between  $\delta\text{D}$  and  $\delta^{18}\text{O}$  in atmospheric  
 260 precipitation in the SYR Basin (Fig. 3). It is clear that the slope (7.52) and intercept  
 261 (7.58) of the local meteoric water line (LMWL) are smaller than the global meteoric

262 water line (GMWL), which can be attributed to the basin's location in an inland arid  
263 region, where precipitation disturbances are less frequent and evaporative  
264 fractionation of precipitation is stronger. On the other hand, compared with the slopes  
265 of the LMWL, the slopes of the surface water line (SWL) and the groundwater line  
266 (GWL) are relatively close (Fig. 3), indicating that there is a strong hydraulic  
267 connection between groundwater and river water in the SYR basin, and the slopes of  
268 GWL and RWL show  $GWL > RWL$  in all seasons, suggesting that the river water is  
269 most affected by evaporation and groundwater is less affected by evaporation. In  
270 addition, both surface water and groundwater sampling points were distributed near  
271 the LMWL, indicating that both river water and groundwater receive recharge from  
272 precipitation. Overall, the H-O isotopic composition of surface water samples from  
273 the SYR showed a linear regression of  $\delta D = 5.63\delta^{18}O - 6.11$ , and the slope of RWL  
274 was the largest in the autumn (slope = 6.65) and the smallest in the summer (slope =  
275 5.56), which indicated that the river water evaporated the weakest in the autumn and  
276 the strongest in the summer.



277

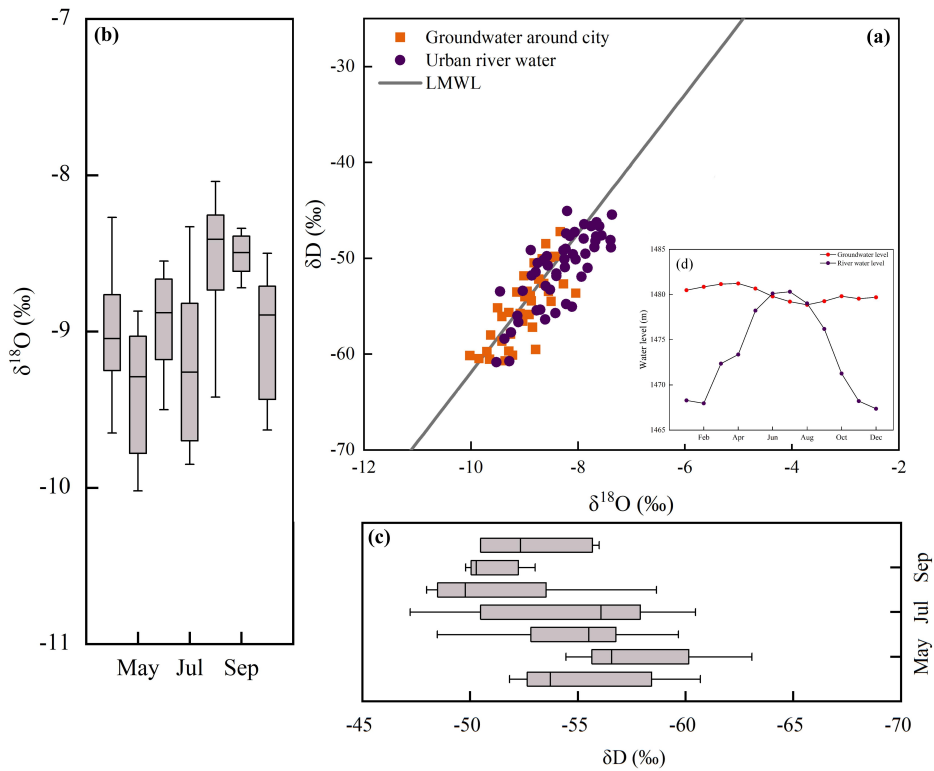
278 **Figure 3 Relationship between  $\delta D$  and  $\delta^{18}O$  in various water bodies in the SYR Basin during**  
 279 **different seasons (a,d,g represent spring, summer, autumn; j represent the comparison of RWL,**  
 280 **GWL, LMWL and GMWL during the entire sampling period;b-c, e-f, h-i represent the**  
 281 **distribution of  $\delta D$  and  $\delta^{18}O$  in river water and groundwater in spring, summer and autumn).**

282 Isotopic analysis of groundwater samples reveals a range of  $\delta D$  and  $\delta^{18}O$  values  
 283 spanning from -50.7‰ to -71.9‰ and from -7.23‰ to -10.4‰, respectively.  
 284 Moreover, the groundwater samples analyzed in the study displayed a linear  
 285 regression of  $\delta D = 6.3\delta^{18}O - 2.15$  ( $R^2 = 0.86$ ). And it is interesting to note that  
 286 groundwater also shows significant enrichment near the urban landscape dams (Fig.  
 287 2), indicating that groundwater is also affected by evapotranspiration, mainly because  
 288 the Wuwei urban area is in the region of a large alluvial fan in front of the mountains,  
 289 the sand and gravel aquifers are very permeable, and the depth of groundwater burial

290 is shallow, making the groundwater more susceptible to the effects of evaporation.

### 291 **4.3 Impact of urbanization on groundwater**

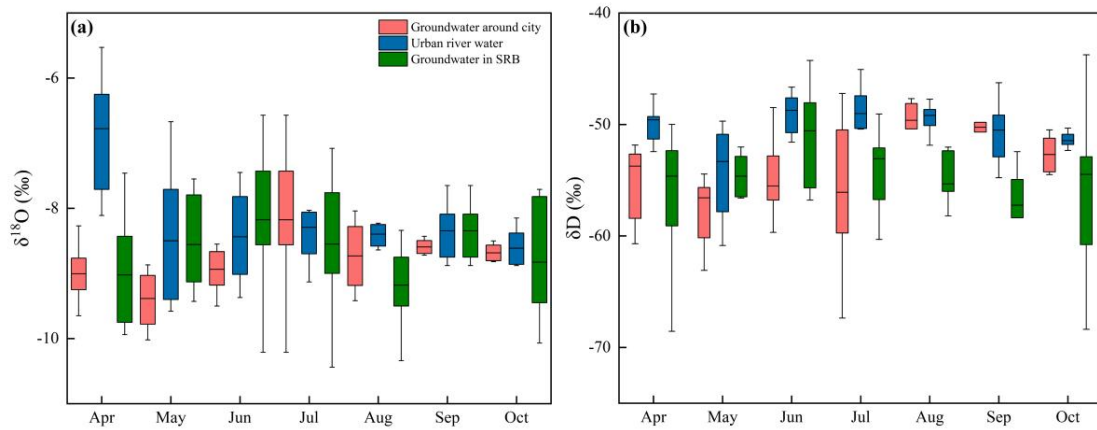
292 We compared monthly variations in isotopic values of groundwater near the city  
293 with monthly variations in river water from a landscaped dam and found that the  
294 monthly variations in groundwater near the city were closely related to river water  
295 from a landscaped dam. The concentration of groundwater sampling sites near the city  
296 near the sampling sites of the dam water indicates that the groundwater around the  
297 city has similar isotopic signatures to the dam and river water (Fig. 4). This suggests  
298 that groundwater near the city is recharged by river water during the summer months.  
299 In addition, we demonstrated this by comparing the data of the dam river water with  
300 the groundwater level. In addition, a portion of the groundwater sampling sites around  
301 the city are located in the lower right corner of the LMWL, which suggests that the  
302 groundwater around the city may also experience some degree of evaporation.



303  
 304 Figure 4 (a) Relationship between  $\delta^{18}\text{O}$  and  $\delta\text{D}$  of groundwater around city and urban river water;  
 305 (b) Monthly variations of  $\delta^{18}\text{O}$  in groundwater around city; (c) Monthly variations of  $\delta\text{D}$  in  
 306 groundwater around city.

307 In addition, we also compared and analyzed the changes of groundwater isotope  
 308 values with those of groundwater around the city in the whole basin, and found that  
 309 there was a close correlation between the changes of groundwater around the city and  
 310 those of the river, while the other groundwater isotope values did not have a strong  
 311 correlation with the river (Fig. 5). In the urban area, the mean values of  $\delta\text{D}$  and  $\delta^{18}\text{O}$   
 312 of the dammed river water were  $-8.26\text{‰}$  and  $-49.88\text{‰}$ , respectively, while the mean  
 313 values of  $\delta\text{D}$  and  $\delta^{18}\text{O}$  of the groundwater around the city were  $-8.44\text{‰}$  and  $-50.36\text{‰}$ ,  
 314 respectively, which indicated that the  $\delta\text{D}$  and  $\delta^{18}\text{O}$  values of the groundwater around  
 315 the city were similar to those of the river water in the dammed city. In addition, the  
 316 isotopic mean values of  $\delta\text{D}$  and  $\delta^{18}\text{O}$  of groundwater throughout the SYR basin were

317 -8.73‰ and -54.78‰, which are significantly different from the isotopic values of  
 318 river water in the urban dam.



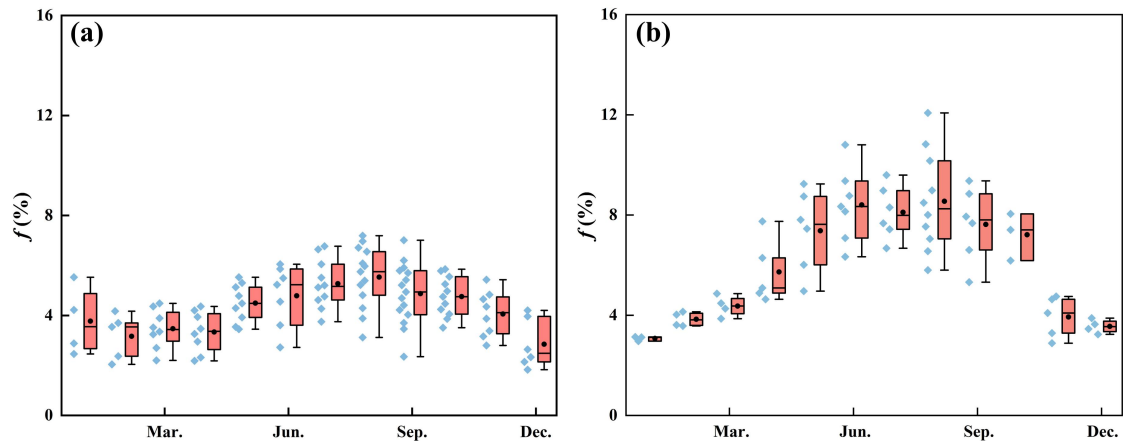
319  
 320 Figure 5 (a) Monthly variations of  $\delta^{18}\text{O}$  in urban river water and groundwater around city, (b)  
 321 Monthly variations of  $\delta\text{D}$  in urban river water and groundwater around city.

#### 322 4.4 Temporal and spatial variation of surface water evaporation losses in the 323 urban area of Wuwei

324 In addition to being an essential part of the hydrological cycle, evaporation is  
 325 widely recognized as one of the most significant factors driving climate change in  
 326 semi-arid regions and in telluric ecosystems (Gibson et al., 2002; Gibson and Edwards,  
 327 2002). An obviously spatial and temporal fluctuation can be seen in the amount of  
 328 surface water that is lost to evaporation in the upper mountain area as well as the  
 329 intermediate urban area of the SYR basin (Fig. 6). Analyzed from a time-varying  
 330 perspective, there is significant seasonal variation in surface water evaporation losses  
 331 both in the upstream mountainous region and the midstream urban area of Wuwei,  
 332 with the highest rates occurring during summer and the lowest during winter (Fig.6).  
 333 Additionally, a spatial comparison reveals that surface water evaporation losses in the  
 334 midstream urban area of Wuwei are significantly greater than those in the upstream



335 mountainous area.



336

337 Figure 6 Evaporation losses from surface water in different areas of the SYR (a) Upper reaches

338 mountainous area, (b) Middle reaches urban areas.

339 Differences contributing to evaporation losses from the river in the upstream and

340 midstream urban areas can be explained mainly by the landscape characteristics of the

341 basin. In the upstream of the Shiyang River, higher vegetation cover and atmospheric

342 humidity in the mountainous areas result in weaker evaporation losses, while the

343 midstream are dominated by urban land, and urban landscapes increase the watershed

344 area and slow down the river, exacerbating evaporation losses from the river.

## 345 5 Discussion

### 346 5.1 Effects of Urbanization on the Rainfall-Runoff Process

347 Fig. 7 depicts the regression model of rainfall events in the SYR Basin,

348 represented by a sine wave, and the fitting of surface water  $\delta^{18}\text{O}$  across the research

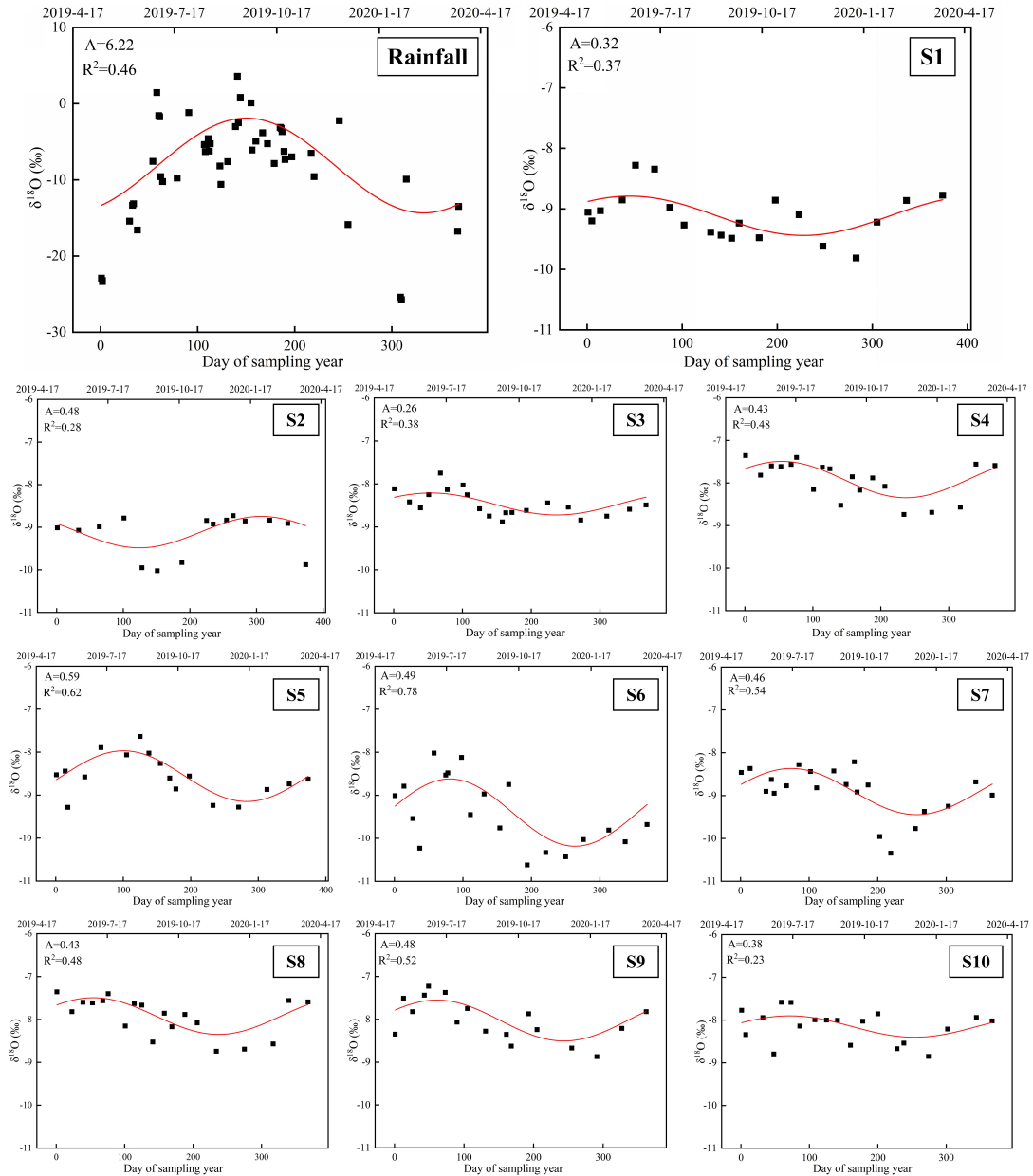
349 season. The  $\delta^{18}\text{O}$  levels of precipitation reported in the SYR Basin have an excellent

350 regularity ( $R^2=0.46$ ) and a seasonal patterns trend that effectively depicts the nfluence

351 of the monsoon climate on the local environment (Zhu et al., 2019). Seasonal

352 variations are seen in the generally steady  $\delta^{18}\text{O}$  and  $\delta^{18}\text{O}$  values of the upstream water.

353 These results indicate that the predominant component of the river water is the  
354 baseflow resulting from recent precipitation runoff. Throughout the duration of the  
355 study, the majority of the lowest  $\delta^{18}\text{O}$  values in the 10 surface water sample points  
356 were recorded during the winter, whilst the highest values were recorded during the  
357 summer. These trends coincide with both the temporal variation of precipitation  
358 isotopes in the SYR Basin, indicating that precipitation input is the underlying cause  
359 of isotope changes in river water. Nevertheless, variations in the isotopes of river  
360 water differ in range across various regions within the SYR Basin, with significant  
361 variation in the degree of fit for the regression curve. The fitting degree of surface  
362 water in the upper and lower reaches is relatively low ( $R^2=0.37$ ,  $R^2=0.28$ ,  $R^2=0.23$ ),  
363 implying limited seasonal isotopic variability in these regions. The midstream surface  
364 water exhibits a notably higher degree of conformity as compared to its upstream and  
365 downstream counterparts ( $R^2=0.38$ ,  $R^2=0.48$ ,  $R^2=0.62$ ,  $R^2=0.78$ ,  $R^2=0.54$ ,  $R^2=0.48$ ,  
366  $R^2=0.52$ ). Moreover, the isotopic composition of surface water throughout this area  
367 exhibits notable cyclic variations.



368

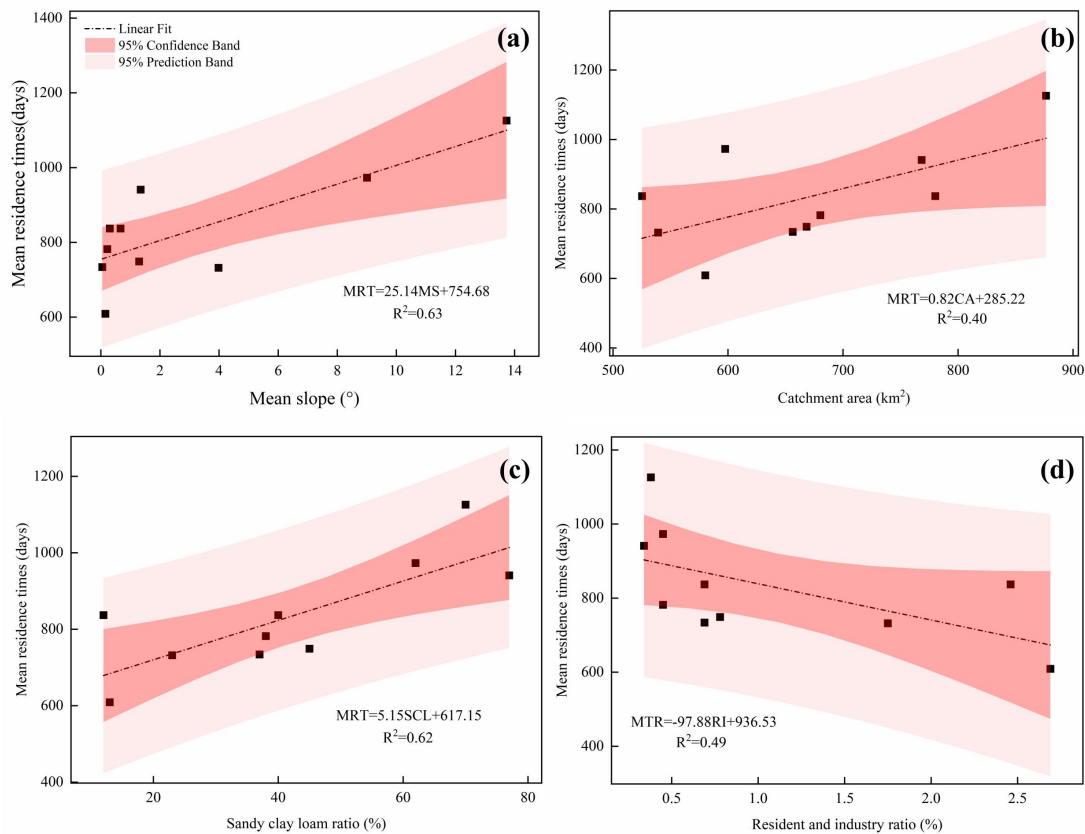
369 Figure 7 Fits the annual regression model of  $\delta^{18}\text{O}$  in SYR Basin precipitation and river water (time:  
 370 2019/4/17—2020/4/23; S1-S10 are surface water sampling points).

371 The reasons for differences in isotope periodicity in different regions may be  
 372 attributed to local water management systems, topographic features and urban  
 373 development. At points S1, S2, and S10, the correlation of model simulations was low,  
 374 which could be attributed to the presence of Xiyang Reservoir in the upstream as well  
 375 as Hongyashan Reservoir in the downstream (Sang et al., 2023), where seasonal

376 variations in the isotope values of the river water are interfered by the reservoir  
377 dispatching activities. At points S3 to S5, the correlation of the model simulation is  
378 higher, which is because in the middle reaches of the SYR basin, the expansion of  
379 urban built-up areas leads to a significant increase in surface runoff during the rainy  
380 season, and according to the land use data, the land area of the towns in Wuwei City  
381 has continued to increase by 134.38 km<sup>2</sup> from 2010 to 2018, resulting in the surface  
382 water showing a cyclical trend comparable to that of the precipitation. Since the 1950s,  
383 in order to better utilize water resources, 13 small and medium-sized reservoirs with a  
384 total storage capacity of 900,000 m<sup>3</sup> were constructed during this period (Ma et al.,  
385 2010), increasing the proportion of rainfall in the runoff constituents as a result of The  
386 correlation of the model simulation is at a high level at points S6~S9, where, in  
387 contrast to the high-elevation areas in the upper reaches, the terrain in the middle and  
388 lower reaches of the SYR basin is relatively flat, mainly with cultivated land and  
389 deserts, and is less disturbed by human activities (Sun et al., 2021), which further  
390 reflects the responsiveness to recent precipitation inputs.

391 The Dunnett's test revealed a significant difference ( $P < 0.05$ ) between the MRT  
392 of the river and the annual magnitude of  $\delta^{18}\text{O}$  of the river. We further investigated the  
393 relationship between the estimated mean residence time and basin landscape features  
394 such as topography (Fig. 8). Using the digital elevation model (DEM) to calculate the  
395 mean slope of the SYR basin, we found that the mean residence time was also  
396 strongly correlated with the mean basin slope ( $R^2 = 0.63$ ), and that the upper reaches  
397 of the Shiyang River basin are mainly high-elevation mountainous areas, where the

398 topography is sloped, but where the vegetation cover is high and dominated by alpine  
 399 meadows, subalpine scrub and Qinghai spruce (Zhang et al. 2023), the greater slope  
 400 leads to a higher gravitational potential, which tends to result in a negative correlation  
 401 with mean residence time (McGuire et al., 2005), which also contributes to the  
 402 potentially higher MRT values in the upstream mountains. In our study, catchment  
 403 area (CA) had a low correlation with MRT ( $R^2 = 0.40$ ), and a weak relationship  
 404 between catchment area and MRT has been observed in other studies (McGlynn et al.,  
 405 2003; McGuire et al., 2005).



406  
 407 **Figure 8 Correlation between MRT and (a) mean slope of the basin, (b) catchment area, (c) sand**  
 408 **clay loam ratio, and (d) percentage area of residential and industrial use in the basin, with 95%**  
 409 **Confidence and Prediction bands.**

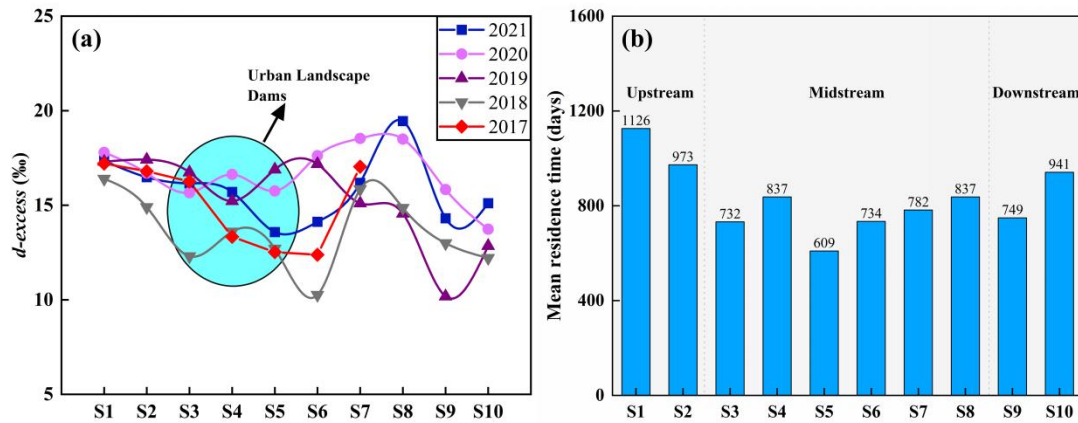
410 Soil is an important component of basin hydrology, and the physical properties

411 of soil, such as water-holding capacity and pore space distribution, have an important  
412 influence on the response to precipitation in the basin and the sand-clay-loam soil  
413 ratio is used here to investigate the possible relationship with MRT. The results  
414 showed that the content of sand clay loam ratio showed a strong positive correlation  
415 with MRT ( $R^2=0.62$ ). Wuwei City is located in the pre-mountain flood-fan belt, and  
416 the soil is dominated by sandy soil (Zhang et al., 2023), which is loose in texture, has  
417 good permeability and good water retention properties, and is mainly used for  
418 agricultural cultivation. Its good permeability increases the vertical movement of  
419 water and the length of flow paths, leading to a longer MRT. There is a strong  
420 negative correlation between the MRT and the ratios of resident and industrial areas  
421 (RI) ( $R^2=0.49$ ), which also indicates that as urbanization progresses, with the increase  
422 of urban land, this undoubtedly leads to a significant shortening of the MRT. However,  
423 the MRT in the mid-river urban area is not much shorter as compared to the  
424 downstream, which may be attributed to the fact that the mid-river The large number  
425 of landscape dams constructed in the urban areas, currently 51 urban landscape dams  
426 have been built in the peri-urban areas of Wuwei City, and the considerable number of  
427 landscape dams may have counteracted the impact of the urban land use, resulting in a  
428 lengthening of the MRT in the middle reaches as well.

## 429 **5.2 Effects of Water Conservancy Projects in Urban Areas on Isotope Dynamics**

430 Recent studies have suggested that the development of dam-reservoir systems  
431 may result in river fragmentation and modifications in flow regimes in terms of their  
432 volume, frequency, and duration (Négrel et al., 2016; Murgulet et al., 2016; Peñas and

433 Barquín, 2019; Maavara et al., 2020). Furthermore, chemical-containing nutrient  
434 migration, such as phosphorus, may occur during sediment movement, resulting in  
435 widespread eutrophication problems (Yang et al., 2007; Duan et al., 2019). As of 2019,  
436 a total of 51 urban landscape dams, primarily consisting of artificial landscape  
437 waterfalls and rubber dams, have been constructed in and around Wuwei city (Zhu et  
438 al., 2021). In the metropolitan coast of Wuwei, many landscape dams have led to  
439 isotopic enrichment in surface water. This damping effect has been observed in  
440 numerous dammed rivers across the globe, including the Rio Grande in the  
441 southwestern United States (Vitvar et al., 2007) and the Ebro River in Spain (Négrel  
442 et al., 2016), as evidenced by isotopic tracers. In the metropolitan coast of Wuwei, a  
443 number of landscape dams have led to the enrichment of isotopic tracers in the surface  
444 water. The results indicate that the  $\delta D$  and  $\delta^{18}O$  levels of the surface water at the  
445 outflow of Wuwei City are greater than those at the inflow (Fig. 2). Moreover, the  
446 influence of evaporation on isotopic composition should not be overlooked, as it can  
447 lead to a decrease in *d-excess* values (Peng et al., 2012). Consistent with previous  
448 studies (Wang et al., 2019), we observed that the *d-excess* of influent water was higher  
449 than that of urban river water (Fig. 9). This observation further supports the  
450 accumulation of heavy H-O isotopes in the surface waters of the dam areas, as shown  
451 in Fig. 9a. In contrast, due to the confluence of tributaries prior to the S7 sampling  
452 point, the river water has lower isotopic values, resulting in elevated *d-excess* values  
453 between S6 and S8.



454

455 Figure 9 (a) The longitudinal variation of the surface water *d-excess* of the SYR, (b) The

456 longitudinal variation of the surface water MRT of the SYR.

### 457 5.3 Effects of Urbanization on the Water Cycle of basins

458 Localized microclimates in urban areas allow for changes in precipitation and

459 evapotranspiration processes, while urbanization alters the pristine subsurface,

460 complicating water cycle processes in the basin (Jacobson, 2011; Westra et al., 2014;

461 Oudin et al., 2018). In terms of the impact on runoff, it is mainly reflected in the

462 increase of surface impermeability due to urbanization, the land use area of Wuwei

463 urban land increased by about 134.38 km<sup>2</sup> from 2010 to 2018, which greatly

464 weakened the infiltration process in urban areas, and the rainfall runoff process

465 simulated by sinusoidal cyclic regression method showed that there were significant

466 differences in the river metro in different parts of the Shiyang River Basin, and that

467 the middle reaches of the river had the highest degree of urbanization, and the time of

468 the metro was the shortest, which further increases the contribution of rainfall to

469 runoff. Regarding the effect of urbanization on evapotranspiration, a large number of

470 dams were constructed on the Shiyang River and flowed through the urban area of

471 Wuwei, causing significant evapotranspiration losses, in addition, these landscape



472 dams also led to hydrogen and oxygen isotope enrichment, and the numerous  
473 reservoirs that were constructed for the construction and development of the city (Ma  
474 et al., 2010), and these reservoirs also contributed to a significant evapotranspiration  
475 loss effect, which has been previously confirmed in our study was also confirmed  
476 (Sang et al., 2023). On the other hand, our study found that the isotopic compositions  
477 and trends of urban nearshore groundwater were similar to those of surface water,  
478 which suggests that there is a close correlation between urban nearshore groundwater  
479 and river water, and that the difference in water levels between river water and  
480 groundwater may be the main reason for river recharge of urban nearshore  
481 groundwater (Fig. 4). In the rainy season, the river level gradually rises, which  
482 decreases the difference between the water levels of urban nearshore groundwater and  
483 river water, and the river water recharges the groundwater, and in the dry season, the  
484 river level decreases, and the urban nearshore groundwater, which is buried at a  
485 shallow depth, in turn recharges the river.

486 In addition, the growth of urbanization has had a dramatic impact on the water  
487 environment in cities, where water problems occur frequently (Giri and Qiu, 2016;  
488 Ma et al., 2022). Urbanization has increased impervious surfaces such as parking lots,  
489 rooftops, roads, and sidewalks, leading to increased runoff, which creates additional  
490 pathways for pollutants to be transported from landscapes to water bodies (Ren et al.,  
491 2014; Wilson and Weng, 2010; Nolan et al., 2023). On the other hand, agricultural  
492 activities have increased some of the fertilizers, pesticides, herbicides and dairy  
493 manure in the farmland into the nearest water bodies, which can directly and

494 indirectly affect will reduce water quality (Yu et al., 2013). The Shiyang River Basin  
495 in the Northwest Arid Zone is an inland river basin with the highest development  
496 intensity and the sharpest conflict between water supply and demand in the region.  
497 The Liangzhou district in the central part of the Shiyang River basin is the most  
498 densely populated artificial oasis with the largest scale of water demand in the entire  
499 basin. Our previous study found that direct discharge of industrial and community  
500 domestic wastewater into the river led to deterioration of surface water quality around  
501 the Shiyang River basin (Ma et al., 2021). In addition agricultural activities have less  
502 impact on the upper reaches of the Shiyang River and relatively more impact on the  
503 middle and lower reaches , and the application of nitrogen-based fertilizers during  
504 agricultural cultivation is the main cause of high  $\text{NH}_4^+$  and  $\text{NO}_3^-$  concentrations in the  
505 area (Ma et al., 2021), which may also lead to increased salinity and accelerated  
506 eutrophication of the river, threatening the safety of the basin's water environment.  
507 Overall, human activities (urbanization) may alter the water cycle processes inherent  
508 in inland river basins, and the implications of such changes need to be further  
509 explored.

## 510 **6 Conclusions**

511 In this study, we investigated the hydrometeorological and isotopic data of the  
512 Shiyang River Basin from 2017 to 2021, and our investigations showed that  
513 urbanization had a significant impact on the water cycle of the basin. The results  
514 showed that the isotopic values of the river water showed a significant enrichment  
515 from upstream to downstream, but facilities such as landscape dams and reservoirs in

516 the urban area significantly altered this natural pattern, and the isotopic values of the  
517 river water in the urban area ( $\delta D=-48.31\text{‰}$ ;  $\delta^{18}\text{O}=-7.49\text{‰}$ ) were higher than those of  
518 the natural river water ( $\delta D=-55.77\text{‰}$ ;  $\delta^{18}\text{O}=-8.98\text{‰}$ ), and landscape dams aggravated  
519 the evaporation losses of river water, due to the increase of urban land area, which  
520 accelerated the rainfall-runoff conversion process, the residence time of surface water  
521 in different regions of the Shiyang River Basin had obvious differences, and the MRT  
522 from the upstream to the downstream showed a fluctuating downward process, which  
523 was shortened from 1,126 days in the upstream to 941 days in the downstream, and  
524 the MRT was mainly controlled by the basin's landscape features. In addition, there  
525 was a strong relationship between the isotopic composition of the reservoir and the  
526 surrounding groundwater. Overall, urbanization has a profound impact on the  
527 hydrological system of the basin, and the results of this study can provide some  
528 references for future research on urbanization and the water cycle, and improve our  
529 understanding of the hydrological processes of basin in arid zones.

### 530 **Acknowledgements**

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### 533 **Author contributions statement**

534 Rui Li: Writing-Original draft preparation; Guofeng Zhu: Writing-Reviewing and  
535 Editing; Siyu Lu: Methodology; Liyuan Sang and Gaojia Meng: Data processing and  
536 Experiment; Longhu Chen and Yinying Jiao: Methodology and visualization;  
537 Qinqin Wang : Visualization;

538 **Data availability Statement**

539 The isotopic data that support the findings of this study are openly available in  
540 Zhu, Guofeng (2022), “Stable water isotope monitoring network of different water  
541 bodies in SYR Basin, a typical arid river in China”, Mendeley Data, V1, doi:  
542 10.17632/vhm44t74sy.1. The source of soil data comes from the Harmonized World  
543 Soil Database (HWSD) constructed by the Food and Agriculture Organization of the  
544 United Nations (FAO) and the International Institute for Applied Systems (IIASA) on  
545 2009. The land-use and land-cover change data of the Shiyang River Basin were  
546 obtained from Chinese Academy of Sciences, the data centre of resources and  
547 environmental science (<http://www.resdc.cn>).

548 **Competing Interests**

549 We undersigned declare that this manuscript entitled “Effects of Urbanization on  
550 the water cycle in the SYR Basin: Based on stable isotope method” is original, has not  
551 been published before and is not currently being considered for publication elsewhere.

552 The authors declare that they have no known competing financial interests or  
553 personal relationships that could have appeared to influence the work reported in this  
554 paper.

555 **Reference**

556 Anderson, B. J., Slater, L. J., Dadson, S. J., Blum, A. G., and Prosdocimi, I.:  
557 Statistical Attribution of the Influence of Urban and Tree Cover Change on  
558 Streamflow: A Comparison of Large Sample Statistical Approaches, Water  
559 Resources Research, 58, e2021WR030742,  
560 <https://doi.org/10.1029/2021WR030742>, 2022.

561 Asano, Y., Uchida, T., and Ohte, N.: Residence times and flow paths of water in steep  
562 unchannelled catchments, Tanakami, Japan, *Journal of Hydrology*, 261, 173–192,  
563 [https://doi.org/10.1016/S0022-1694\(02\)00005-7](https://doi.org/10.1016/S0022-1694(02)00005-7), 2002.

564 Baker, A.: Land Use and Water Quality, in: *Encyclopedia of Hydrological Sciences*,  
565 edited by: Anderson, M. G. and McDonnell, J. J., John Wiley & Sons, Ltd,  
566 Chichester, UK, hsa195, <https://doi.org/10.1002/0470848944.hsa195>, 2005.

567 Bhaskar, A. S. and Welty, C.: Analysis of subsurface storage and streamflow  
568 generation in urban basins, *Water Resour. Res.*, 51, 1493–1513,  
569 <https://doi.org/10.1002/2014WR015607>, 2015.

570 Blum, A. G., Ferraro, P. J., Archfield, S. A., and Ryberg, K. R.: Causal Effect of  
571 Impervious Cover on Annual Flood Magnitude for the United States,  
572 *Geophysical Research Letters*, 47, e2019GL086480,  
573 <https://doi.org/10.1029/2019GL086480>, 2020.

574 Bruwier, M., Maravat, C., Mustafa, A., Teller, J., Piroton, M., Erpicum, S.,  
575 Archambeau, P., and Dewals, B.: Influence of urban forms on surface flow in  
576 urban pluvial flooding, *Journal of Hydrology*, 582, 124493,  
577 <https://doi.org/10.1016/j.jhydrol.2019.124493>, 2020.

578 Burian, S. J. and Shepherd, J. M.: Effect of urbanization on the diurnal rainfall pattern  
579 in Houston, *Hydrol. Process.*, 19, 1089–1103, <https://doi.org/10.1002/hyp.5647>,  
580 2005.

581 Caldwell, P. V., Sun, G., McNulty, S. G., Cohen, E. C., and Moore Myers, J. A.:  
582 Impacts of impervious cover, water withdrawals, and climate change on river

583 flows in the conterminous US, *Hydrol. Earth Syst. Sci.*, 16, 2839–2857,  
584 <https://doi.org/10.5194/hess-16-2839-2012>, 2012.

585 Chen, G., Li, X., Liu, X., Chen, Y., Liang, X., Leng, J., Xu, X., Liao, W., Qiu, Y., Wu,  
586 Q., and Huang, K.: Global projections of future urban land expansion under  
587 shared socioeconomic pathways, *Nat Commun.*, 11, 537,  
588 <https://doi.org/10.1038/s41467-020-14386-x>, 2020.

589 Dansgaard, W.: Stable isotopes in precipitation, *Tellus*, 16, 436–468,  
590 <https://doi.org/10.1111/j.2153-3490.1964.tb00181.x>, 1964.

591 De Niel, J. and Willems, P.: Climate or land cover variations: what is driving observed  
592 changes in river peak flows? A data-based attribution study, *Hydrol. Earth Syst.*  
593 *Sci.*, 23, 871–882, <https://doi.org/10.5194/hess-23-871-2019>, 2019.

594 Deng, K., Yang, S., Lian, E., Li, C., Yang, C., and Wei, H.: Three Gorges Dam alters  
595 the Changjiang (Yangtze) river water cycle in the dry seasons: Evidence from  
596 H-O isotopes, *Science of The Total Environment*, 562, 89–97,  
597 <https://doi.org/10.1016/j.scitotenv.2016.03.213>, 2016.

598 Duan, W., Hanasaki, N., Shiogama, H., Chen, Y., Zou, S., Nover, D., Zhou, B., and  
599 Wang, Y.: Evaluation and Future Projection of Chinese Precipitation Extremes  
600 Using Large Ensemble High-Resolution Climate Simulations, *Journal of Climate*,  
601 32, 2169–2183, <https://doi.org/10.1175/JCLI-D-18-0465.1>, 2019.

602 Fekete, B. M., Gibson, J. J., Aggarwal, P., and Vörösmarty, C. J.: Application of  
603 isotope tracers in continental scale hydrological modeling, *Journal of Hydrology*,  
604 330, 444–456, <https://doi.org/10.1016/j.jhydrol.2006.04.029>, 2006.

605 Flörke, M., Schneider, C., and McDonald, R. I.: Water competition between cities and  
606 agriculture driven by climate change and urban growth, *Nat Sustain*, 1, 51–58,  
607 <https://doi.org/10.1038/s41893-017-0006-8>, 2018.

608 Förstel, H. and Hützen, H.: Oxygen isotope ratios in German groundwater, *Nature*,  
609 304, 614–616, <https://doi.org/10.1038/304614a0>, 1983.

610 Fu, X., Yang, X., and Sun, X.: Spatial and Diurnal Variations of Summer Hourly  
611 Rainfall Over Three Super City Clusters in Eastern China and Their Possible  
612 Link to the Urbanization, *JGR Atmospheres*, 124, 5445–5462,  
613 <https://doi.org/10.1029/2019JD030474>, 2019.

614 Gammons, C. H., Poulson, S. R., Pellicori, D. A., Reed, P. J., Roesler, A. J., and  
615 Petrescu, E. M.: The hydrogen and oxygen isotopic composition of precipitation,  
616 evaporated mine water, and river water in Montana, USA, *Journal of Hydrology*,  
617 328, 319–330, <https://doi.org/10.1016/j.jhydrol.2005.12.005>, 2006.

618 Gessner, M. O., Hinkelmann, R., Nützmann, G., Jekel, M., Singer, G., Lewandowski,  
619 J., Nehls, T., and Barjenbruch, M.: Urban water interfaces, *Journal of Hydrology*,  
620 514, 226–232, <https://doi.org/10.1016/j.jhydrol.2014.04.021>, 2014.

621 Gibson, J. J., Edwards, T. W. D., Birks, S. J., St Amour, N. A., Buhay, W. M.,  
622 McEachern, P., Wolfe, B. B., and Peters, D. L.: Progress in isotope tracer  
623 hydrology in Canada, *Hydrol. Process.*, 19, 303–327,  
624 <https://doi.org/10.1002/hyp.5766>, 2005.

625 Gibson, J. J. and Edwards, T. W. D.: Regional water balance trends and  
626 evaporation-transpiration partitioning from a stable isotope survey of lakes in

627 northern Canada: REGIONAL WATER BALANCE USING STABLE  
628 ISOTOPES, *Global Biogeochem. Cycles*, 16, 10-1-10-14,  
629 <https://doi.org/10.1029/2001GB001839>, 2002.

630 Gibson, J. J., Prepas, E. E., and McEachern, P.: Quantitative comparison of lake  
631 throughflow, residency, and catchment runoff using stable isotopes: modelling  
632 and results from a regional survey of Boreal lakes, *Journal of Hydrology*, 2002.

633 Gillefalk, M., Tetzlaff, D., Hinkelmann, R., Kuhlemann, L.-M., Smith, A., Meier, F.,  
634 Maneta, M. P., and Soulsby, C.: Quantifying the effects of urban green space on  
635 water partitioning and ages using an isotope-based ecohydrological model,  
636 *Hydrol. Earth Syst. Sci.*, 25, 3635–3652,  
637 <https://doi.org/10.5194/hess-25-3635-2021>, 2021.

638 Giri, S. and Qiu, Z.: Understanding the relationship of land uses and water quality in  
639 Twenty First Century: A review, *Journal of Environmental Management*, 173,  
640 41–48, <https://doi.org/10.1016/j.jenvman.2016.02.029>, 2016.

641 Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., and  
642 Briggs, J. M.: Global Change and the Ecology of Cities, *Science*, 319, 756–760,  
643 <https://doi.org/10.1126/science.1150195>, 2008.

644 Guan, M., Sillanpää, N., and Koivusalo, H.: Storm runoff response to rainfall pattern,  
645 magnitude and urbanization in a developing urban catchment: Storm Runoff  
646 Response to Rainfall Pattern, Magnitude and Urbanization, *Hydrol. Process.*,  
647 n/a-n/a, <https://doi.org/10.1002/hyp.10624>, 2015.



648 Hamilton, S. K., Bunn, S. E., Thoms, M. C., and Marshall, J. C.: Persistence of  
649 aquatic refugia between flow pulses in a dryland river system(Cooper Creek,  
650 Australia), *Limnol. Oceanogr.*, 50, 743–754,  
651 <https://doi.org/10.4319/lo.2005.50.3.0743>, 2005.

652 Han, S., Slater, L., Wilby, R. L., and Faulkner, D.: Contribution of urbanisation to  
653 non-stationary river flow in the UK, *Journal of Hydrology*, 613, 128417,  
654 <https://doi.org/10.1016/j.jhydrol.2022.128417>, 2022.

655 Jacobson, C. R.: Identification and quantification of the hydrological impacts of  
656 imperviousness in urban catchments: A review, *Journal of Environmental*  
657 *Management*, 92, 1438–1448, <https://doi.org/10.1016/j.jenvman.2011.01.018>,  
658 2011.

659 Liu, J., Shen, Z., and Chen, L.: Assessing how spatial variations of land use pattern  
660 affect water quality across a typical urbanized basin in Beijing, China,  
661 *Landscape and Urban Planning*, 176, 51–63,  
662 <https://doi.org/10.1016/j.landurbplan.2018.04.006>, 2018.

663 Ma, H., Zhu, G., Zhang, Y., Sang, L., Wan, Q., Zhang, Z., Xu, Y., and Qiu, D.: Ion  
664 migration process and influencing factors in inland river basin of arid area in  
665 China: a case study of Shiyang River Basin, *Environ Sci Pollut Res*, 28,  
666 56305–56318, <https://doi.org/10.1007/s11356-021-14484-3>, 2021.

667 Ma, J., Pan, F., Chen, L., Edmunds, W. M., Ding, Z., He, J., Zhou, K., and Huang, T.:  
668 Isotopic and geochemical evidence of recharge sources and water quality in the

669 Quaternary aquifer beneath Jinchang city, NW China, *Applied Geochemistry*, 25,  
670 996–1007, <https://doi.org/10.1016/j.apgeochem.2010.04.006>, 2010.

671 Ma, X., Li, N., Yang, H., and Li, Y.: Exploring the relationship between urbanization  
672 and water environment based on coupling analysis in Nanjing, East China,  
673 *Environ Sci Pollut Res*, 29, 4654–4667,  
674 <https://doi.org/10.1007/s11356-021-15161-1>, 2022.

675 Maavara, T., Chen, Q., Van Meter, K., Brown, L. E., Zhang, J., Ni, J., and Zarfl, C.:  
676 River dam impacts on biogeochemical cycling, *Nat Rev Earth Environ*, 1,  
677 103–116, <https://doi.org/10.1038/s43017-019-0019-0>, 2020.

678 Małoszewski, P., Rauert, W., Stichler, W., and Herrmann, A.: Application of flow  
679 models in an alpine catchment area using tritium and deuterium data, *Journal of*  
680 *Hydrology*, 66, 319–330, [https://doi.org/10.1016/0022-1694\(83\)90193-2](https://doi.org/10.1016/0022-1694(83)90193-2), 1983.

681 Martin, K. L., Hwang, T., Vose, J. M., Coulston, J. W., Wear, D. N., Miles, B., and  
682 Band, L. E.: basin impacts of climate and land use changes depend on magnitude  
683 and land use context, *Ecohydrology*, 10, e1870, <https://doi.org/10.1002/eco.1870>,  
684 2017.

685 McDonough, L. K., Santos, I. R., Andersen, M. S., O’Carroll, D. M., Rutledge, H.,  
686 Meredith, K., Oudone, P., Bridgeman, J., Gooddy, D. C., Sorensen, J. P. R.,  
687 Lapworth, D. J., MacDonald, A. M., Ward, J., and Baker, A.: Changes in global  
688 groundwater organic carbon driven by climate change and urbanization, *Nat*  
689 *Commun*, 11, 1279, <https://doi.org/10.1038/s41467-020-14946-1>, 2020.

690 McGlynn, B., McDonnell, J., Stewart, M., and Seibert, J.: On the relationships  
691 between catchment scale and streamwater mean residence time, *Hydrol. Process.*,  
692 17, 175–181, <https://doi.org/10.1002/hyp.5085>, 2003.

693 McGuire, K. J., McDonnell, J. J., Weiler, M., Kendall, C., McGlynn, B. L., Welker, J.  
694 M., and Seibert, J.: The role of topography on catchment-scale water residence  
695 time: CATCHMENT-SCALE WATER RESIDENCE TIME, *Water Resour. Res.*,  
696 41, <https://doi.org/10.1029/2004WR003657>, 2005.

697 Murgulet, D., Murgulet, V., Spalt, N., Douglas, A., and Hay, R. G.: Impact of  
698 hydrological alterations on river-groundwater exchange and water quality in a  
699 semi-arid area: Nueces River, Texas, *Science of The Total Environment*, 572,  
700 595–607, <https://doi.org/10.1016/j.scitotenv.2016.07.198>, 2016.

701 Négrel, P., Petelet-Giraud, E., and Millot, R.: Tracing water cycle in regulated basin  
702 using stable  $\delta^{18}\text{O}$ – $\delta^2\text{H}$  isotopes: The Ebro river basin (Spain), *Chemical Geology*,  
703 422, 71–81, <https://doi.org/10.1016/j.chemgeo.2015.12.009>, 2016.

704 Nolan, T. M., Reynolds, L. J., Sala-Comorera, L., Martin, N. A., Stephens, J. H.,  
705 O’Hare, G. M. P., O’Sullivan, J. J., and Meijer, W. G.: Land use as a critical  
706 determinant of faecal and antimicrobial resistance gene pollution in riverine  
707 systems, *Science of The Total Environment*, 871, 162052,  
708 <https://doi.org/10.1016/j.scitotenv.2023.162052>, 2023.

709 Oudin, L., Salavati, B., Furusho-Percot, C., Ribstein, P., and Saadi, M.: Hydrological  
710 impacts of urbanization at the catchment scale, *Journal of Hydrology*, 559,  
711 774–786, <https://doi.org/10.1016/j.jhydrol.2018.02.064>, 2018.

712 Peñas, F. J. and Barquín, J.: Assessment of large-scale patterns of hydrological  
713 alteration caused by dams, *Journal of Hydrology*, 572, 706–718,  
714 <https://doi.org/10.1016/j.jhydrol.2019.03.056>, 2019.

715 Peng, T.-R., Huang, C.-C., Wang, C.-H., Liu, T.-K., Lu, W.-C., and Chen, K.-Y.:  
716 Using oxygen, hydrogen, and tritium isotopes to assess pond water's contribution  
717 to groundwater and local precipitation in the pediment tableland areas of  
718 northwestern Taiwan, *Journal of Hydrology*, 450–451, 105–116,  
719 <https://doi.org/10.1016/j.jhydrol.2012.05.021>, 2012.

720 Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Boone, C. G., Groffman, P. M.,  
721 Irwin, E., Kaushal, S. S., Marshall, V., McGrath, B. P., Nilon, C. H., Pouyat, R.  
722 V., Szlavecz, K., Troy, A., and Warren, P.: Urban ecological systems: Scientific  
723 foundations and a decade of progress, *Journal of Environmental Management*, 92,  
724 331–362, <https://doi.org/10.1016/j.jenvman.2010.08.022>, 2011.

725 Qian, H., Dou, Y., Li, X.J., Yang, B.C., and Zhao, Z.H.: Changes of  $\delta^{18}\text{O}$  and  $\delta\text{D}$   
726 along Dousitu River and its indication of river water evaporation. *Hydrogeol.*  
727 *Eng. Geol.* 34 (1), 107–112,  
728 <https://doi.org/10.16030/j.cnki.issn.1000-3665.2007.01.024>, 2007.

729 Ren, L., Cui, E., and Sun, H.: Temporal and spatial variations in the relationship  
730 between urbanization and water quality, *Environ Sci Pollut Res*, 21,  
731 13646–13655, <https://doi.org/10.1007/s11356-014-3242-8>, 2014.

732 Rodgers, P., Soulsby, C., Waldron, S., and Tetzlaff, D.: Using stable isotope tracers to  
733 assess hydrological flow paths, residence times and landscape influences in a

734 nested mesoscale catchment, *Hydrol. Earth Syst. Sci.*, 9, 139–155,  
735 <https://doi.org/10.5194/hess-9-139-2005>, 2005.

736 Salvadore, E., Bronders, J., and Batelaan, O.: Hydrological modelling of urbanized  
737 catchments: A review and future directions, *Journal of Hydrology*, 529, 62–81,  
738 <https://doi.org/10.1016/j.jhydrol.2015.06.028>, 2015.

739 Sang, L., Zhu, G., Xu, Y., Sun, Z., Zhang, Z., and Tong, H.: Effects of Agricultural  
740 Large-And Medium-Sized Reservoirs on Hydrologic Processes in the Arid  
741 Shiyang River Basin, Northwest China, *Water Resources Research*, 59,  
742 e2022WR033519, <https://doi.org/10.1029/2022WR033519>, 2023.

743 Shastri, H., Paul, S., Ghosh, S., and Karmakar, S.: Impacts of urbanization on Indian  
744 summer monsoon rainfall extremes, *J. Geophys. Res. Atmos.*, 120, 496–516,  
745 <https://doi.org/10.1002/2014JD022061>, 2015.

746 Skrzypek, G., Mydłowski, A., Dogramaci, S., Hedley, P., Gibson, J. J., and Grierson,  
747 P. F.: Estimation of evaporative loss based on the stable isotope composition of  
748 water using Hydrocalculator, *Journal of Hydrology*, 523, 781–789,  
749 <https://doi.org/10.1016/j.jhydrol.2015.02.010>, 2015.

750 Sun, G., Caldwell, P. V., and McNulty, S. G.: Modelling the potential role of forest  
751 thinning in maintaining water supplies under a changing climate across the  
752 conterminous United States: Response of Water Yield to Forest Thinning and  
753 Climate Change, *Hydrol. Process.*, 29, 5016–5030,  
754 <https://doi.org/10.1002/hyp.10469>, 2015.

755 Sun, G. and Lockaby, B. G.: Water Quantity and Quality at the Urban-Rural Interface,  
756 in: Urban-Rural Interfaces, edited by: Laband, D. N., Lockaby, B. G., and  
757 Zipperer, W. C., American Society of Agronomy, Soil Science Society of  
758 America, Crop Science Society of America, Inc., Madison, WI, USA, 29–48,  
759 <https://doi.org/10.2136/2012.urban-rural.c3>, 2012.

760 Sun, Z., Zhu, G., Zhang, Z., Xu, Y., Yong, L., Wan, Q., Ma, H., Sang, L., and Liu, Y.:  
761 Identifying surface water evaporation loss of inland river basin based on  
762 evaporation enrichment model, *Hydrological Processes*, 35, e14093,  
763 <https://doi.org/10.1002/hyp.14093>, 2021.

764 Talma, S, Woodborne, S. and Lorentz, S.: South African Contribution to the Rivers  
765 CRP, 2012.

766 UN-Habitat: World cities report 2020 : the value of sustainable urbanization,  
767 UN-Habitat, Nairobi, Kenya, 377 pp., 2020.

768 United Nations Department of Economic and Social Affairs: World Urbanization  
769 Prospects 2018: Highlights, United Nations,  
770 <https://doi.org/10.18356/6255ead2-en>, 2019.

771 Vitvar, T., Aggarwal, P. K., and Herczeg, A. L.: Global network is launched to  
772 monitor isotopes in rivers, *Eos Trans. AGU*, 88, 325–326,  
773 <https://doi.org/10.1029/2007EO330001>, 2007.

774 Vystavna, Y., Harjung, A., Monteiro, L. R., Matiatos, I., and Wassenaar, L. I.: Stable  
775 isotopes in global lakes integrate catchment and climatic controls on evaporation,  
776 *Nat Commun*, 12, 7224, <https://doi.org/10.1038/s41467-021-27569-x>, 2021.

777 Wang, B., Zhang, H., Liang, X., Li, X., and Wang, F.: Cumulative effects of cascade  
778 dams on river water cycle: Evidence from hydrogen and oxygen isotopes,  
779 *Journal of Hydrology*, 568, 604–610,  
780 <https://doi.org/10.1016/j.jhydrol.2018.11.016>, 2019.

781 Wei, W., Shi, P., Zhou, J., Feng, H., Wang, X., and Wang, X.: Environmental  
782 suitability evaluation for human settlements in an arid inland river basin: A case  
783 study of the Shiyang River Basin, *J. Geogr. Sci.*, 23, 331–343,  
784 <https://doi.org/10.1007/s11442-013-1013-y>, 2013.

785 Westra, S., Fowler, H. J., Evans, J. P., Alexander, L. V., Berg, P., Johnson, F.,  
786 Kendon, E. J., Lenderink, G., and Roberts, N. M.: Future changes to the intensity  
787 and frequency of short-duration extreme rainfall, *Rev. Geophys.*, 52, 522–555,  
788 <https://doi.org/10.1002/2014RG000464>, 2014.

789 Wilson, C. and Weng, Q.: Assessing Surface Water Quality and Its Relation with  
790 Urban Land Cover Changes in the Lake Calumet Area, Greater Chicago,  
791 *Environmental Management*, 45, 1096–1111,  
792 <https://doi.org/10.1007/s00267-010-9482-6>, 2010.

793 Wing, O. E. J., Bates, P. D., Smith, A. M., Sampson, C. C., Johnson, K. A., Fargione,  
794 J., and Morefield, P.: Estimates of present and future flood risk in the  
795 conterminous United States, *Environ. Res. Lett.*, 13, 034023,  
796 <https://doi.org/10.1088/1748-9326/aaac65>, 2018.

797 Yang, L., Ni, G., Tian, F., and Niyogi, D.: Urbanization Exacerbated Rainfall Over  
798 European Suburbs Under a Warming Climate, *Geophysical Research Letters*, 48,  
799 e2021GL095987, <https://doi.org/10.1029/2021GL095987>, 2021.

800 Yang, S. L., Zhang, J., and Xu, X. J.: Influence of the Three Gorges Dam on  
801 downstream delivery of sediment and its environmental implications, *Yangtze*  
802 *River, Geophys. Res. Lett.*, 34, L10401, <https://doi.org/10.1029/2007GL029472>,  
803 2007.

804 Yu, D., Shi, P., Liu, Y., and Xun, B.: Detecting land use-water quality relationships  
805 from the viewpoint of ecological restoration in an urban area, *Ecological*  
806 *Engineering*, 53, 205–216, <https://doi.org/10.1016/j.ecoleng.2012.12.045>, 2013.

807 Zhang, W., Wan, Q., Zhu, G., and Xu, Y.: Distribution of soil organic carbon and  
808 carbon sequestration potential of different geomorphic units in Shiyang river  
809 basin, China, *Environ Geochem Health*, 45, 4071–4086,  
810 <https://doi.org/10.1007/s10653-022-01472-w>, 2023.

811 Zhu, G., Guo, H., Qin, D., Pan, H., Zhang, Y., Jia, W., and Ma, X.: Contribution of  
812 recycled moisture to precipitation in the monsoon marginal zone: Estimate based  
813 on stable isotope data, *Journal of Hydrology*, 569, 423–435,  
814 <https://doi.org/10.1016/j.jhydrol.2018.12.014>, 2019.

815 Zhu, G., Sang, L., Zhang, Z., Sun, Z., Ma, H., Liu, Y., Zhao, K., Wang, L., and Guo,  
816 H.: Impact of landscape dams on river water cycle in urban and peri-urban areas  
817 in the Shiyang River Basin: Evidence obtained from hydrogen and oxygen  
818 isotopes, *Journal of Hydrology*, 602, 126779,



