Effects of ecological construction on the transformation of different water types on Loess Plateau, China

Zhao Binhua, Li Zhanbin

State Key Laboratory of Eco-hydraulics in Northwest Arid Region of China, Xi'an University of Technology

Vienna

5 May, 2020

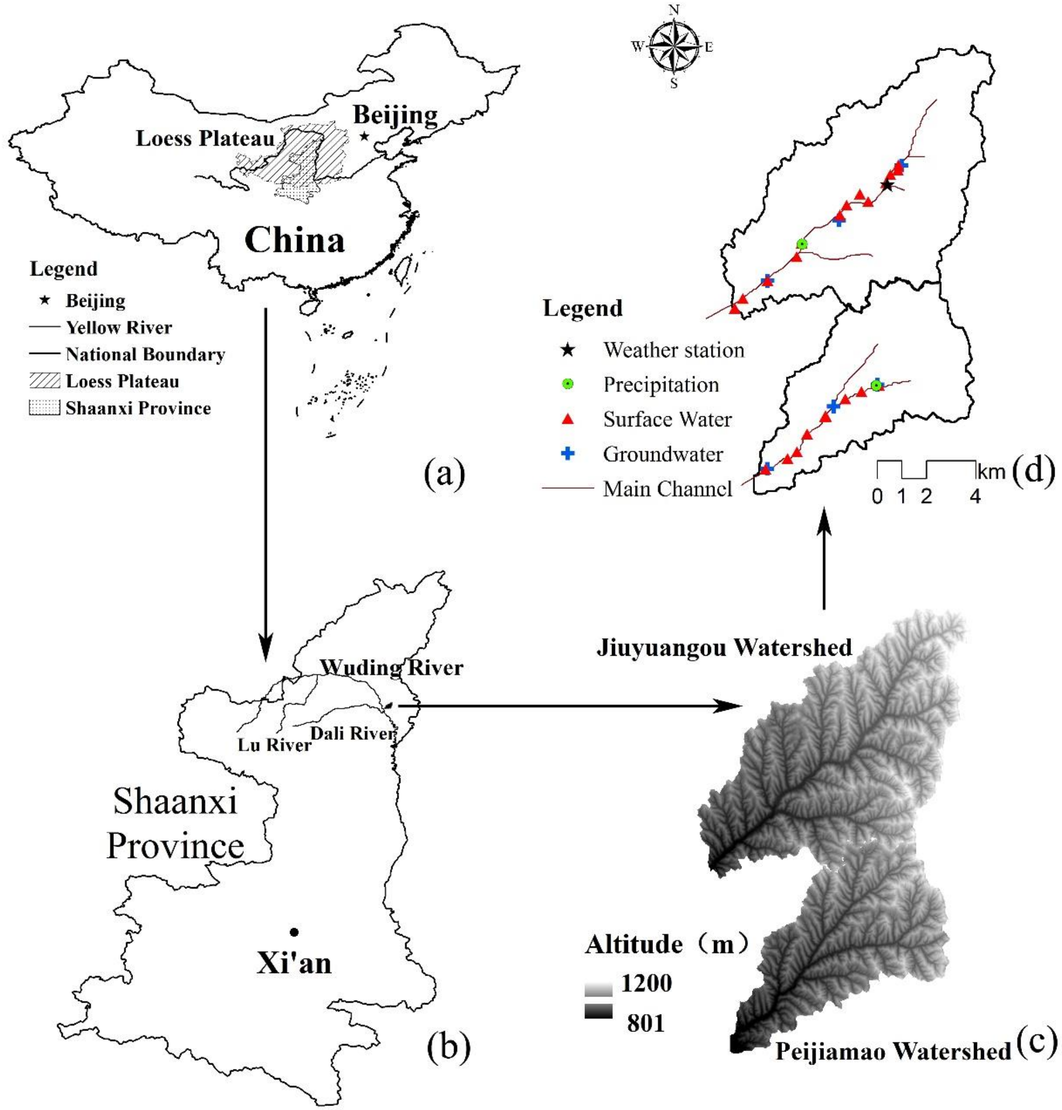
Overview

- *Changes of hydrological characteristics* under ecological construction conditions.
- *Water transmission times change* in two contrasting hilly and gully watersheds.
- Variation in the *water supply ratio* in dry and wet seasons under ecological construction.

Initial conditions

Ecological construction conditions

Study site



- Area of Jiuyuangou is 70.7km^2, and Peijiamao is 40.4km^2. Proportion of governance is 75.1% and 11.2% in Jiuyuangou and Peijiamao, respectively.
- A total of 1028 water samples were collected from 30 sites during 2015~2016, while 79 precipitation samples were collected from stations.
- A small automatic weather station (HOBO U30 NRC USA) is located in the middle of the Jiuyuangou watershed.

Sample Collection

- **A automatic weather station (HOBO U30 NRC USA) is set in Jiuyuangou, which is mainly used for observation of atmospheric temperature and used to record time and rainfall, rainfall events meteorological observation frequency set to 5 min/time.**

- **Sample collection time is from January 2015 to December 2016, and the sampling period of stream water, well water and reservoir water were 15 days, and the sampling of precipitation and snow water were collected from stations.**

Field work photos

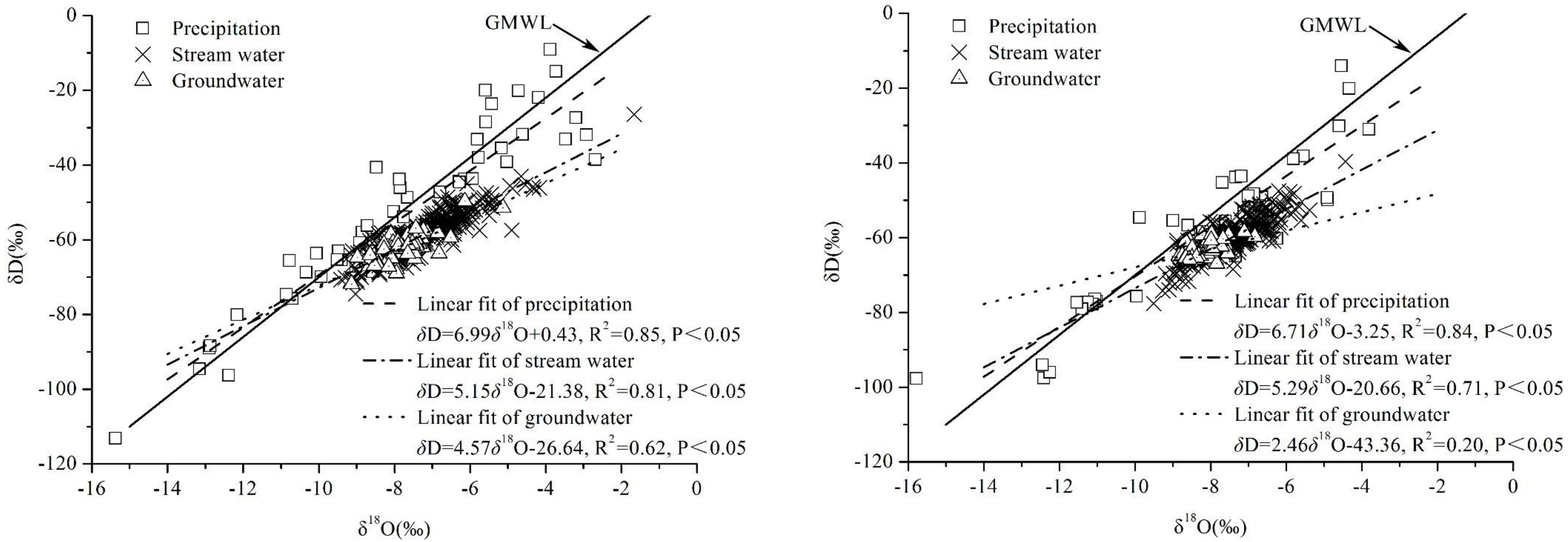
1 Statistical characteristics of stable isotopes in different water bodies

Data fitting for different water bodies in the contrasting watersheds

Contrast watershed	Water types	Number of samples	δD (‰)				δ^{18}O (‰)			
			Max	Min	Ave	SD	Max	Min	Ave	SD
Jiuyuangou	Precipitation	51	-9.11	-113.12	-52.25	21.54	-2.92	-15.37	-7.67	2.78
	Stream water	432	-26.48	-74.53	-59.62	5.13	-1.66	-9.41	-7.31	1.15
	Groundwater	104	-34.94	-71.85	-62.76	5.84	-0.89	-9.14	-7.89	1.30
Peijiamao	Precipitation	28	-24.01	-97.72	-57.02	18.13	-4.33	-15.78	-8.08	2.58
	Stream water	360	-39.62	-96.12	-60.53	5.16	-4.43	-11.73	-7.49	0.85
	Groundwater	53	-58.49	-66.95	-63.45	2.10	-6.52	-9.67	-8.14	0.54

- **Average δD and δ^{18}O isotope values in stream water in the two watersheds were bigger than those in groundwater, indicating a stronger evaporative effect in the former.**
- **Stream water and groundwater within the Jiuyuangou are enriched compared to the Peijiamao because ecological construction projects have effectively slowed down the rate of water transformation and reduced flow rate.**

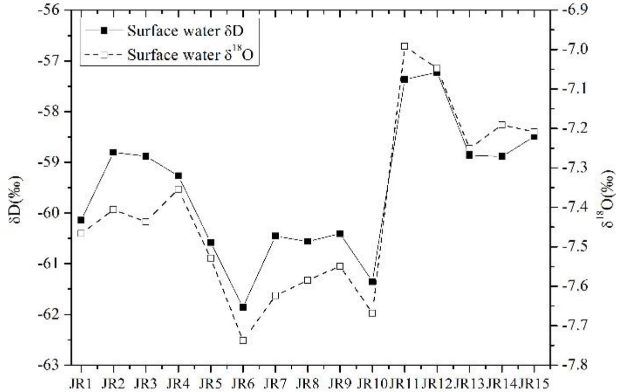
2 Relationships between hydrogen (H) and oxygen (O) isotopes



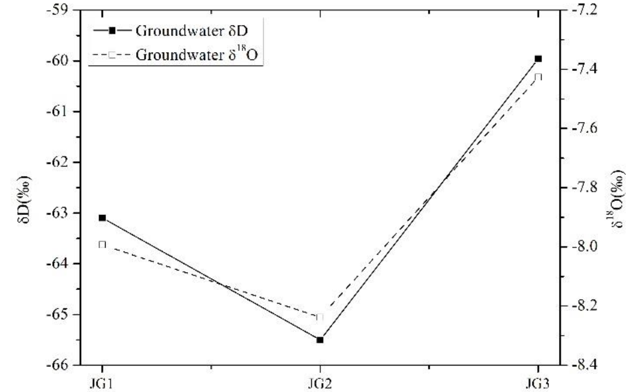
Data fitting for different water bodies in the contrasting watersheds

- **Results show that both the isotope slope and the intercept of the precipitation line in the study area are below the global meteoric water line (GMWL), $\delta D = 8\delta^{18}O + 10$. This result is consistent with the climatic characteristics of the Loess Plateau.**
- **The local meteoric water line (LMWL) was above both stream water and groundwater, while the slope and intercept are both greater than stream water and groundwater. This result suggests that stream water isotopes are located in the lower LMWL and demonstrates that this water is strongly effected by evaporation and fractionation.**

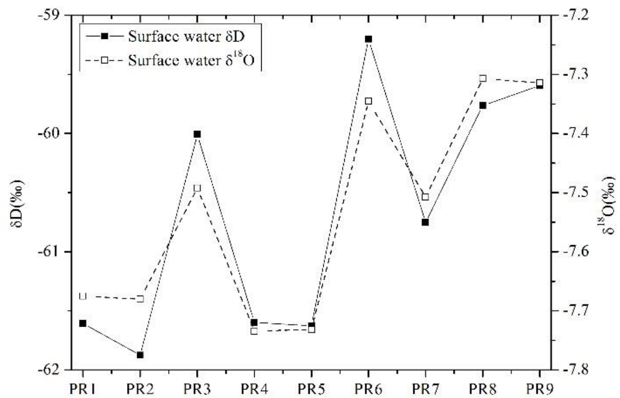
3 The evolution of stable isotopes with increasing river length



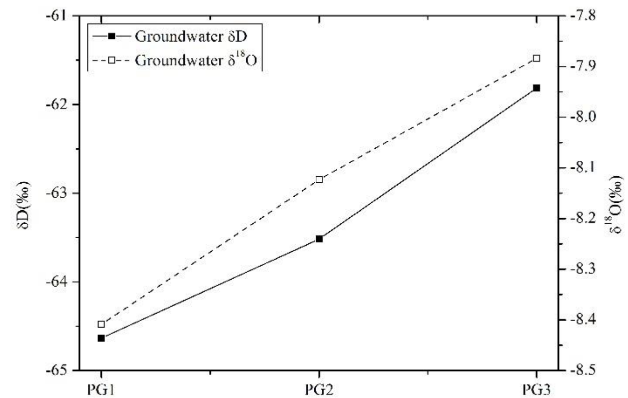
（a）Site of surface water samples in Jiuyuangou



（b）Site of groundwater samples in Jiuyuangou



（c）Site of surface water samples in Peijiamao



（d）Site of groundwater samples in Peijiamao

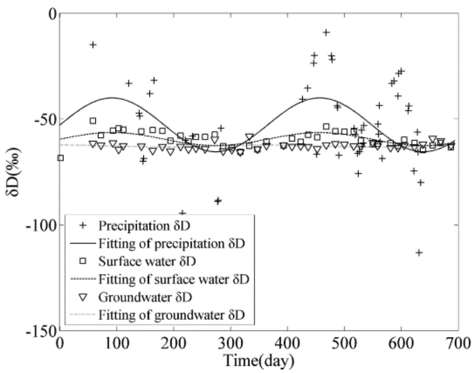
The evolution of stable isotopes in stream water and groundwater as distance increases

- **With increasing mileage from river source, δD and $\delta^{18}O$ values are gradually enriched mainly because of increasing elevation and surface evaporation as distance varies from upstream to downstream.**
- **As elevation and latitude decrease, the water evaporation effect along the river is enhanced and both stream water and groundwater are frequently exchanged and complemented.**

4 Water transmission time in the two contrasting watersheds

$$T = c^{-1}\left[\left(\frac{A_{z2}}{A_{z1}}\right)^{-2} - 1\right]^{0.5}$$

T refers to WTT, while A_{z1} is the amplitude of the input signal, A_{z2} is the amplitude of the output signal, and c is the fluctuation frequency (0.017214 rad d^{-1}).



Sine regression parameters and water transmit time

Stable isotopes	Contrast watersheds	Water types	N	Average/‰	Amplitude	WTT(day)	RMSE
δD	Jiuyuangou	Precipitation	51	-52.76	12.71	235	19.59
		Stream water	41	-59.48	3.05		2.96
		Precipitation	51	-52.76	12.71	1535	19.59
		Groundwater	40	-62.76	0.48		1.60
	Peijiamao	Precipitation	42	-59.56	8.32	117	19.27
		Stream water	40	-61.23	3.70		3.05
		Precipitation	42	-59.56	8.32	1361	19.27
		Groundwater	20	-63.45	0.35		1.08
$\delta^{18}O$	Jiuyuangou	Precipitation	51	-7.74	1.55	166	2.56
		Stream water	41	-7.38	0.51		0.51
		Precipitation	51	-7.74	1.55	1211	2.56
		Groundwater	40	-7.89	0.07		0.31
	Peijiamao	Precipitation	42	-8.53	1.21	145	2.61
		Stream water	40	-7.58	0.45		0.56
		Precipitation	42	-8.53	1.21	958	2.61
		Groundwater	20	-8.14	0.07		0.31

- **P-S WTT for Jiuyuangou were 1.53 times those of Peijiamao, which demonstrates that the WTT in the governance basin is larger compared to its natural counterpart. The implementation of ecological construction projects such as dams, reservoirs, and grasslands have effectively slowed the transformation of water and reduced flow rates.**
- **P-G WTT was about 7.6 times higher than that for P-S, revealing a complex transformation relationship between precipitation, stream water, and groundwater. The connection between precipitation and stream water is closer, however, while that between stream water and groundwater decreased.**

5 Water supply ratio in dry and wet seasons under ecological construction

Equilibrium equation:

$$Q_t = Q_u + Q_v$$

$$Q_t C_t = Q_u C_u + Q_v C_v$$

- **Precipitation and groundwater predominantly recharge stream water during the dry season. precipitation and groundwater recharge stream water supply ratios were 23.35% and 76.65%, and 74.26% and 25.74%, respectively.**
- **Precipitation and stream water mainly recharge groundwater during the wet season. Precipitation and stream water recharge groundwater supply ratios were 30.94% and 69.06%, and 87.80% and 12.20%, respectively.**

Water supply ratio analysis in dry and wet season

Contrast watersheds	Season	Water types	$\delta^{18}O$ (‰)	Supply ratio (%)
Jiuyuangou	Dry season	Precipitation	-5.53	23.35
		Stream water	-7.37	-
		Groundwater	-7.92	76.65
	Wet season	Precipitation	-8.22	30.94
		Stream water	-7.54	69.06
		Groundwater	-7.75	-
Peijiamao	Dry season	Precipitation	-7.25	74.26
		Stream water	-7.50	-
		Groundwater	-8.22	25.74
	Wet season	Precipitation	-8.16	87.80
		Stream water	-7.45	12.20
		Groundwater	-8.07	-

- **Ecological construction has significantly altered hydrological processes in the basin under governance basin. The fact that our stream water samples were taken along the channel while groundwater sample points were distributed to the sides also led to a close connection between the two and the continued occurrence of mutual conversions.**

Conclusions

Main Conclusions

- **Stable isotopes of stream water and groundwater in watershed under governance were enriched compared to those in natural watershed. Results show that upstream-to-downstream as mileage increases isotopes become enriched.**
- **WTTs are effectively extended in the watershed under governance via the implementation of ecological construction projects including dams, reservoirs, and grassland. Although different water bodies convert into each other in the same ways, the supply ratio is different between the two watersheds. Results show that precipitation and groundwater mainly recharged stream water in the dry season, while precipitation and stream water recharged groundwater during the wet season.**
- **The promotion of soil and water conservation measures to extend the WTT is shown to have a constructive effect on the Loess Plateau, although additional studies are required to further analyze WTT variation given ecological construction.**


Thank you!
我