Study on the Change of Hydrological Regime of the Major Tributary in Tao River Basin

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Objectives

This paper, taking the Yemu river, the primary tributary of Tao river, upstream of the Yellow River as the research object, analyzes its hydrological regime change so as to offer the data for verifying the effect of ecological protection and high-quality development implementation. Meanwhile, specific measures for strategy implementation in future are proposed considering the development status of the Yemu river basin, as a result, the policy for high-quality development of the basin and the example for others to follow are also provided.

Methods

（1）The MannKendall-Pettitt trend test proposed by Charles Rouge et al. is used to analyze the abrupt change point of the Yemu river basin caused by the dual effect. Assuming a time series n as X_n(n=1,2,…,n), $\forall \tau, 1 \le \tau \le n$, τ（1≤τ≤n）is any time nodes,the matrix A of n×n order is defined as:

$$a_{ij} = \begin{cases} \operatorname{sgn}(x_j - x_i) & if\ j \succ i \\ 0 & if\ j \le i \end{cases} \quad (1)$$

$$k(\tau, d) = \sum_{i=1}^{\tau+d} \sum_{j=\tau+1}^{n} a_{ij} \quad (2)$$

$$T_c = \arg\max\{|k(\tau, d)|\} \quad (3)$$

Then, define d_c as the minimum of $|S| \le |k(T_c, d)|$, the expression is written as:

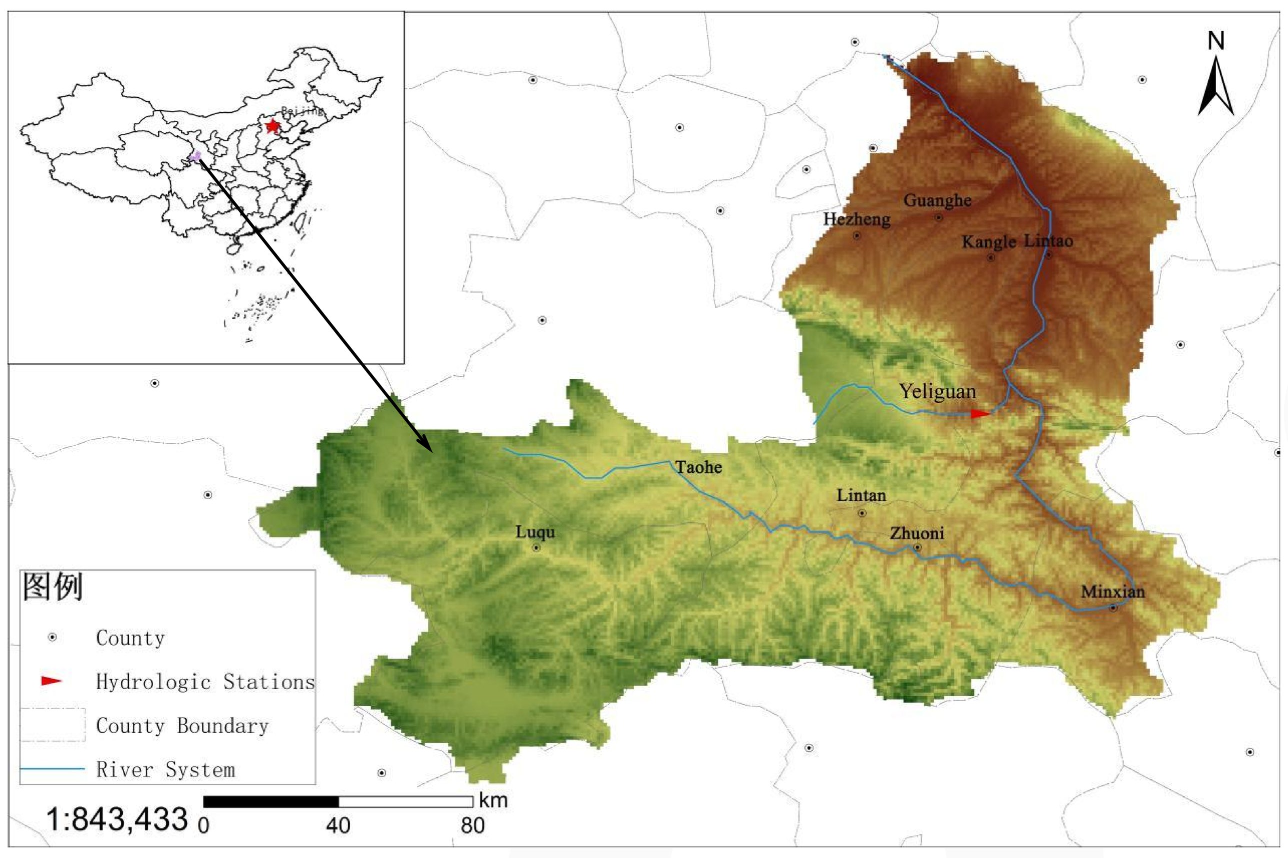
$$d_c = \arg\min_d \{d / |k(T_c, d)| \succ |S|\} \quad (4)$$

D is defined as a threshold value without physical meaning and its data range is determined by D/n in a range between 0.1 and 0.5. d_c will be steady change point after seeking out if d_c＞D, otherwise, will be abrupt change point.

（2）The hydrological regime similarity of the Yemu river in the climate change and anthropogenic intervention affected periods is evaluated by IHA-DTW. IHA is used for separately calculating the 33 indices representing the hydrological regime of the two periods, following that, their similarity is computed by DTW, which will reveal the similarity change taken place in the Yemu river.

Results

The DTW distance in flow characteristics, time distribution and change rate in both periods is less, explaining that the strategy implementation has exerted little effect on the above indices. However, the flow frequency and time-lapse are quite large, telling that the water conservation measure leads to aggrandizement of occurring frequency of runoff extreme value, but its time duration shortens.



Conclusions

(1) The gradual change point of runoff in the Yemu river appears in 2018 and there exists no abrupt change.

(2) The annual average flow increases by 0.38~6.5m³/s (29.79%) in the effected period, compared with that of the basis period. That explains the river ecological management and water conservation measure mainly by afforestation in the effected period have intensified its water conservation capacity. The river base flow somewhat increases, the background value of ecological base flow recovers to some extent, and the forewarning management for ecological flow is preferably good as well. Meanwhile, water conservation measure adopted in the effected period robs the baseflow, resulting in an evident baseflow reduction.

(3) The risk of drought and flooding in the river basin will increase and flow change will shift from stable to unstable.

Table 1. Calculating results of IHA for the two periods

Group	IHA	Basis period	Effected period
Parameter Group #1(flow characteristics)	Average flow in Jan./($m^3 \cdot s^{-1}$)	1.65	2.3
	Average flow inFeb./($m^3 \cdot s^{-1}$)	1.54	2.15
	Average flow in Mar./($m^3 \cdot s^{-1}$)	2.05	2.43
	Average flow inApr./($m^3 \cdot s^{-1}$)	4.39	4.89
	Average flow inMay/($m^3 \cdot s^{-1}$)	5.41	6.72
	Average flow in Jun./($m^3 \cdot s^{-1}$)	6	7.56
	Average flow inJul./($m^3 \cdot s^{-1}$)	7.3	13.8
	Average flow inAug./($m^3 \cdot s^{-1}$)	6.96	9.4
	Average flow in Sep./($m^3 \cdot s^{-1}$)	7.5	9.22
	Average flow inOct./($m^3 \cdot s^{-1}$)	7.34	8.18
	Average flow inNov./($m^3 \cdot s^{-1}$)	4.64	5.19
	Average flow inDec./($m^3 \cdot s^{-1}$)	2.44	3.12
Parameter Group #2(time distribution)	1-day minimum/($m^3 \cdot s^{-1}$)	1.29	1.77
	3-day minimum/($m^3 \cdot s^{-1}$)	1.333	1.88
	7-day minimum/($m^3 \cdot s^{-1}$)	1.364	1.969
	30-day minimum/($m^3 \cdot s^{-1}$)	1.485	2.082
	90-day minimum/($m^3 \cdot s^{-1}$)	1.795	2.304
	1-day maximum/($m^3 \cdot s^{-1}$)	34.1	33.8
	3-day maximum/($m^3 \cdot s^{-1}$)	24.67	30.23
	7-day maximum/($m^3 \cdot s^{-1}$)	19.11	25.66
	30-day maximum/($m^3 \cdot s^{-1}$)	13.01	17.39
	90-day maximum/($m^3 \cdot s^{-1}$)	10.04	13.58
	Number of zero days	0	0
	Base flow index	0.2643	0.2584
Parameter Group #3(frequency characteristics)	Date of minimum	29	70
	Date of maximum	189	215
Parameter Group #4(time-lapse)	Low pulse count	3	7
	Low pulse duration	7	1
	High pulse count	11	11
	High pulse duration	3	3
Parameter Group #5(change rate)	Rise rate	0.33	0.25
	Fall rate	-0.3	-0.38
	Number of reversals	123	170

Table 2. Calculating results of hydrological regime similarity for two periods

Group	IHA	DTW Distance
Parameter Group #1(flow characteristics)	Average flow in Jan./($m^3 \cdot s^{-1}$)	0.26
	Average flow inFeb./($m^3 \cdot s^{-1}$)	0.26
	Average flow in Mar./($m^3 \cdot s^{-1}$)	0.27
	Average flow inApr./($m^3 \cdot s^{-1}$)	0.27
	Average flow inMay/($m^3 \cdot s^{-1}$)	0.25
	Average flow in Jun./($m^3 \cdot s^{-1}$)	0.24
	Average flow inJul./($m^3 \cdot s^{-1}$)	0.24
	Average flow inAug./($m^3 \cdot s^{-1}$)	0.26
	Average flow in Sep./($m^3 \cdot s^{-1}$)	0.21
	Average flow inOct./($m^3 \cdot s^{-1}$)	0.24
	Average flow inNov./($m^3 \cdot s^{-1}$)	0.24
	Average flow inDec./($m^3 \cdot s^{-1}$)	0.24
Parameter Group #2(time distribution)	1-day minimum/($m^3 \cdot s^{-1}$)	0.49
	3-day minimum/($m^3 \cdot s^{-1}$)	0.49
	7-day minimum/($m^3 \cdot s^{-1}$)	0.46
	30-day minimum/($m^3 \cdot s^{-1}$)	0.26
	90-day minimum/($m^3 \cdot s^{-1}$)	0.23
	1-day maximum/($m^3 \cdot s^{-1}$)	0.24
	3-day maximum/($m^3 \cdot s^{-1}$)	0.2
	7-day maximum/($m^3 \cdot s^{-1}$)	0.24
	30-day maximum/($m^3 \cdot s^{-1}$)	0.26
	90-day maximum/($m^3 \cdot s^{-1}$)	0.26
	Number of zero days	0
	Base flow index	0.19
Parameter Group #3(frequency characteristics)	Date of minimum	0.23
	Date of maximum	0.24
Parameter Group #4(time-lapse)	Low pulse count	0.2
	Low pulse duration	0.26
	High pulse count	0.23
	High pulse duration	0.26
Parameter Group #5(change rate)	Rise rate	0.26
	Fall rate	0.27
	Number of reversals	0.44

Notes: The similarity is computed using the average flow of two time series, i.e. January of the years of 1981-2017 and the years of 2018-2020, so do the other indices.