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Quantitative Estimation of Annual Runoff Variation from the Hotan River, China

Lingmei Huang, Lina Wu & Bing Shen

Shaanxi Province Key Lab of Water Resources and Environment, Xi'an University of Technology

Xi'an 710048, China

E-mail: huanglm@xaut.edu.cn

Abstract

Starting from the existing analysis of runoff from the Hotan River, the varying cause of runoff in the Hotan River is analyzed using the annual runoff accumulated curves and the orderly cluster method, pointing out that the runoff from the Hotan River coming from the mountains falls into the natural runoff with the fluctuations because of being subject to climate changes. It is worth noticing that the Xiaota annual runoff flowing into Tarim River was reduced by 0.322 billion m^3 in comparison of the postior 1989 series with the prior 1989 series and under the join action by both human being activities and climate changes.

Keywords: Human activity, Climate change, Runoff

Economic development is very slow and environment is vulnerable because of water shortage, low rate of exploitation and utilization and waste for water resources in the arid area, China. The runoff in the arid area is changing under the climate warming and human activities, so its uncertainty of space-time distribution will increase. Water resource is the key to survival and development for the oasis in the arid area. To study the change of runoff in the rivers can provide the rational advice for the exploitation of soil and water resources, environment protection and sustainable utilization of water sources. Therefore, it is significant to conduct this work in the arid.

1. General situation

The Hotan river basin is located at the north of the Kunlun Mountain and the southeast of Tarim Basin. The Hotan River is 1127km long whose area is 48870km^2. It is the biggest river in the southeast of Tarim Basin and the secondly big river in the north of the Kunlun Mountain. It flows into the Tarim Basin from south to north, comes through the Takelamagan Desert and arrives to the Tarim River. It is the only river throughout the Takelamagan Desert and one of four existing source regions, too.

The Hotan river basin falls into the arid desert climate in the warm temperate zone with abundant light and heat resources. Temperature is 12.2℃ yearly and rainfall is 35.6 mm yearly on average. The observed values of water evaporation range from 2159mm to 3137mm. Dry degree is higher than 20, thus making for conduct the plant diseases and insect pests. Strong wind occur in spring and sand storms often break out in April and May that can bring the serious economic loss affect the life of the local persons.

There are two tributaries in the upper reach of the Hotan River. One is the Yulongkashi River; the other is the Kalakashi River. They converge at Kuoshilashi. There are three hydrological stations on the Hotan River (Fig.1), one is Tonguziluoka station on the Yulongkashi River, second is Wuluwati station on the Kalakashi River, and the other is Xiaota station on the lower reach of the Hotan River, whose catchment area is 48870 km^2. Surface water flowing into and out the Hotan Oasis is determined by three hydrological stations.

The Hotan Basin is one of the aridest areas in Xinjiang. Drought, sand storm and salt-alkalization are three natural disasters in the Hotan Basin; the utilization of soil and water resources is very low. The area of natural forest decreases 36% by disafforestation; the area of soil salt-alkalization accounts for 37.3% of the whole farmland; the area of soil desertification account for 52% of the whole area. The desertification area is increasing gradually because of big wind and sand storm. The lower reach of the Hotan River flows through the Takelamagan Desert where vegetation is very thin and big wind and sand storm is very so that its ecological system is very sensitive for the outer effect. Its capacity of renewing itself is very poor, thus it is the most frangible headstream. The area of vegetation cultivated by human in the middle reaches accounts for 32.4% of the oasis area. At a certain extent, the environment frangibility is improved, but the comprehensive assessment shows that the environment quality of the Hotan River falls into the moderate

vulnerability(Wang, 2001).

Uyre, as a minority in China, is the main people in the Hotan River Basin. Irrigation agriculture plays an important role for the local economy. However, the limited water resources restrict the social and economic development, restoring and building on environment. The change low of runoff from the Hotan River is studied to develop the local economy, improve the life and protect the environment, etc. under the condition of global climate warming and human activities.

2. Existing situation of runoff

There is a great deal of glaciers whose area is 10785 km^2 where annual precipitation is up to 800mm in the high mountainous area of the Hotan River distributes, so it is the place where runoff generates; in the low mountainous area falling into the hungriness zone, the vegetation is very thin and the velocity of runoff is very high, therefore it is not benefit for the runoff generation without the regulation fluctuation for the runoff supply; in the middle-lower reaches of the Hotan River falling into the transportation area and dissipation area of runoff, the runoff is gradually decreased, even dry, because of water diversion for agricultural irrigation, strong evaporation and seepage loss.

The Hotan River is the biggest river in the southwest of the Tarim Basin. The total of runoff is 43.8×10^8 m^3 on average (from 1957 to 2003) which can be taken as the surface water resources flowing into the Hotan Oasis, in which it is 22.3×10^8 m^3 for the Yulongkashi River, and 21.5×10^8 m^3 for the Kalakashi River. At the same time, there is 10.1×10^8 m^3 on average (from 1961 to 2003), accounting for 23.3% of the total of the Hotan River runoff, which is very important to maintain the ecological balance of the Tarim River and the whole Tarim Basin, prevent the desert from erosion and protect the green corridor.

The runoff distribution in a year lies on the supply condition. According to the calculation(Yang, 1987), the runoff from glaciers is 14.8×10^8 m^3 for the Yulongkashi River, accounting for 66.4% of its total; 10.01×10^8 m^3 for the Kalakashi River, accounting for 46.6% of its total. In addition, there are 18.3% and 24.3% respectively from the groundwater which is from the glaciers in the mountain area. So it is evident that the glaciers are the main source of runoff. The flood season occurs in July and August affected by the temperature and heat in the Hotan River Basin; the runoff highly concentrates in summer, accounting for 80.7%and 72.9%, respectively for the Yulongkashi River and the Kalakashi River; that is very less than 10% in Winter. Therefore, runoff can not be used effectively in flood season when the pressure of flood control is very large; water shortage is very serious in spring and in winter for agricultural irrigation and hydroelectric power.

3. Runoff change

The Hotan River Basin has a long history; oasis economy is closely linked with the runoff from the Hotan River. It is observed that no water is no oasis, no agriculture, either. So the stability of the runoff from the Hotan River is the prior condition of survival and development for the Hotan Oasis. According to the previous findings, it can be known that the runoff from the Hotan River has an unremarkable degression trend and the runoff flowing into the Tarim River has a remarkable degression trend(Huang, 2000).

3.1 Accumulated curves of the annual runoff

If the runoff is not affected by human activities, it has stochastic change among high, normal and low water. The accumulated runoff is dotted in a coordinate graph, which has no systematic deviation. By contrast, if the runoff is affected, its accumulated curves take on the systematic deviation. So we can judge whether the runoff series is affected by human activities according to its accumulated curve (Zhou, 2002).

The annual runoff accumulated curves of the Hotan River are made in Fig. 2. These curves of the Kalakashi River and the Yulongkashi River take on the fluctuation, but they basically like as a straight line. Their fluctuation occurs because of the stochastic change of hydrological series with the climate change. It can be seen that the runoff from two tributaries is not affected by human activities. The curve of Xiaota station has an outstanding deviation trend. The deviation dot presents in 1989, that is, the curve basically takes on a straight line before 1989 and it deviate from the straight line after 1989. While the Hotan River flows through the Hotan Oasis, runoff is diverted out the river to be used for agricultural irrigation. It became a seasonal stream in 1962. When the temperature rises in summer and runoff increases, surplus runoff flows through the desert to the Tarim River; no runoff flows to the lower reaches in the other seasons. So runoff under the canal headwork is affected by human. From the curves of Xiaota station, the interference is larger after 1989 than before 1989. The runoff series can be taken as two series from the time angle: one is before 1989; the other is after 1989.

3.2 The orderly cluster method

The hydrological series is affected by human activities is different from the intrinsic one. From the ‘cluster’ angle, it can be taken as two ‘cluster’. The cutting point can be found with the orderly cluster method (Liu, 1991).

The cutting point is the outstanding interference point in the hydrological series. It can make the sum of deviation square smallest for the same cluster series (in equation 1 and 2) and the sum of deviation square relatively bigger for the

different cluster series (in equation 3).

$$V_\tau = \sum (X_i - \overline{X}_\tau)^2 \quad (1)$$

$$V_{n-\tau} = \sum (X_i - \overline{X}_{n-\tau})^2 \quad (2)$$

$$S_n(\tau) = V_\tau + V_{n-\tau} \quad (3)$$

In which, τ is the interference point; $\overline{X}_\tau$ is mean value of hydrological series before the interference point; $\overline{X}_{n-\tau}$ is the mean value of hydrological series after the interference point; $S_n(\tau)$ is the total deviation. When equation 4 exists, the outstanding interference point τ is found:

$$S_n^*(\tau) = \min\ [S_n(\tau)] \quad (4)$$

From the runoff accumulated curves, only the runoff series of Xiaota station is affected by human activities. As a sample of Xiaota runoff, the interference point τ and its corresponding $S_n(\tau)$ are calculated with the orderly cluster method. The relation between $S_n(\tau)$ and year presents in Fig. 3. From the Fig. 3, it can be known that the minimum value of $S_n(\tau)$ occurred in 1989 consistent with the result of the runoff accumulated curves. Therefore, the outstanding interference point of Xiaota runoff series occurred in 1989. More than 50% runoff is diverted into the irrigation area when runoff flowing through the oasis, especially in spring seeding season, all of runoff is diverted to lead to flow-break in the lower reaches. The runoff flowing through the oasis has be interfered by human since 1961 when the runoff data are observed. According to the orderly cluster method and the accumulated curves, the outstanding point is found, that is 1989. The result is consistent with the practical condition that the plane reservoirs were built, the irrigation area and the intakes under the canal headwork were gradually increased.

3.3 Quantitative estimation

According to the former analyses, the runoff from two tributaries is not affected by human. The effect degree for Xiaota runoff is calculated. Xiaota runoff observed by human is not natural, so the absolute effect degree can not be analyzed. Based on the runoff series before 1989, the relative effect degree can be calculated and the future change can be predicted.

According to the outstanding point, Xiaota runoff series become two series, one from 1961 to 1988 (No. I series), the other from 1990 to 2002 (No. II series). Mean values for No. I and II are $11.66\times10^8 m^3$, $8.44\times10^8 m^3$, respectively. From the mean values, it can be seen that No. II series is affected larger than No. I series. According to the correlation analysis, the correlation equation can be obtained:

$$Y=11.615t+0.5997 \quad R=0.9987 \quad (5)$$

In which, Y presents the accumulated value of annual runoff, 10^8 m^3; t presents the time, t=1, 2, ……. The correlation coefficient R is closed to 1, which makes clear that the simple straight correlation exists between annual runoff and year. The relation can be used to estimate the decrease of the No. II series, compared with No. I series. The results are listed in Tab. 1.

From Tab. 1, accumulated decrease of Xiaota runoff is up to 45.13×10^8 m^3 from 1990 to 2002 on the base of No. I series, which is slightly larger than the total runoff from the Hotan River. Mean decrease per year is 3.22×10^8 m^3. The degression trend may continue before the effective measures are made to control over the runoff. The trend is not benefit for green corridor in the lower reaches of the Hotan River and affects the ecological environment of the Tarim River, too.

The main reasons that the runoff decreases are as follows. Firstly, water diversion for irrigation makes runoff in rivers decrease. Rainfall is very rare and evaporation is strong, irrigation is the life line of oasis agriculture. The irrigation area with 1.6 million ha farmland lies on the Hotan River. The river length through the irrigation is 165km, while the total length of canal system distributing in the irrigation area is 16979km. seepage loss and ineffective evaporation because of water diversion from the canal system largely increase. Secondly, the rivers gradually degrade, its capacity of draining floods is weaker and the overflow loss during the flood period is very serious. The main steam under the lower reaches of the Hotan River often is no water; the deserts along the rivers are approaching the rivers. Because of big wind, drift sand covers the river. When flood takes place, a great lot of water flows over the river to make loss. In the oasis, for flood control, flood is diverted into irrigation area from canal headwork to low-lying during flood period. This presented in 2000 and 2001. Lastly, the runoff from the two upper hydrological stations has an unremarkable degression trend. According to analysis, runoff has decreased 2.77×10^8 m^3 every year since 1989. Water use doesn't change, the runoff flowing to the lower reaches correspondingly decreases. So it can be seen that the main reasons of Xiaota station runoff decrease are human activities and climate change while that of the runoff from two upper hydrological stations is climate change.

4. Conclusion

Global climate warming and the effect of human activities make runoff from the Hotan River changing. Climate change

in the south of Xinjiang, the northwest arid regions and the whole globe affects the temperature in Kunlun Mountain to lead to an unremarkable degression trend of the runoff from the source regions of the Hotan River. In the source regions, runoff is not affected by human activities because of under population. When the Hotan River flows through the oasis, a great lot of runoff is diverted into the irrigation area to give rise to obvious runoff decrease flowing from the Xiaota station to the Tarim River. Water diversion for irrigation, evaporation, seepage and overflow are main reason to lead to runoff decrease flowing to the Tarim River, that is, the combination with human activities and climate change.

The change trend of the runoff from the Hoton River is not good to the development of the agricultural economy and ecological environment, not good to the survive and maintainment of the "green corridor" of the main river of Horton River in the Desert, and not good to the ecological protection and economic stability of the Tiam main river. So it is necessary that the scientific planning and comprehensive treatment are carried out for the Horton River.

Acknowledgement

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Table 1. Quantitative estimation of annual runoff from Xiaota station for human activity(unit: 10^8 m^3)

Year	Accumulated	decrease	Year	Accumulated	decrease
1989	337.4	7.31	1997	430.4	31.71
1990	349.0	5.41	1998	442.0	36.50
1991	360.7	8.26	1999	453.6	38.09
1992	372.3	15.24	2000	465.2	40.63
1993	383.9	26.48	2001	476.8	42.09
1994	395.5	14.36	2002	488.4	45.13
1995	407.1	24.96	Average		3.22
1996	418.7	28.11			

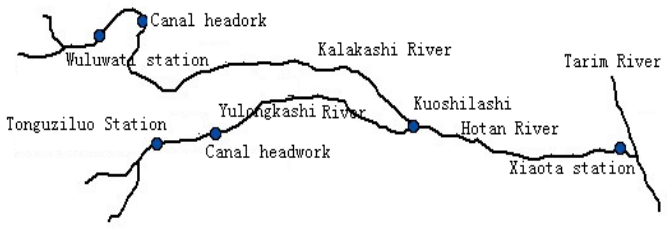

Figure 1. The water system of the Hotan River

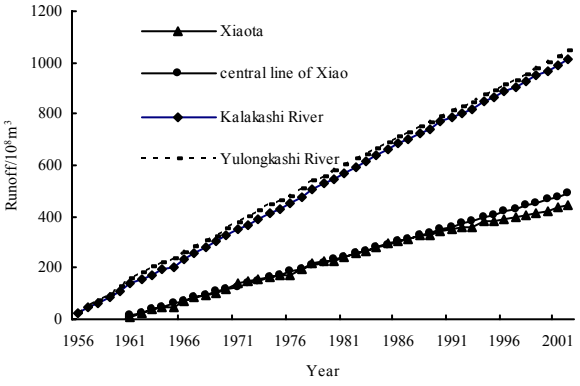

Figure 2. The annual runoff accumulated curves about three gauging stations of the Hotan River

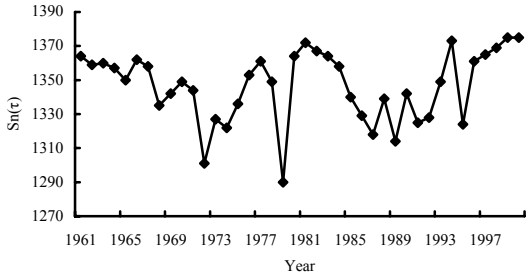

Figure 3. $S_n(\tau)$ hydrograph of annual runoff from Xiaota station