Analysis of Rainfall-Runoff Variation Characteristics and Influencing Factors in the Dawen River Basin in the Past 50 Years

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Abstract: Based on the hydrological data of Daicunba Hydrological Station of Dawen River from 1966 to 2017 and the meteorological data of surrounding stations, this paper analyzes the characteristics of the interannual variation of rainfall and runoff in the basin, and discusses the effects of rainfall and human activities on runoff. The results show that: (1) Rainfall and runoff in the Dawen River Basin showed an insignificant upward trend, with rising rates of 0.9541mm/a and 0.5398mm/a respectively; (2) Rainfall has a cycle of 4, 7, and 22 years, of which 22 annual cycle is the main cycle, and the runoff has a cycle of 5, 7, 18, and 22 years, of which 22 years are the main cycle, and the main cycle of rainfall and runoff is consistent; the rainfall mutation point occurred in 1997 and 2002, and the runoff mutation point occurred in 2002, the runoff had a significant increase trend after the sudden change; (3) According to the sudden change point of the runoff, the study area was divided into the base period (1966-2002) and the change period (2003-2017), so as to obtain the change of human activities on the runoff. The contribution rate is 60.6%, and the contribution rate of rainfall to runoff is 39.4%, indicating that the runoff of the Dawen River Basin is mainly affected by human activities.

1. Introduction

Water is the most basic natural resource and the most important factor of ecological cycle. It plays an important role in human production and life [1]. Studies have shown that in recent years, the temporal and spatial distribution of runoff in various river basins have changed significantly, which is manifested in the active occurrence of disasters such as droughts and floods. This is the combined effect of violent climate changes and frequent human activities. Therefore, it is necessary to strengthen the comprehensive study of the characteristics of runoff changes in the basin [2,3].

In recent years, domestic scholars have conducted a large number of studies on runoff and climate change in the Dawen River Basin. For example, Zhu Yizhen [4] used MK non-parametric statistics and linear trend methods to study the runoff mutation characteristics and precipitation of the Dawen River. The characteristics of temporal and spatial changes, the results show that the runoff and rainfall in the Dawen River Basin have been highly synchronized in the past 40 years, and both have an obvious upward trend. The runoff changes in the basin are mainly affected by changes in meteorological elements, but human destructive activities such as land use changes intensified the impact on runoff.
Zhang Rong [5] and others used Mann-Kendall trend analysis method and Spearman correlation analysis method to analyze the trend and correlation of various hydrological elements, and the results showed that the annual precipitation has a slight upward trend, and the runoff is opposite to the precipitation. There was a slight downward trend, and the evaporation showed an obvious downward trend. There was a positive correlation between precipitation and runoff, while the correlation between precipitation and runoff and evaporation was low, and there was an obvious negative correlation.

2. Study area and data sources

2.1 Overview of the study area
The Dawen River Basin is located between 116°11′15″-118°0′0″E and 35°37′30″-36°32′30″N. The Dawen River is an important surface water resource in Tai’an City, Shandong Province. Source: The drainage area is about 8762km², of which the drainage area in Tai’an City is 6726km². Its origin is the Xuangu Mountain Range in Yiyuan County. It connects with many water systems in the Taishan and Mengshan Mountains and flows from east to west through Shandong There are 7 counties and cities in the province, and finally into the Yellow River after going to Dongping Lake. It is the country's largest "backflow river" and a very important water system in the North China Plain [7].

2.2 Data sources
The meteorological data in this article comes from the China Meteorological Data Network (http://data.cma.cn/), selecting six stations including Taishan Station, Tai’an Station, Yiyuan Station and the nearby Zichuan Station, Yanzhou Station and Chaoyang Station in the Dawen River Basin. Meteorological and runoff data for 52 years from 1966 to 2017. The surface rainfall of the basin is calculated by the Tyson polygon method based on the rainfall data at six stations. The selection principle mainly considers the two aspects of having relatively complete long-term measured data and controlling the area of the basin as large as possible.

3. Research methods
The methods used in this paper include linear trend method [7], Mann-Kendall mutation test [8], wavelet analysis [9], and double cumulative curve contribution rate [10] methods. See references for details.

4. Results
4.1 Interannual variation and trend analysis of rainfall and runoff
Based on the 52 annual rainfall data of 6 meteorological stations in the Dawen River Basin from 1966 to 2017, the linear trend method was used to draw the annual rainfall trend map. From the analysis in
Figure 2(a), the annual rainfall in the Dawen River Basin has an increasing trend throughout the entire period, with a rate of 0.9541 mm/a. The average annual rainfall in the Dawen River Basin is 753.97 mm; Rainfall fluctuates in a wide range. During the entire analysis period, the maximum and minimum rainfall in the basin were 1,290.29 mm (1990) and 404.8 mm (2002), respectively. Combined with the Mann-kendall trend test, the statistic Z value is 0.12, indicating that the rainfall increase trend is not significant.

Figure 2(b) reflects the interannual variation trend of the runoff of the Dawen River from 1966 to 2017. The runoff showed an increasing trend throughout the entire period, with a rate of 0.5398 mm. The multi-year average runoff depth of the Dawen River Basin is 106.57 mm. In the whole analysis period, the maximum and minimum runoff in the basin are 301.49 mm (2004) and 30.1 mm (2002). Combined with the Mann-kendall trend test statistics, the Z value is 0.99, indicating that the runoff increasing trend is not significant.

4.2 Periodic analysis of rainfall and runoff

It can be seen from Figure 3(a) that the annual rainfall changes in the Dawen River Basin are mainly based on three time scales: 3-14 years, 15-25 years, and 26-32 years. The main cycle of annual rainfall in the Dawen River Basin is further analyzed by drawing the rainfall wavelet variance map. It can be seen from Figure 3(c) that 22 years, 7 years and 4 years are the three obvious main peaks on the wavelet variance curve. The main cycle of annual rainfall in the basin is the time scale corresponding to the largest peak on the curve. By analogy, the 22-year cycle is the main cycle, and the time scales of 7 and 4 years correspond to the second and third cycles.

As shown in Figure 3(b), the annual runoff changes in the Dawen River Basin are mainly based on three time scales: 3-12 years, 13-19 years and 20-32 years. From Figure 3(d), we can see that 5, 7, 18 and 22 years are the four obvious main peaks on the wavelet variance curve. The first main cycle of runoff is the time scale corresponding to the maximum peak on the curve, and so on, the main cycle is 22 years, and the time scales of 18, 7 and 5 years correspond to the second, third and fourth cycles.
4.3 Analysis of sudden change in rainfall and runoff

The M-K inspection of annual rainfall in the Dawen River Basin is shown in Figure 4(a). The UF curve and the UB curve intersect in the confidence zone in 1989, 2012 and 2016 respectively, but the UF did not exceed the critical value afterwards, so these three intersection points are not the mutation points of the rainfall sequence in the study area.

Figure 4(b) shows the M-K test of the annual runoff of the Dawen River Basin. It can be drawn from the figure that the UF curve has roughly gone through three stages of change, of which the value was below zero from 1966 to 1969. The figure shows that the UF curve and the UB curve have intersection points in 1970, 2007 and 2011 respectively. After 1970, the UF curve exceeded the confidence line twice, but did not exceed the confidence line after 2003, 2007, and 2011. The watershed runoff only experienced significant abrupt changes in 1970 and 2002.

4.4 Analysis of the causes of rainfall and runoff

Combining the Mann-kendall mutation test and the rainfall-runoff double accumulation curve, the most significant mutation point is determined to be 2002. The increase in runoff is attributed to the combined influence of the increase in rainfall and human activities. Therefore, the relative contribution rate of rainfall factors and human activities to runoff is further quantified based on the double accumulation curve. The results are shown in Table 1. The contribution rate of human activities to runoff changes was 60.6%, while the contribution rate of rainfall to runoff was 39.4%, which indicates
that the runoff of the Dawen River Basin is mainly affected by human activities. (Table 1)

| Period         | Measured average runoff depth /mm | Calculate the average net flow depth /mm | Rainfall factors | Human impact |
|---------------|----------------------------------|----------------------------------------|-----------------|--------------|
| Action value /mm | Impact rate /%                   | Action value /mm | Impact rate /% |
| 1966-2002     | 89.9                             | 91.69                                   | 23.59           | 39.4         | 36.21       | 60.6        |
| 2002-2017     | 149.7                            | 113.49                                  |                 |              |              |

5. Conclusion

Based on the hydrological and meteorological data of the Dawen River Basin, this paper analyzes the interannual variation characteristics, suddenness and periodicity of rainfall and runoff in the watershed, and finally discusses the effects of rainfall and human activities on runoff, and draws the following main conclusions:

(1) The rainfall and runoff in the Dawen River Basin showed an insignificant upward trend, with the rising rates being 0.9541 mm/a and 0.5398 mm/a respectively.

(2) Using wavelet analysis, we can get that rainfall has cycles of 4, 7, 22 years, of which 22 years are the main cycle; runoff has cycles of 5, 7, 18, and 22 years, of which 22 years are the main cycle, rainfall and runoff. Combined with Mann-kendall test and analysis, it can be obtained that the rainfall mutation point occurred in 1997 and 2002, and the runoff mutation point occurred in 2002.

(3) The double accumulation curve is used to quantitatively analyze the contribution of rainfall and human activities, and the study area is divided into a base period (1966-2002) and a change period (2003-2017), and the contribution rate of human activities to runoff change is 60.6%. And the contribution rate of rainfall to runoff was 39.4%, indicating that the runoff of the Dawen River Basin is mainly affected by human activities.

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