Precipitation Features of the Luoyugou Basin in Recent 26 Years

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Abstract. Precipitation is the main dynamic factors of soil erosion on the loess plateau region; the spatial and temporal distribution of precipitation has a great impact on the process of runoff and sediment yield. Luoyugou watershed is a typical small one of the third sub-region in gully and hilly regions of the Loess Plateau, which was laid the precipitation stations and the transfer stations for rainfall, runoff, sediment observation since the mid-1980s by the Tianshui Soil and Water Conservation Experimental station of Yellow River Conservancy Committee, who carried out the rule of basin soil erosion research. In this paper, on the basis of the observation data of Luoyugou watershed since 1985 to 2010, the precipitation features of the Luoyugou basin in recent 26 years were analyzed. And the analyzing results indicated that: The average annual rainfall of Luoyugou watershed is 548.4 mm, and the interannual and in-year precipitation of the watershed change greatly, uneven distribution of time and space; MK test showed that there is a slight increasing trend of the annual area rainfall, but is insignificant, and three break points occurred during the period on the base of the observed annual rainfall data. Meanwhile, relation between the annual precipitation, runoff and sediment yield was analyzed, and it turned out that the annual precipitation and annual runoff had a higher related degree. In conclusion, the rainfall has its own characteristics and has obvious impact on runoff and sediment yield. However, more study on the features of precipitation under different scales is required in the future.

Introduction

Precipitation is the main dynamic factors of soil erosion on the loess plateau region; quantitative description of the influence of rainfall on the erosion is the foundation of the correctly forecasting of soil loss. The space-time distribution of precipitation has a large influence on the runoff and sediment yield process. In the loess plateau region, due to the local precipitation, gustiness and strong strength, makes a quantitative description of precipitation characteristics has the certain difficulty [1]. Especially the influence of the topography and elevation, spatial distribution of precipitation in the basin is quite different [2].

According to the rainfall sites distributed in the basin, the relationship between precipitation, runoff and sediment was analyzed. The precipitation station is discrete distribution on the space, cannot fully reflect the actual continuous distribution of precipitation in space. In the actual study, we often need from precipitation station network observation to extract the characteristic values of the spatial distribution of rainfall or reasonable simulated rainfall spatial distribution. Analysis of the existing site of rainfall, in how to use the basin rainfall spatial distribution of the process, to the study of vegetation and land use pattern in the basin of the flood process and the rule of variation of erosion and sediment yield is of great significance.

On the basis of all the single precipitation data of rainfall station distributed in the Luoyugou watershed from 1985 to 2010, the average precipitation was calculated by using the Thiessen polygon method in the basin to analyze the spatial and temporal variations of precipitation and runoff in the basin, which laid a solid foundation for the relationship between erosion and sediment yield.

The study area

Luoyugou, which is a small catchment of 72.79 km^2, located in the northern suburbs of Tianshui, Gansu province, which is a primary branch lander by the left bank of the secondary tributary of the Yellow River, ranges from longitude 105°30' E to 105°45' E and latitude 34° 34' N to 34° 40' N, belongs to the third sub-region in gully and hilly regions of the Loess Plateau. Luoyugou watershed originates in Phoenix mountain foothill, flow from west to east, and disembogues into Xihe in the east of Qinzhou district of Tianshui. The canal system is a long and narrow pinnate, and the main channel is 21.81 km long, 3.37 km wide on the average, with the gully density being 2.34 km/km^2[3].

The terrain of Luoyugou watershed is from northwest to southeast tilt, with the average elevation of 1537.6 m. Water erosion and gravity erosion are the main types of soil erosion in the Luoyugou basin, with the average annual precipitation being 548.4 mm (1985~2010).

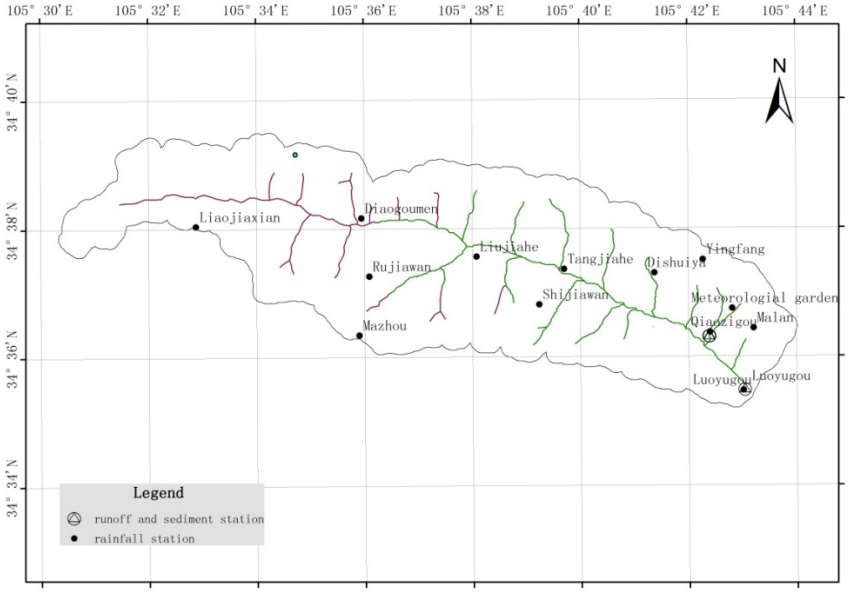

Fig.1 The precipitation stations layout in the Luoyugou watershed

Data presentation and method

2.1 Data presentation

Zuojiachang observation station was set up by Tianshui Experimental station on Soil and Water Conservation of the Yellow River Conservancy Committee in 1985, together with the precipitation stations (Fig. 1), began to be used to precipitation, runoff, and sediment monitoring work, which made up the rich observation data of rainfall, runoff and sediment discharge. In this paper, research was conducted by applying the data during the period of 1985-2010 in the Luoyugou watershed to identify the trends of the rainfall change of the basin and its relationship with runoff and sediment.

2.2 Method

2.2.1 The average rainfall analysis of the watershed

Based on all the single precipitation data of the Luoyugou watershed during the period of 1985 to 2010, considering the distribution of precipitation station, the Theissen polygon method (Fig. 2) was used in ArcGIS to calculate the average rainfall of the basin [4], which lays the foundation for analyzing the spatial and temporal variations of precipitation and the relation between rainfall, erosion and sediment yield.

Fig. 2 Theissen polygon figure of rainfall distribution in the Luoyugou watershed

2.2.2 Regression analysis

Regression analysis is a method commonly used in hydrological statistics, mainly including linear regression and nonlinear regression. Generally speaking, linear regression equations can be calculated by least square method[5]. In this paper, the regression analysis was used to analyze the relation between rainfall, erosion and sediment yield.

2.2.3 Mann-Kendall statistical test

The non-parametric Mann-Kendall (MK) statistical test has been popularly used to assess the significance of trend in climatic and hydrological time series [6]. Its advantage is that doesn't need to follow a certain distribution, also is not affected by the interference of a few outliers. The null hypothesis in the Mann-Kendall test is that the data are independent and randomly ordered. In this paper, MK statistical test was used to analyze the trend of precipitation of the study watershed.

Results and discussion

According to the observatory data of precipitation stations in the Luoyugou watershed from 1985 to 2010, the average interannual and in-year rainfall change trend are analyzed by using Theissen polygon method and MK test method.

3.1 The average in-year precipitation changes in the watershed

Calculated by the measured data, the average rainfall of Luoyugou watershed is 548.4 mm (1985-2010), uneven distribution during the year. It mainly concentrated in the flood season (from May to October), accounted for 82.9% of annual rainfall, of which accounted for 62.4% from June to September is 342.1 mm. The biggest monthly rainfall which accounts for 16.8% of annual precipitation occurred in July, minimum monthly rainfall in December, accounts for only 0.9% of annual rainfall (Fig. 3).

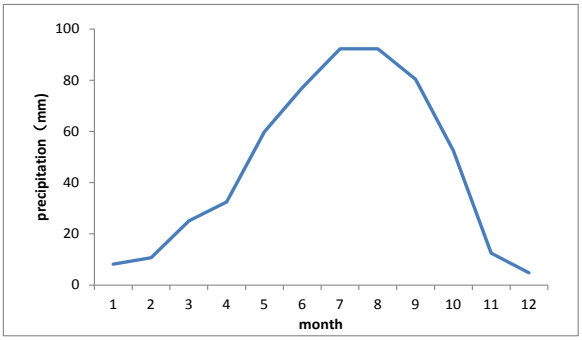

Fig. 3 The average in-year precipitation distribution in the Luoyugou watershed

3.2 The interannual variation of the average precipitation

As shown in Figure 4, the annual precipitation had great variation; the maximum value 841.4 mm (2003) is more than 2 times bigger than the minimum value 378.2 mm (1997). Through MK trend test, the results showed that the mean value is 548.4138mm, Z statistic is 0.61716, and slope

estimate is 1.2879, which means that there is a slight increasing trend of the annual area rainfall in the watershed, but is insignificant.

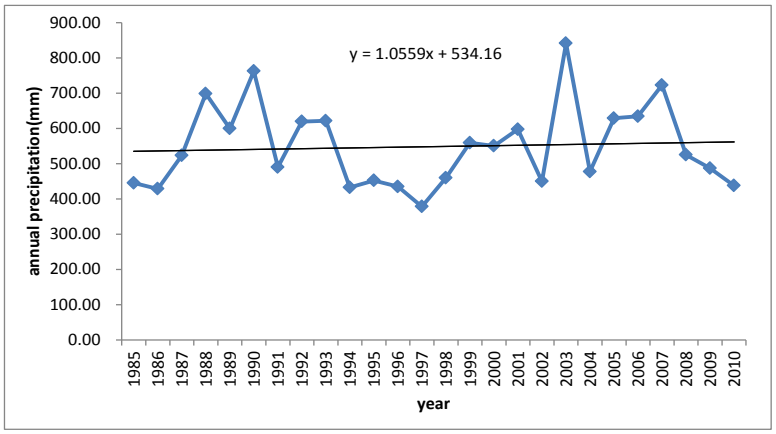

Fig. 4 The annual precipitation variation in the Luoyugou watershed

Meanwhile, based on 1985-2010 precipitation information of the Luoyugou watershed, abrupt change analysis of the MK test is used to analyze trend of precipitation in the past 26 years. As shown in Figure 5, there were three break points occurred in 1987, 1993 and 1999 respectively, which mean that since 1987 and 1999, the precipitation showed an evident uptrend, and showed a declined tendency since 1999.

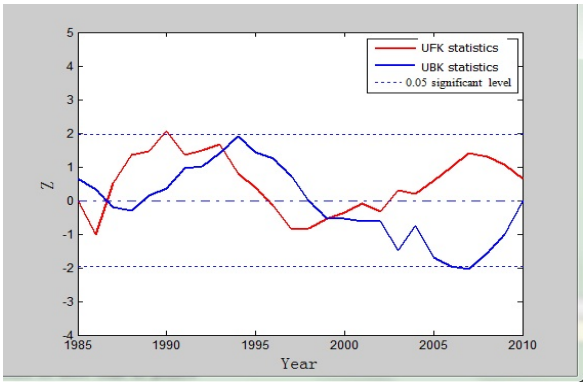

Fig. 5 Result of Mann-Kendall breaks of representative annual precipitation in the Luoyugou watershed

3.3 Analysis of relation between the annual precipitation, runoff and sediment yield

In order to further study the precipitation feature in the Luoyugou basin, relation between the annual precipitation, runoff and sediment yield was analyzed. Based on the observed statistical data year by year from 1985 to 2010, changes of annual rainfall-runoff-sediment discharge in the Luoyugou watershed were presented by Fig. 6.

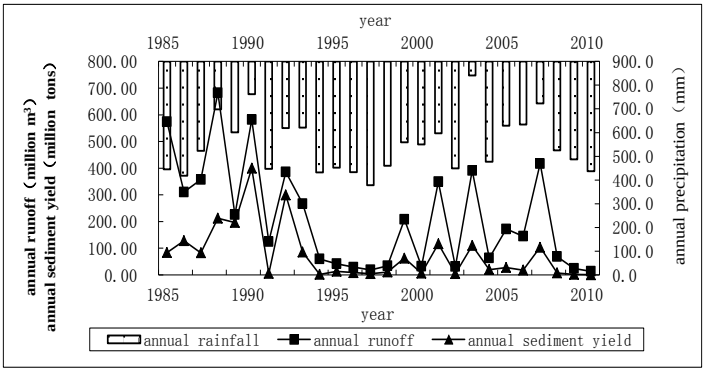

Fig. 6 Change of annual rainfall-runoff-sediment discharge for 1985–2010 in the Luoyugou watershed

From Fig. 6, it can be seen that the variation in the annual runoff and the sediment yield is basically consistent with variation in the annual rainfall. Then it is necessary to study the relationship between them more accurately.

3.3.1 Relation between the annual precipitation and annual runoff

As shown in Fig. 6, the changes of annual runoff and precipitation are identical for 1985-2010 in the basin. While Fig. 7 showed a linear relationship between the annual runoff and annual precipitation for 1985–2010 in the Luoyugou watershed. By Fig. 7, it can be seen that the annual runoff had positive linear relation to the annual precipitation, with the correlation coefficient R being 0.8729.

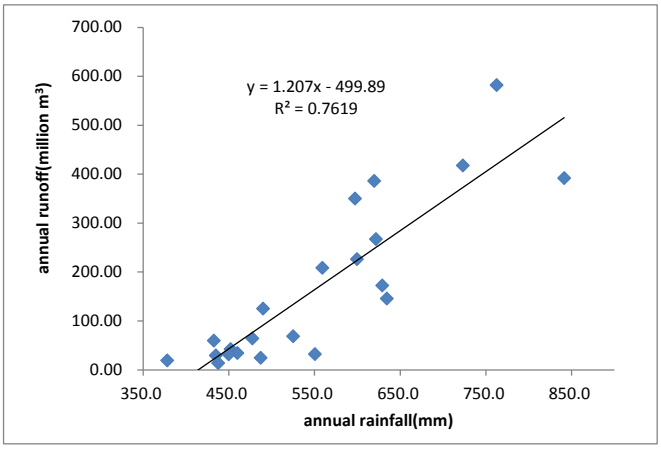

Fig. 7 The relation between annual rainfall and annual runoff for 1985–2010 in the Luoyugou watershed

3.3.2 Relation between the annual precipitation and annual sediment yield

Also as shown in Fig. 6, the annual sediment yield changed greatly over the past 26 years as well, basically in agreement with the tendency of the annual rainfall. But the difference was exhibiting as Fig. 8: the annual sediment yield changed with the annual precipitation in power function. The relation can be expressed as the formula $y = 6E\text{-}13x^{4.8864}$(R=0.7255).

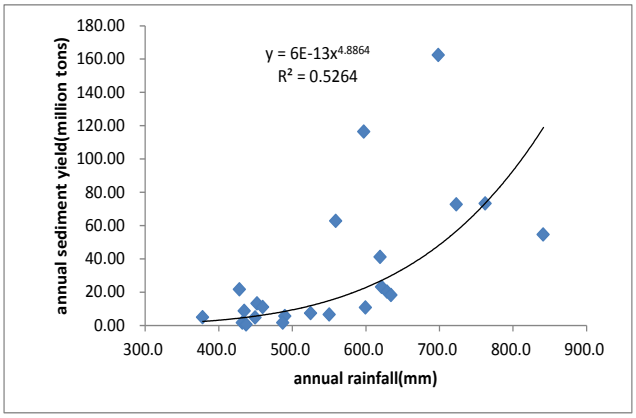

Fig. 8 The relation between annual rainfall and annual sediment yield for 1985–2010 in the Luoyugou watershed

Conclusions

Based on the observatory data of precipitation stations in the Luoyugou watershed from 1985- 2010, the average interannual and in-year rainfall change trends are analyzed by means of the Theissen polygon method and MK test method, which came to the following conclusions:

1）The average annual rainfall of Luoyugou watershed is 548.4 mm, and the in-year precipitation of the watershed change greatly, uneven distribution of time and space, which mainly concentrated in the flood season.

2）The interannual precipitation had great variation; the maximum value is more than 2 times bigger than the minimum value. Through MK trend test, it came to that there is a slight increasing trend of the annual area rainfall in the watershed, but is insignificant.

3）Based on the precipitation date in the past 26 years, MK test showed that there were three break points occurred in 1987, 1993 and 1999 respectively, which mean that since 1987 and 1999, the precipitation showed an evident uptrend, and showed a declined tendency since 1999.

4）The relation between the annual precipitation, runoff and sediment yield was analyzed, and it turned out that the annual runoff had positive linear relation to the annual precipitation, and the annual sediment yield changed with the annual precipitation in power function. It can be observed that the annual precipitation and annual runoff had a higher related degree by the value of the correlation coefficient.

It is obvious from the above that the rainfall has its own characteristics and has obvious impact on runoff and sediment yield. However, more study on the features of precipitation under different scales is required in the future.

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