RELATION BETWEEN PRECIPITATION IN DABIE MOUNTAIN WATERSHED AND SEDIMENT TRANSPORT IN DASHA RIVER VALLEY

Zhang Jian-chun[A] *and Shi Zhi-gang*[B]
[A] College of Territorial Resources and Tourism, Anhui Normal University, Wuhu 241000, PRC
[B] Water Conservancy Department of Anhui Province, Hefei 230022, PRC

Abstract
The study of sediment production and its relationship to climatic and hydrological factors in watersheds is of major environmental concern in the international community. Based on the observational records covering the period from 1954 to 1999, the characteristics of precipitation changing over Dasha River Watershed and its connection to sediment yield were studied using tendency analysis and correlation analysis. Results showed that the precipitation of Dasha River Watershed has a high variability. In those 46 years, 34% of spring rainfall, 58% of summer rainfall and 30% of annual rainfall will be considered anomaly. The gray correlation analysis shows that sediment discharge correlates most closely with the frequency of the rainstorm with a daily precipitation above 100 mm, secondly with the rainfall and the frequency of the rainstorm of a daily precipitation of 50-100 mm, and thirdly with the number of rainy days. The gray correlation grades are 0.98, 0.90 and 0.85 respectively. In addition, the paper suggests the major countermeasures and methods for controlling of soil and water losses in this area.

Additional Keywords: rainfall, sediment discharge, correlation grade

Introduction
Soil erosion and floods are probably serious environment problem worldwide and a major threat to the sustainability of agriculture and economic development. The study on sediment production and its relationship with climatic and hydrological factor in watershed is a major environment issues of concern in the international community. This paper, based on the data of the monthly average precipitation in Shahefu Hydrologic Station from 1954 to 1999, attempts to analyze the variation of the precipitation resources in Dashahe Watershed during the past 46 years and to predict the tendency of this variation. Meanwhile, in order to analyze the rainfall runoff factors and the features of the sediment in Dashahe Valley, results of the survey concerning silt-carrying runoff in this area from 1970 to 2000 have been employed and further analyzed to see if there is any correlation between the rainfall runoff factors and the sediment. The results show that these two closely correlate with each other.

Methods and Materials
Study area
The Dasha River, a 127.6 km-long tributary of Caizi Lake water system, originates in Yuexi County, Anhui Province, and flows into Caizi Lake via Shahefu Hydrologic station, which was established in 1950. It lies in longitude $116^0$50’ east, latitude $29^0$41’ north, The Dasha River controls an watershed area of 460 km^2, with a total population of 79400 in the year of 2000 and cultivated land of 0.38 ha per capita. Gross output value of agriculture and industry per capita is 918 and 1088 yuan respectively in 2000. The watershed mountain region’s economy is rather backward, partly because of the soil and water losses in Dabie mountain, which results in ecological environment degradation and harms the local people’s living condition and production. Therefore, it is quite meaningful to conduct a study on the natural variation of the precipitation in Dashahe Watershed and its relation with the sediment transport in Dashahe valley. Its findings will encourage rational exploitation of water resources, help to prevent and control water loss and soil erosion, and promote the formulation of the plan for social and economic development.

The elevation of most part of the upper reaches of Dasha river watershed is 200 m to 1500 m above sea level. Around 30% of the area is above 500 m. The morphology in this watershed is rather contrasting with deeply incised valleys and undulating mountains. Moreover, the parent material of this area is made of metamorphic rocks and granite, etc. This area is full of yellow-red earth down to 400 m and yellow-brown earth down to 1000 m, the vertical zonal distribution of soil and vegetation is very obvious.

The Huangbo Mountains in Dashahe Watershed is one of the rainstorm centre in Anhui province. The daily precipitation in history is 482.8 mm (16^{th} July, 1969). While the highest rainfall of a year amounts to 2708.5 mm (1969), and the lowest one is 781.3 mm (1978). The climate of this region is featured as a transition from the typical climate of Northern China to that of Southern China. On average, the temperature reaches 15.4^0C annually, $1\text{-}2.1^0$C in January and 27^0C in July. While the highest temperature of a year amounts to 41^0C, the lowest one is only -22^0C. The annual precipitation ranges from 600 mm to 1500 mm, about 60% of which can be accounted by the rainfall in flood period, i.e. from May to September. The area’s climate is especially prominent for its frequent rainstorms and variability of precipitation.

Variation of precipitation in Dasha River watershed

According to the data of precipitation in the past 46 years, on average, the annual precipitation of this region amounts to 1374.9 mm, among which 414.3 mm is in Spring, 630.2 mm in Summer, 197.4 mm in Autumn, and 133.0 mm in Winter. Obviously, in this area, it is mainly in summer, especially from June to August, that it rains, while spring follows suit. Rainfall in these two seasons accounts for 76% the total amount of precipitation of this year. After analyzing the data of the monthly average rainfall obtained from Shahefu Hydrologic Stations, from 1954 to 1999, the anomaly percentage curve of the annual rainfall and those of the Spring and the Summer have been worked out. If the anomaly percentage 25% is taken as a criterion in judging whether the rainfall is abundant or not in the past 46 years (WANG 1999), there are 11 summers which can be considered as being rich in rainfall, while 16 others experienced a shortage of rainfall. The results correspond to the severe floods or droughts occurring in that area. The summers when the highest anomaly percentages of rainfall have been achieved are respectively in 1954 (the anomaly percentage reaches 133.3%), 1969 (98.6%), 1991 (75.2%), 1977 (65.5%), 1963 (59.2%), 1955 (55.0%), 1981 (49.2%), 1983 (38.9%), 1974 (33.6%), 1996 (29.6%) and 1980 (28.9%). On the contrary, the anomaly percentage of rainfall declined to the lowest points in the summers of the following 10 years: 1967 -63.0%, 1978 (-61.2%), 1976 (-59.4%), 1985 (-53.1%), 1990 (-46.6%), 1968 (-43.1%), 1965 (-42.8%), 1989 (-37.4%), 1992 (-37.0%) and 1960 (-35.9%) .

In terms of the anomaly percentage of rainfall in spring, there are 8 years in which the percentage is above 25%, and another 8 years with a percentage below 25%. Thus, it can be said that in spring it is more likely to have a rainfall with the normal level, that is, the anomaly percentage of rainfall ran up to72.5% in 1963, while in 1997 came the lowest -48.3%. In terms of the total amount of annual precipitation, there are 6 years that have a higher anomaly percentage of rainfall than 25%, i.e. 1954 (88.7%), 1991 (53.0%), 1983 (48.4%), 1977 (46.8%), 1963 (37.5%) and 1969 (32.1%), whereas the anomaly percentage of the rainfall does not come to -25% in another 8 years, i.e. 1978 (-44.2%), 1967 (-38.7%), 1976 (-36.1%), 1994 (-32.9%), 1966 (-28.4%), 1968 (-26.0%), 1997 (-25.3%) and 1965 (-25.1%).

From the statistics of annual rainfalls, it can be found that the 6 highest rainfalls, together with 8 lowest rainfalls appear in the 1960s, 1970s, 1980s and 1990s respectively. In this sense, the annual rainfalls of Dasha River Watershed show lower variability. But it can be found that 3 of the 8 lowest rainfalls of spring, together with 6 of the 16 lowest rainfalls of summer appear in the 1990s. In this sense, the spring and summer rainfalls of Dasha River Watershed, with an even higher variability, have tended to decline since 1990. In the same way, the annual rainfalls also show certain tendency while varying by stages.

Moreover, accumulated anomaly percentage curve has also been worked out so that the way in which the annual rainfall and that of spring and summer tend to vary in a long period of time can be figured out. In the past 46 years, it is obvious that the precipitation has undergone variation by stages. Spring rainfall has achieved a high variability, with a declining tendency from the end of 1970s to the end of 1980s. Then from 1990 onwards, it has been showing a rising tendency. As regards the summers precipitation, an increasing amount of rainfall has been obtained from the end of the 1980s to the beginning of the 1990s. After that, however, the rainfall has been declining. In general, the annual precipitation has varied in accordance with that of summer□that is, in the middle and later part of the 1990s, the rainfall has been inclined to decrease. But with a view to the whole picture of the rainfall in the past 46 years, a tendency of decline has been shown in spring rainfall, in summer rainfall and that of annual.

Results and Discussion

Features of rainfall and floods

According to the statistics on the average rainfall from 1954 to 1999, in Dashahe Watershed, 74.8% of the annual precipitation comes in spring and summer. While that of the flood period (from May to September) amounts to 65.2% of the annual rainfall. Moreover, during flood period it is much likely to have rainstorms. From the later part of March till the beginning of November, rainstorms can occur. On an average scale, rainstorms would be likely from the middle part of June to the middle part of August. The length of the days with downpour varies from year to year, and more than 10 days in 1999, 1991, 1975, 1977 and in 1983, while none in 1978.

According to the data of the precipitation from 1970 to 2000, provided by Shahefu Hydrologic Station of Dashahe Valley, there are 102 days whose rainfall reached 50-100 mm, and 21 days with daily precipitation above 100 mm since 1970. The largest daily rainfall in 1970s, 1980s and in 1990s, is on July 28th, 1977 (201.3 mm), July 4, 1983 (210 mm) and August 6, 1991 (122.2 mm) respectively . What is more, the storm flow is closely related to the flood discharge in Dasha Valley. For instance, immediately after a strong downpour on July 4, 1983, on July 9th the largest flood discharge in history so far, one of 2370 m^3/s, which is 5 times as large as the average flow of the rest of the years in 1980s followed. Another example lies in the fact that, the largest daily flood discharge following the rainstorm on July 28th, 1977, is almost twice as large as the average flow of 1977. With mountains surging in Dasha River Watershed, a long-time strong rainstorm is bound to scour the bare rock on the dip and even wash away the thin slope wash or saprolite, aggravating the soil erosion and further sterilizing the soil on the Dabie mountains. Rainfall and rainfall erosivity is an important factor in water and soil losses .

Features of sediment

After analyzing the data from 1970 to 2000 (Table 1), it was found that the largest sediment discharge of a year and that of the flood season tend to be influenced by rainstorms and floods. As shown in Table 1, in the 1970s, the annual amount of sediment transport, amounting to 243400 t and 1.42 times as large as the average of the rest 31 years. Moreover, 83.77% of the sediment discharge of the 1970s, that is, 207500 t, can be ascribed to the sediment transport in flood period. According to the statistics conducted during the 31 years (1970-2000), on average, the sediment discharge of flood period accounts for 86.04% of that whole year, while water discharge of flood period takes 69.94% of the annual one, and rainfall in flood period 64.43%. Conclusions can be drawn from this rainfalls and floods in flood period are correlated with the sediment discharge.

Besides, the average annual amount of rainfall and runoff in the 1980s is larger than that of in the 1970s, but the average annual amount of sediment transport is lower than that of in the 1970s. This is because 9 small watersheds, an area of 180.74 km^2, have been treated with soil-water conservation measures since 1982, the controllable area takes up 82.93% of the total area in Dasha river watershed. Compared with the 1970s, the average annual sediment reduction is 43000 t in the 1980s, and had significant profits of reducing sediment yield.

Table 1. Distribution of annual rainfall, runoff and sediment discharge

Year	Distribution of annual rainfall (mm)			Distribution of annual runoff (10^8 m^3)			Distribution of annual sediment discharge (10^4 t)		
	Flood period	Annual	(%)	Flood period	Annual	(%)	Flood period	Annual	(%)
1970s	919.07	1380.1	65.53	2.73	3.80	69.35	20.75	24.34	83.77
1980s	978.77	1473.2	66.47	3.27	4.48	73.43	18.52	20.04	92.96
1990s	795.95	1281.2	61.27	2.36	3.40	67.03	5.86	6.93	81.39
average	897.93	1378.2	64.43	2.79	3.90	69.94	15.04	17.11	86.04

Gray correlation analysis of the sediment discharge and the rainfall runoff factors

According to the data provided by Shahefu Hydrologic Station, a table concerning the monthly distribution of the sediment discharge, the precipitation and the runoff of Dashahe Watershed in the past 31 years (1970-2000) has been worked out. Based on these figures obtained from observation, gray correlation analysis, which was proposed by Tang Qi-yi in The Practical Statistics and DPS Data Processing System (Tang, 2002), was conducted to the sediment discharge and various rainfall runoff factors in Dashahe Watershed (Table 2). The results calculated in Table 2 indicates that, the sediment discharge correlates most closely with frequency of the rainstorm with a daily precipitation above 100 mm, the gray correlation grade is 0.98; in the second place, with a daily precipitation of 50-100 mm, the gray correlation grade is 0.90; and thirdly with the number of rainy days, the Correlation grade is 0.85.

The above findings well correspond to the reality of Dasha River Watershed. Owing to this area’s undulating land forms, poor incrusting substance, instead of being totally absorbed and stored by the soil, should most probably become surface runoff, resulting in the loss of water and soil erosion. In this sense, it can be said that the sediment discharge correlates most closely with the rainstorm with a daily precipitation above 100 mm and 50-100 mm. The number of rainy days in Dabei Mountains appears more frequently than that of other areas. In the long run, the rainy days will contribute more to soil erosion than others areas. Admittedly, not all the rainfall leads to surface runoff and soil erosion. Thus, the weakest correlation has been found between the sediment discharge and the monthly average rainfall.

Table 2. Correlation grade between sediment discharge and rainfall-runoff factors

Sediment discharge	Rainfall	Runoff	Rainstorm (50~100 mm)	Rainstorm (≥100 mm)	Rainy days
1	0.60	0.71	0.90	0.98	0.85

Conclusions

According to the monthly average precipitation from 1954 to 1999, the precipitation of Dasha River Watershed has a high variability. If 25% is set as the criterion in judging whether the rainfall is an anomaly or not, in those 46 years, 34% of spring rainfall, 58% of summer rainfall and 30% of annual rainfall will be considered anomaly. Those summer seasons having anomaly precipitation suffer mostly from drought rather than flood. Periodicity features in the variation of precipitation. With respect to the long-term varying process in the past 46 years, a tendency of decline has been shown in spring rainfall, in summer rainfall and that of annual. As shown in the gray correlation analysis of the sediment discharge and the rainfall runoff factors in Dasha River Valley from 1970 to 2000, the rainstorm with a daily precipitation above 100 mm and of 50-100 mm have been identified as the main factors affecting the sediment discharge. Therefore, it is of great importance to strengthen the hydrologic prediction and defense of unusual flood hazards in mountain areas.

References

Tang, Q.Y. (2002). Practical statistics and DPS Data Processing System. Science Press, Beijing

Wang, Qun Ying, Gong Dao Yi (1999). Variation of rainfall over North China and its possible connection to El Nino. *Journal of Natural Resources* 14(2), 03-108.