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Analysis on Water and Sediment Reduction Effects of Soil and Water Conservation Measures in the Sanchuanhe River Basin of the Yellow River

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Abstract. According to the research, during 1997 to 2006, comprehensive harnessing on water and soil conservation reduced 34.77 million m^3 of flood, the rate of flood reduction is 62.7%, The amount of sediment decreased by 1.482 million tons, a decrease of 83.6%. Compared with the rate in the past, flood and sediment reduction rate has an increasing trend year by year. The rate of flood reduction during 1997 to 2006 increased nearly twice as much as that in 1970s and 1980s; the rate of sediment reduction is also significantly higher than past years. Water and soil conservation measures have a great effect in SanChuanhe River basin.

1. Introduction

Sanchuanhe river is a typical branch located in the production of coarse sediment area, in Hekou Town to Longmen Area of the Yellow River. It originated from Chijianling, Northeast of Fangshan County, Shanxi Province，compiled by the three major tributaries of Beichuan River, Dongchuan River and Nanchuan River (fig.1). The basin area is 4,161km^2. Houdacheng hydrometric station is the outlet hydrological station of the basin. Because the basin is located in the Loess Plateau, it belongs to arid and semi-arid continental climate, and its water resources are extremely poor. In addition, the terrain is complex, the coverage of vegetation is small, and the soil erosion is serious. The total drainage area of the whole basin is 2800km^2, accounting for 67.5% of the total area. The spatial and temporal distribution of sediment production is concentrated. In the flood season, the sediment discharge accounts for 98% of the annual sediment discharge, while the sediment discharge in July and August accounts for 90.6% of the sediment discharge in the flood season. The area of sand production in the basin is mainly concentrated in the hilly area and beam-shaped hilly area. The area of the above two areas accounts for 24.71% and 41.04% of the basin area, respectively, and the sand production accounts for 51.3% and 39.98% of the whole basin[1-4].

From 1982 to 1997, the basin was classified as the Key Soil and Water Conservation Management area in the state, the country and Shanxi Province invested massive manpower and material resources in Sanchuanhe river basin's water and soil conservation. Through reservoir construction, expansioned irrigation area, developed soil and water conservation measure , basin's management has been rapidly developed, economic and ecological environment has been greatly improved. This paper use

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hydrological method calculat the flood and sediment reduction by water and soil conservation measures in recent ten years, and evaluate the effects of water conservation management in recent years[5-8].

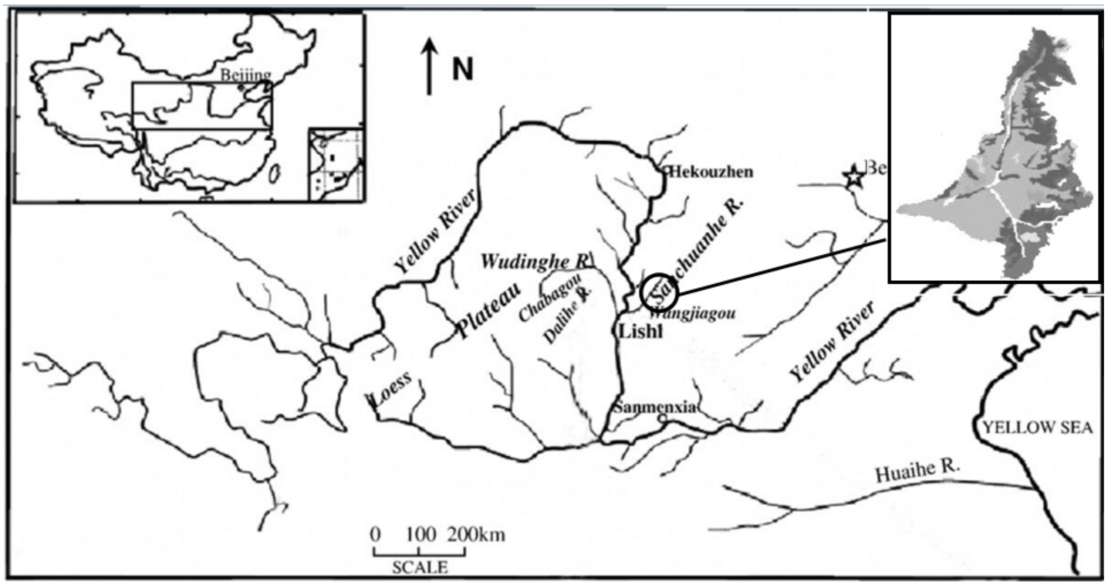

Figure 1. Location of the Sanchuanhe river basin

2. Materials and methods

2.1. Data collection

The analysis and calculation of water reduction and sediment reduction in soil and water conservation in a basin is based on the observation of hydrological sediment data and the number of water conservation measures in the basin. The reliability of the data directly affects the credibility of the calculation results. From the current hydrological data, the main problem is the station is not equality, data series are not regular[9]. In water and soil conservation data, the existence of large-scale water and soil conservation measures not clear, the statistical work affected by means and human factors not conform to reality, that not only serious affected the integrity of data, but also serious affected the data's representativeness and reliability. So we should widely collected hydrological data, extend basic data.

The so-called "serialized process", is take rainfall data in more stations for the standard, establish rainfall data correlation between a few stations with more stations. To do so, it can take full advantage of the rainfall data, while ensuring the data's consistency[10].

2.2. Calculation methods

This paper uses the empirical formula to calculate the flood and sediment reduction by water and soil conservation measures, the empirical formula is the most important hydrology method in flood reduction rate calculation, its basic principle is: through analysis the basic rule of rainfall, take datum time's rainfall, flood and sediment data which before the water and soil conservation measure has obviously effect as the basis, establish Rainfall-Sediment model; Take measured rainfall data after 1970 in this model, Calculate the amount of water and sand that should be produced when the underlying surface is constant. The difference between calculated and measured water and sediment is the reduction by human activities, specific formulas are as follows.

(1) Flood reduction

Use the data before management, the rainfall-flood equation in Houdacheng station is:

$$W_H = 0.00365\, P_{7+8}^{2.6665} \quad (R = 0.94) \tag{1}$$

In the formula: W_H is the flood production (10^4 m^3); P_{7+8} is precipitation in July and August (mm).

(2) Rainfall and reduction of flood benefits

Flood sediment is sediment carried by flood. In the basin, sediment is nearly all carried by flood. Use flood sediment in base period fitting with the rainfall can establish the rainfall-sediment model:

$$W_{HS} = 0.0248 P_{7+8}^{2.9778} / P_N^{\ 0.7595} \quad (R=0.92) \tag{2}$$

In the formula: W_{HS} is flood sediment (10^4 t); P_{7+8} is precipitation in July and August (mm); P_N is yearly precipitation (mm).

(3) Empirical formula calculate flood and sediment reduction rate

Empirical formula calculate flood and sediment reduction formula as below:

$$\eta(\%) = \Delta W / W_c \times 100\% \tag{3}$$

In the formula: η is flood (sediment) reduction rate (%); W_c is calculated flood (sediment) values by use of rainfall producing model; ΔW is the difference between the measured value and calculated value.

(4) Flood and sediment affected by rainfall

Rainfall affection take the period without human impact as the base, compared with the base period's sediment and run-off value, the difference between them is the rainfall variation changes, the formula is:

$$\Delta W_r = W_{mb} - W_{ca} \tag{4}$$

In the formula: ΔW_r is flood and sediment variation affected by rainfall; W_{mb} is measured flood or sediment in base period; W_{ca} is calculated flood or sediment after management.

Flood and sediment variation affected by rainfall or human activities use the percentage:

$$\text{Rainfall influence} = \Delta W_r / (W_{mb} - W_{ma}) \times 100\% \tag{5}$$

$$\text{Human activity influence (\%)} = \Delta W_p / (W_{mb} - W_{ma}) \times 100\% \tag{6}$$

In the formula: W_{ma} is measured flood (sediment) after management; ΔW_p is flood and sediment variation by human activity, ΔW_p can calculate according to the equation below:

$$\Delta W_p = W_{ca} - W_{ma} \tag{7}$$

3. Results and discussions

3.1. Flood and sediment reduction

Using the formula (1) ~ (3), can calculated flood and sediment reduction in Sanchuanhe River basin, flood and sediment reduction rate (Table 1 and Table 2).

Table 1. The results of flood and sediment calculated by empirical formula in Sanchuanhe River basin

year	P_{7+8}(mm)	P_N(mm)	W_H（10^4 m^3）	W_{HS}（10^4 t）
1997	151.3	332.8	2372.4	933.0
1998	154.1	411.1	2492.3	839.6
1999	195.6	353.2	4708.3	1917.3
2000	258.5	498.8	9902.5	3383.3
2001	180.9	411.2	3819.4	1352.1
2002	122.5	493.8	1350.4	368.5
2003	213.1	613.7	5916.4	1626.2
2004	229.9	436.3	7243.4	2641.5
2005	173.8	405.9	3434.5	1212.7
2006	250.7	492.7	9120.8	3115.7

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Table 2. The results of flood and sediment reduction calculated by empirical formula in Sanchuanhe river basin

Year	Flood（10^4 m^3）				Sediment（10^4 t）			
	actual	computation	differential	benefit %	actual	computation	differential	benefit %
1997	632.5	2372.4	1739.9	73.3	86.7	933	846.3	90.7
1998	1264.2	2492.3	1228.1	49.3	373.6	839.6	466.1	55.5
1999	972.7	4708.3	3735.6	79.3	142.2	1917.3	1775.1	92.6
2000	4115	9902.5	5787.5	58.4	1080	3383.3	2303.3	68.1
2001	383.9	3819.4	3435.5	89.9	5.9	1352.1	1346.2	99.6
2002	1225.1	1350.4	125.3	9.3	148.7	368.5	219.8	59.6
2003	2152.9	5916.4	3763.5	63.6	160.7	1626.2	1465.5	90.1
2004	1780.8	7243.4	5462.6	75.4	242.8	2641.5	2398.8	90.8
2005	454.4	3434.5	2980.1	86.8	8.4	1212.7	1204.3	99.3
2006	2609.2	9120.8	6511.6	71.4	324.5	3115.7	2791.2	89.6
1997～2006	1559.07	5036	3437	62.7	257.3	1739	1481.6	83.6

Take the value into formula (4) ~ (7), can obtain the rainfall - flood –sediment reduction and comprehensive management- flood –sediment reduction (Table 3). From table 3, from 1997 to 2006, because rainfall less than the base period, rainfall - flood reduction is 64,850,000m^3, accounting 63% of the annual mean, comprehensive management- flood reduction is 34,770,000 m^3, accounting 37% of the annual mean. Rainfall-sediment reduction is 19,310,000 t, accounting 55.2% of the annual mean, comprehensive management- flood reduction is 14,817,000 t, accounting 44.8% of the annual mean. It can be seen that the recent flood and sediment reduction is more influenced by rainfall.

Table 3. The results of flood and sediment reduction affected by rainfall

Project	Year	Rainfall influence		Government	
		Rainfall	Proportion	Management	Proportion
Flood	1997	9148.6	84	1739.9	16
	1998	9028.7	88	1228.1	12
	1999	6812.7	64.6	3735.6	35.4
	2000	1618.5	21.9	5787.5	78.1
	2001	7701.6	69.2	3435.5	30.8
	2002	10170.6	98.8	125.3	1.2
	2003	5604.6	59.8	3763.5	40.2
	2004	4277.6	43.9	5462.6	56.1
	2005	8086.5	73.1	2980.1	26.9
	2006	2400.2	26.9	6511.6	73.1
	1997～2006	6485	63	3477	37
Sediment	1997	2737	76.4	846.3	23.6
	1998	2830.4	85.9	466.1	14.1
	1999	1752.7	49.7	1775.1	50.3
	2000	286.7	11.1	2303.3	88.9
	2001	2317.9	63.3	1346.2	36.7
	2002	3301.5	93.8	219.8	6.2
	2003	2043.8	58.2	1465.5	41.8
	2004	1028.5	30	2398.8	70
	2005	2457.3	67.1	1204.3	32.9
	2006	554.3	16.6	2791.2	83.4
	1997～2006	1931	55.2	1481.7	44.8

When soil and water conservation measures produce efficiency from 1970 to 2006 (Table 4, 5), flood reduction rate is 44.2%, sediment reduction rate is 63.4%. Compared flood and sediment reduction over the years, we can see flood and sediment reduction rate has an upward trend year after year, from 1997 to 2006, the sediment reduction rate increase more than doubled to the 70 and 80 ages, sediment reduction rate greatly higher than the rate over the years. In 20th century70s and early 90s, comprehensive management-flood reduction rate remarkably, take the leading position, especially in early 90s, sediment reduction is especially remarkable; in 80s and 1997~2006, is the rainfall influence occupy the dominant position, followed by the comprehensive management. From 1970 to 2006, due to the comprehensive management, 33.49 million m3 flood and 16,710,000 t sediment have been reduced.

Table 4. The results of flood and sediment reduction affected by rainfall

Calculated series	Actual	Flood reduction	Management		Rainfall influence		Flood reduction (%)
			Decrement	Proportion (%)	Decrement	Proportion (%)	
1957～1969	11521						
1970～1979	6781	4740	2962	62.5	1778	37.5	30.4
1980～1989	4552	6969	1979	28.4	4990	71.6	30.3
1990～1996	4366	7155	4978	69.6	2177	30.4	53.3
1997～2006	1599	9962	3477	37.0	6485	63.0	62.7
1970～2006	4325	7206	3349	49.4	3857	50.6	44.2

Table 5. The results of flood and sediment reduction affected by rainfall

Calculated series	Actual	Flood reduction	Management		Rainfall influence		Flood reduction (%)
			Decrement	Proportion (%)	Decrement	Proportion (%)	
1957～1969	3670						
1970～1979	1822	1848	1483	80.2	365	19.8	44.9
1980～1989	960	2710	1164	43.0	1546	57.0	54.8
1990～1996	1074	2596	2555	98.4	41	1.6	70.4
1997～2006	257	3413	1482	44.8	1931	55.2	83.6
1970～2006	1028	2642	1671	66.6	971	33.4	63.4

4. Conclusions

From 1997 to 2006, in Sanchuanhe River Basin ,soil and water conservation measures reduce flood 34,770,000 m^3, flood reduction rate is 62.7%, reduce sediment 14,820,000 t, sediment reduction rate is 83.6%. Compared with over the years' results we can see that, flood and sediment reduction rate has an upward trend year by year, from 1997 to 2006, the sediment reduction rate increase more than doubled to the 70 and 80 ages, sediment reduction rate greatly higher than the rate over the years, water and soil conservation measures reduce the flood and sediment achieved had a good effect.

Through calculating Sanchuanhe river basin's flood and sediment rate, we can discover that, in 20th century 70s and 80s and from 1997 to 2006, rainfall difference was not obvious, but runoff and sediment have great disparity, the measured runoff in 70s'much higher than 80s', about 2.5 times to 1997～2006, the measured sediment in 70s'nearly two times bigger than 80s', about 6.9 times to 1997～2006. The reason is : First of all, the Sanchuanhe River in 1983 was listed as the national soil and water conservation management area, in 1992 was successfully completed the first phase of the management, in 1993, Ministry of Finance, Ministry of Water Resources has given approval to the second phase of management, after so many years of management, the basin's flood reduction rate was significant; Secondly, through analysis the frequency of the largest flood peaks, we can see that the 70's flood peak significantly more than that in subsequent years, made flood and sediment

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Obviously large in 70s. From the 80s to today, sediment reduction rate was on the base of favourable climatic conditions, so although the management of the Sanchuanhe River has received remarkable achievements in the past 20 years, but when meet the rainy year , the sediment reduction rate may be weakened.

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