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Regulatory Threshold of Soil and Water Conservation Measures on Runoff and Sediment Processes in the Sanchuan River Basin

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Abstract: Research on the runoff and sediment reduction effects of soil and water conservation measures has always been a topic of interest, which is of great significance for carrying out sustainable strategies for soil and water conservation in the Yellow River Basin. This study aims to find the threshold years of soil and water conservation measures for reductions in runoff and sediment. Through the analysis of various soil and water conservation measures, runoff, sediment, and rainfall data in the Sanchuan River Basin from 1960 to 2019, we determined the threshold years of soil and water conservation measures on runoff and sediment processes using the Hydrology and Lagrange Multiplier method. The results are as follows: The trend in flood season rainfall and annual rainfall in the Sanchuan River Basin is consistent. The 1990s was a turning period in the annual rainfall and flood season rainfall of the Sanchuan River Basin. The 2000s was a turning period of the runoff in the Sanchuan River Basin, while the sediment entered a stable period after 2000. The best periods for reducing runoff and sediment were the initial treatment period (1967–1979) and the centralized treatment period (1980–1996). The runoff and sediment reduction effects of each soil and water conservation measure during the initial treatment period (1967–1979) were terrace (32.8%) > dam (30.1%) > grass (18.6%) > forest (18.5%), while their effects during the centralized treatment period (1980–1996) were grass (53.7%) > terrace (20.7%) > dam (14.6%) > forest (11.0%). The runoff and sediment reduction effects of various soil and water conservation measures during different treatment periods indicate that the runoff reduction effect reached its peak in 2003–2005, while the sediment reduction benefit reached its peak in 2013–2015. Based on the comprehensive benefits of runoff and sediment regulation, 2013–2015 are considered to be the threshold years for various soil and water conservation measures, with the measures covering respective average areas of 4.85×10^4, 17.80×10^4, 1.15×10^4, and 0.82×10^4 hm^2. These research results will have a certain significance for the reasonable allocation of soil and water conservation measures and sustainable development in the Yellow River Basin.

Keywords: soil and water conservation measures; runoff reduction effect; sediment reduction effect; threshold years; Sanchuan River Basin

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1. Introduction

Since the 1960s, a significant amount of water and soil conservation work has been carried out in the middle reaches of the Yellow River, resulting in remarkable achievements in management thus far [1–4]. Studying the effectiveness of soil and water conservation management has become an extremely important topic [5–7]. Soil erosion, influenced by factors such as climate and human activities, alters the underlying surface of the watershed, leading to changes in runoff and sediment discharge [8–11]. Following the implementation of comprehensive soil and water conservation measures, the characteristics of runoff and sediment in the watershed inevitably change [12–15]. However, the runoff and sediment reduction effects of these measures have a certain threshold, rather than an infinite relationship, and the sediment reduction effect of engineering measures has a specific time limit [16,17]. Therefore, studying the threshold of soil and water conservation measures for reducing runoff and sediment can play a crucial role in the rational utilization of water and soil resources and the sustainable development of the Yellow River Basin.

In order to clarify the threshold of soil and water conservation measures in the Sanchuan River Basin on water conservation and sediment reduction in the middle reaches of the Yellow River, hydrological methods and water conservation methods are usually used for analyses, but both have some problems. The foundation of hydrology is the sediment model established based on hydrological data, which is difficult to accurately reflect the laws of rainfall sediment. The water conservation method is based on the established sand reduction quotas for soil and water conservation measures, which are difficult to fully comply with objective [18]. Hydrographic analysis is mainly based on the comparison of typical data measured using hydrological stations during different treatment periods, establishing a correlation between sediment discharge and treatment degree, and thus calculating the sediment reduction effects [18]. Due to the large discreteness of runoff and sediment data, the calculation results of the hydrological methods cannot show a long-term trend of runoff and sediment [19]. Currently, research on the effectiveness of soil and water conservation measures primarily focuses on calculating their benefits in reducing runoff and sediment discharge [20–22]. Wang [23] analyzed the causes of runoff and sediment transport in the upper and middle reaches of the Daling River and established a mathematical model between precipitation, runoff, and sediment yield during the baseline period using the stepwise regression method. Wu et al. [24] examined the correlation between the areas covered by soil and water conservation measures and the reduction in runoff and sediment discharge in the Hekou–Longmen section of the middle reaches of the Yellow River, indicating that soil and water conservation measures are the main reasons for the reduction in runoff and sediment discharge in this area. However, due to the limited rainfall data used to establish the model during the baseline period, the accuracy of the empirical formula is relatively low, and its representativeness is poor. Ouyang et al. [25] analyzed the characteristics of runoff and sediment changes in the Hekou–Longmen section of the middle reaches of the Yellow River using methods such as multi-year moving averages, which improved the accuracy of the established empirical formula. By enhancing the fitting accuracy of long-term hydrological data, the empirical formula better reflects the changes in runoff and sediment under the influence of climate and human activities. For example, Wang et al. [26] analyzed the runoff at six hydrological stations along the main stream of the Songhua River using cumulative anomaly, revealing four stages of runoff variation. The runoff and sediment conditions in different stages reflect the impact of climate and soil and water conservation measures. Therefore, introducing the concepts of 'runoff reduction efficiency' and 'sediment reduction efficiency' can represent the ability of soil and water conservation measures to reduce runoff and sediment discharge.

This study combined hydrology and the Lagrangian multiplier method by taking data from the Houdacheng Hydrological Station in the Sanchuan River Basin from between 1960 and 2019, first using the sliding average method to reduce the dispersion of runoff and sediment data, establishing an optimized polynomial, and then calculating the runoff and sediment at each time node to show their changes in different periods. By calculating the growth of various soil and water conservation measures in different periods and finally calculating the changes in runoff and sediment for each additional hectare of soil and water conservation measures, the threshold year and the area of each soil and water conservation measure can be found. The results are intended to provide valuable insights for guiding future management strategies for the Sanchuan River Basin.

2. Materials and Methods

2.1. Study Area

The Sanchuan River Basin is located in the middle of the region from Hekou to Longmen in the middle reaches of the Yellow River, and is located in the Lvliang region of Shanxi Province (Figure 1). There are three tributaries in the watershed, namely Beichuan, Dongchuan, and Nanchuan, spanning the four counties of Zhongyang, Liulin, Lishi, and Fangshan from north to south, with a total length of 176.4 km and an area of 4161 km^2. The basin is located in the northern part of a semi-arid region in the Yellow River Basin, with obvious continental climate characteristics, four distinct seasons, and concentrated rainfall. Moreover, the rainfall in the flood season is mostly in the form of heavy rain and rainstorms, which easily forms floods and produces a large amount of sediment.

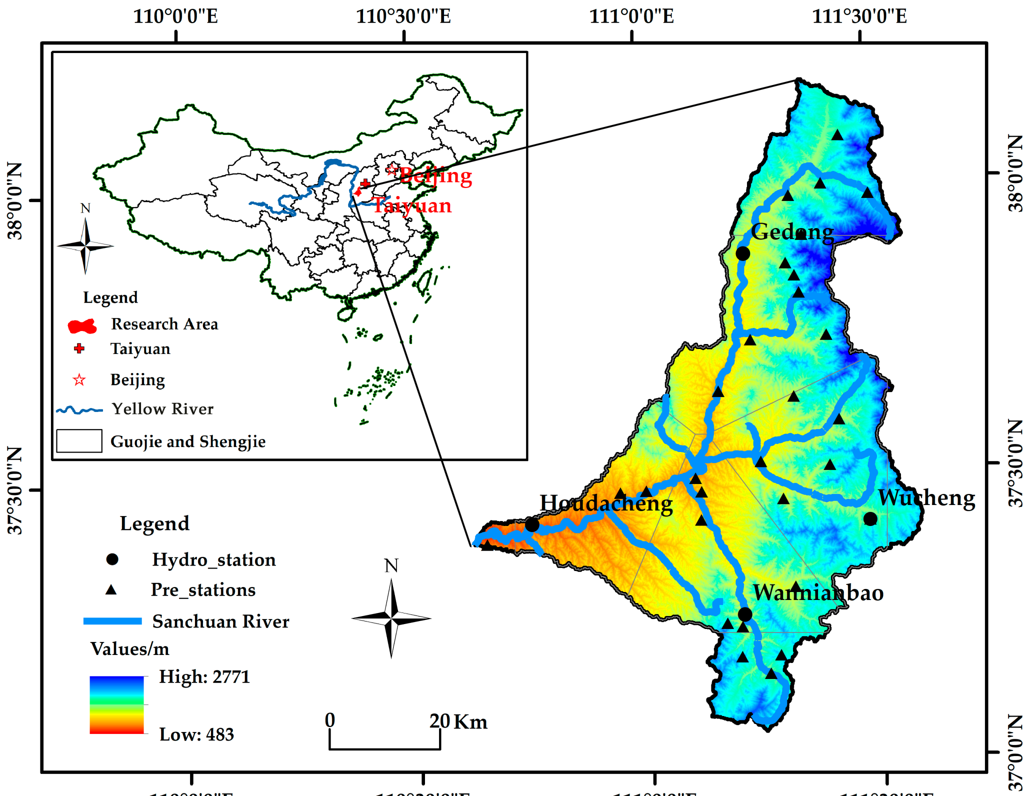

Figure 1. The locations of rainfall and hydrological stations in the Sanchuan River Basin in Shanxi Province.

2.2. Data Sources and Processing

The runoff, sediment, and rainfall data used in this study are all sourced from the Yellow River Hydrological Yearbook. The Houdacheng Hydrological Station in the downstream region of the Sanchuan River Basin records comprehensive runoff and sediment data, which can be analyzed to calculate the runoff and sediment regulatory benefits of its soil and water conservation measures. Rainfall data are recorded at 29 observation stations in the Sanchuan River Basin. Considering the continuity and completeness of the data, as well as the distribution of stations in the loess hilly and gully areas and rocky mountainous areas, rainfall data were obtained from meteorological stations in Gedong, Wucheng, Wannianbao, and Houdacheng in the Sanchuan River Basin. Based on these hydrological data from the Yellow River, we used the Thiessen polygon method to obtain the basin surface rainfall data, and we performed interpolation using the ArcGIS 10.8 (Figure 1). According to the historical data and the runoff and sediment distribution of the Sanchuan River, the timeline of the measures in question can be divided into four periods, namely the initial treatment period (1960–1979), the concentrated treatment period (1980–1996), the stable period (1997–2009), and the effective period (2010–2019). The data on the four soil and water conservation measures were sourced from the literature on CNKI, and the missing years were supplemented using the Lagrange interpolation method [27–30].

The runoff, sediment, and rainfall data were polynomial best-fitted using Python 3.10, and the average runoff and sediment were calculated for different periods, marking the maximum runoff (sediment) year, minimum runoff (sediment) year, and historical average runoff (sediment).

When the runoff and sediment data were fitted using a 3- or 4-order polynomial, the fit goodness of R^2 was relatively low, failing to meet the polynomial accuracy requirements. Moreover, when a 6-order polynomial was used for fitting, the fitted curve exhibited an oscillatory phenomenon, indicating that the data had been overfit (Figure 2). Therefore, this study adopted a 5-order polynomial for fitting both runoff and sediment data, with fitting accuracies of 0.78 and 0.77, respectively. It is preferable that the R^2 value of the polynomials fitted to the runoff and sediment data from the Sanchuan River Basin is closer to 1. According to data statistics, an R^2 value close to 0.8 is also acceptable [31]. However, due to the high dispersion of data in the early stage of governance, the R^2 of the fitted polynomial is often greatly affected. In this study, both runoff and sediment data were fitted using a fifth-order polynomial, with goodness-of-fit values of 0.78 and 0.77, respectively. The goodness-of-fit values for terrace, forest, grass, and dam data were 0.99, 0.95, 0.97, and 0.99, respectively. Therefore, it is reasonable to analyze the impact of soil and water conservation measures on runoff and sediment changes in the Sanchuan River Basin, based on the fitted polynomials.

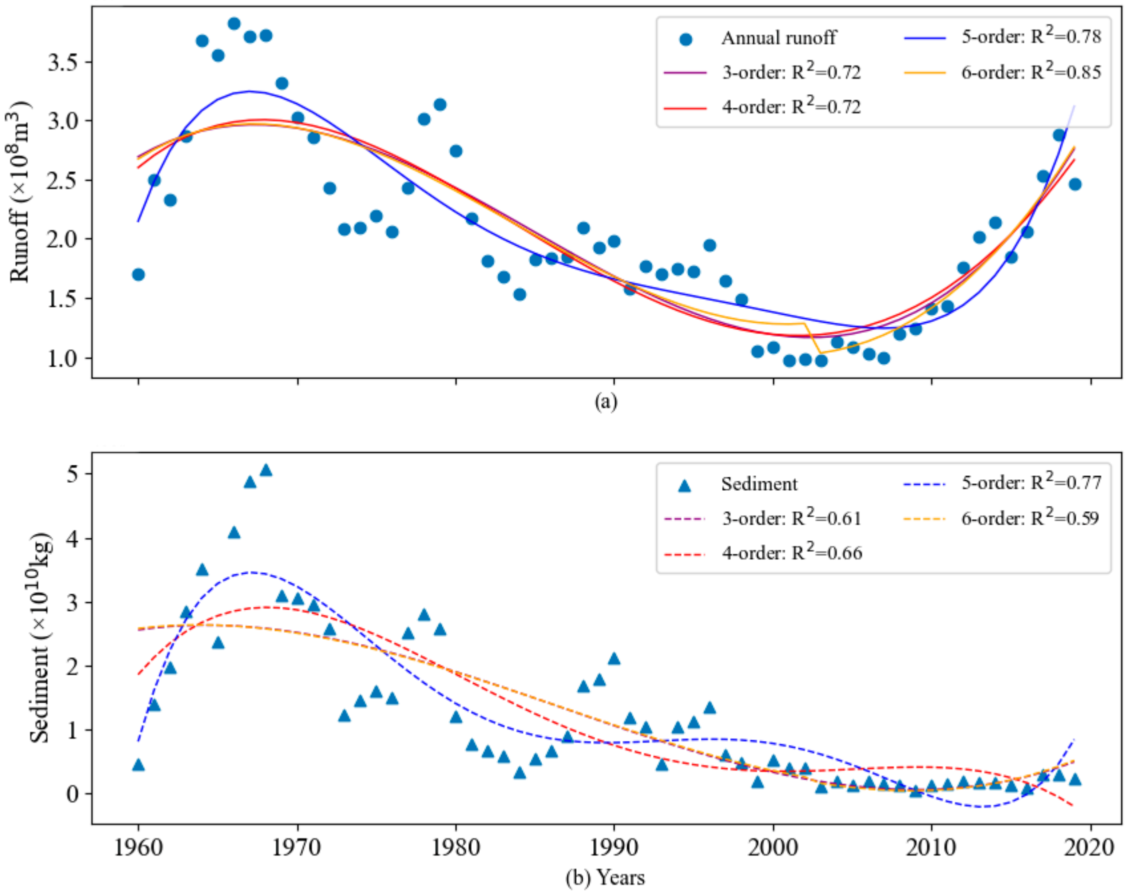

Figure 2. Polynomial fitting of runoff and sediment data in the Sanchuan River Basin using different orders. Note: (**a**) and (**b**) respectively show the fit goodness for runoff and sediment using different order polynomials during the study period.

By introducing the Lagrange multiplier λ, the equality constraint and objective function are combined into a new objective function, as follows:

$$\mathbf{F}(\mathbf{x}, \boldsymbol{\lambda}) = \mathbf{f}(\mathbf{x}) + \sum_{j=1}^{n} \lambda_j h_j(\mathbf{x}) \tag{1}$$

Using F(x, λ) as a new unconstrained objective function to solve its extremum, the result obtained is the extremum of the original objective function f(x) that satisfies the constraint condition $h_j(x) = 0$ (j = 1, 2, . . ., p).

The necessary condition for function F(x, λ) to have an extremum is as follows:

$$\frac{\partial_F}{\partial_{x_i}} = 0 \text{ and } \frac{\partial_F}{\partial_{\lambda_j}} = 0 \quad \text{i} = 1, 2, \ldots, \text{n}; \ \text{j} = 1, 2, \ldots, \text{p} \tag{2}$$

We can then obtain p + n equations, thus solving $X = [x_1, x_2, \ldots x_n]^T$ and λ_j (j = 1, 2, . . ., p) for a total of p + n unknown variables. The $X^* = [x_1^*, x_2^*, \ldots x_n^*]^T$ term obtained from the above equation system is the coordinate value of the extreme point of function f(x).

Firstly, we calculated the values of runoff and sediment in the Sanchuan River Basin at each key time point based on the fitting polynomials, and then we calculated the changes in runoff and sediment at different periods. Based on the proportions of various soil and water conservation measures to the total measures used in different periods, the amount of runoff and sediment affected by all of the measures was calculated, and finally, the runoff and sediment reduction amount of each soil and water conservation measure in different periods was calculated. The calculation formula is as follows:

$$r_e = \frac{\left(A_i - A_j\right) \times \frac{\overline{m}}{\sum \overline{m}}}{M_j - M_i} \tag{3}$$

where r_e represents the amount of runoff and sediment reduction for each additional hectare of a soil and water conservation measure; A_i is the runoff or sediment amount calculated by fitting polynomials at the beginning of a period, in m^3 or kg; A_j is the runoff or sediment amount calculated by fitting polynomials at the end of a period, in m^3 or kg; M_j is the area covered by a soil and water conservation measure at the end of a period, in hm^2; M_i is the area covered by a soil and water conservation measure at the beginning of a period, in hm^2; and $\overline{m}$ is the average value of a soil and water conservation measure during a period.

3. Results

3.1. Changes in Flood Season Rainfall and Annual Rainfall in the Sanchuan River Basin

Due to the runoff and sediment directly generated by rainfall mainly occurring during the flood season, the runoff and sediment transported from July to October were selected for comparison. Figure 3 shows the changes in average annual rainfall and flood season rainfall of the watershed in different years, with a slow decline followed by a sudden increase. It can be seen that, before 2000, the average flood season rainfall in the watershed showed a gradual decrease in the 1960s, 1970s, 1980s, and 1990s. However, the average flood season rainfall significantly increased after 2000, to a value even higher than that of the average flood season rainfall in the 1960s. Compared with the 1960s, the average annual rainfall in the 1970s, 1980s, and 1990s decreased by 7.4%, 11.1%, and 15.5%, respectively; the average annual rainfall during the flood season decreased by 4.1%, 20.0%, and 22.3%, respectively. Compared to the 1990s, the annual rainfall and flood season rainfall both increased in the 2000s and 2010s, increasing by 28.9% and 25.1% and by 33.7% and 32.3%, respectively. Therefore, the overall trend in annual rainfall and flood season rainfall is consistent; the 1990s was a turning period in the annual rainfall and flood season rainfall of the Sanchuan River Basin.

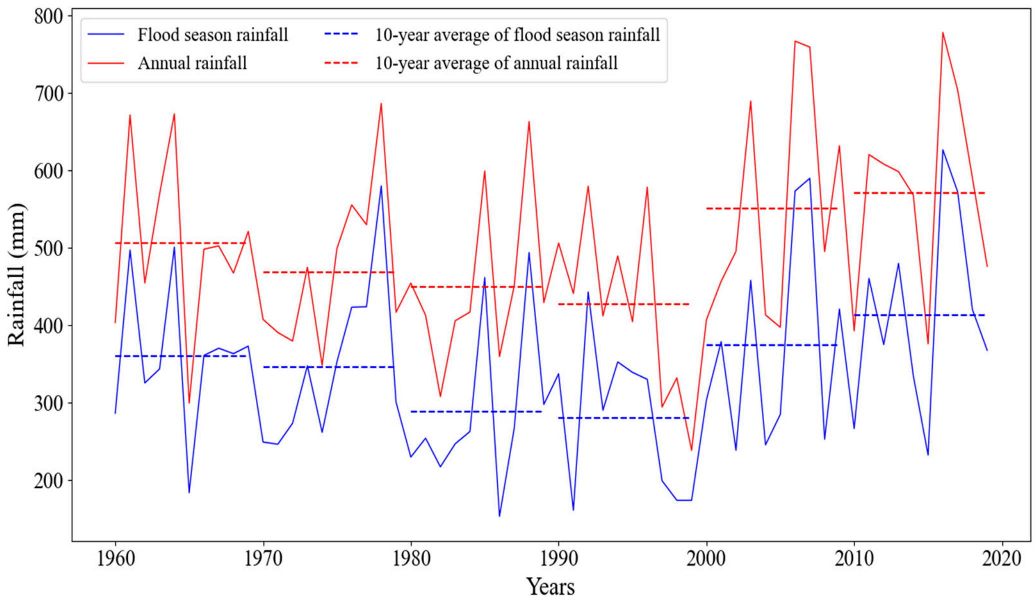

Figure 3. Flood season rainfall and annual rainfall variation in the Sanchuan River Basin.

3.2. Changes in Runoff and Sediment in the Sanchuan River Basin

Based on the data recorded by the Houdacheng Hydrological Station from 1960 to 2019, the evolution curve of runoff and sediment in the basin since the 1960s was obtained (Figure 4). It can be seen that the trend in the average runoff and sediment was consistent before 2010, decreasing year on year; the average runoff has increased significantly since 2010, almost reaching the level recorded in the 1970s, while the average sediment has slightly decreased compared to the first decade of the 21st century. Compared with the 1960s, the average runoff of the 1970s, 1980s, and 1990s decreased by 19.5%, 42.5%, and 50.0%, respectively, while the sediment decreased by 29.4%, 68.5%, and 73.3%, respectively. The runoff first decreased and then increased after the year 2000. Compared to the previous ten years, the runoff increased by 92.9% in the latter ten years, which was a decrease of only 33.2% compared to the 1960s, and therefore was equivalent to the level of runoff in the 1970s; the sediment remained relatively stable in the first two decades of the 21st century compared to the 1960s, with a decrease of 93.1% and 93.7%, respectively. Therefore, the 2000s was a turning period in the runoff of the Sanchuan River Basin, and the sediment began to enter a stable period.

3.3. Analysis of Rainfall, Runoff, and Sediment in the Sanchuan River Basin

Based on the 10-year average values calculated from rainfall, runoff, and sediment data in the Sanchuan River Basin, the line chart shows that, during the early stage of governance (1960–1979), the decrease in runoff and sediment was greater than the decrease in rainfall, and the decrease in runoff and sediment in the 1970s was greater than that in the 1960s, while the decrease in rainfall in the 1970s was smaller than that in the 1960s (Figure 5). This indicates that soil and water conservation measures during this period played a significant role in reducing runoff and sediment. The decrease in runoff and sediment was still smaller than the decrease in rainfall during the centralized management period (1980–1996), but the decrease in runoff and sediment during this period was much smaller than that in the 1970s. During the stable period (1997–2009), there was a significant increase in rainfall, while runoff and sediment were still decreasing. This phenomenon was related to large-scale human production and construction activities. There was a slight increase in rainfall in the period of effect manifestation (2010–2019), with a significant increase in runoff compared to the stable period, while sediment showed a slight decrease compared to the stable period. Under the influence of various soil and water conservation measures, their effects of regulating runoff and reducing sediment were gradually becoming apparent.

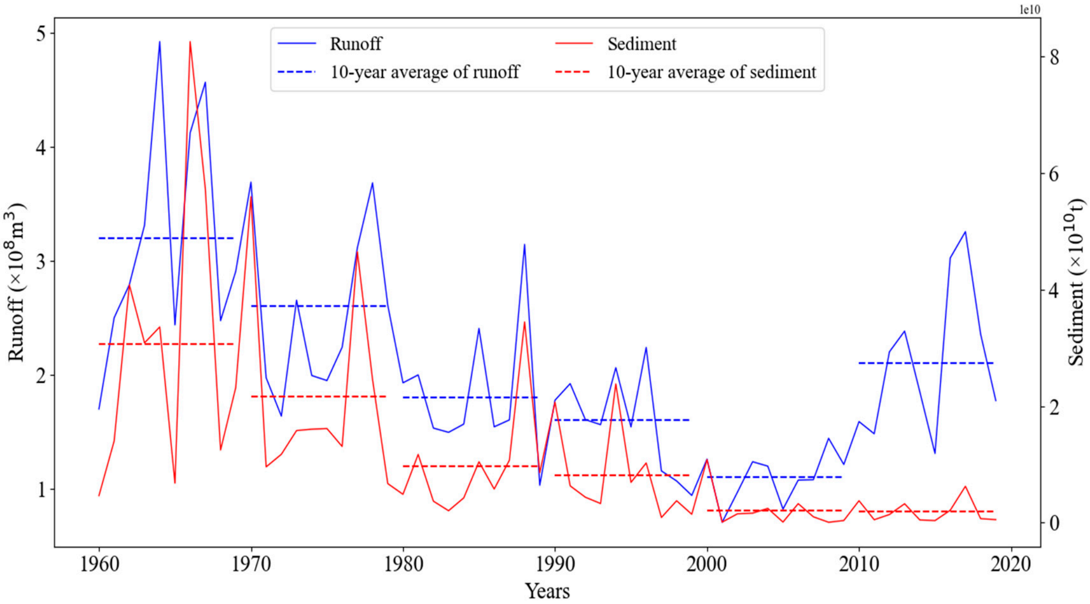

Figure 4. Changes in the runoff and sediment in the Sanchuan River Basin.

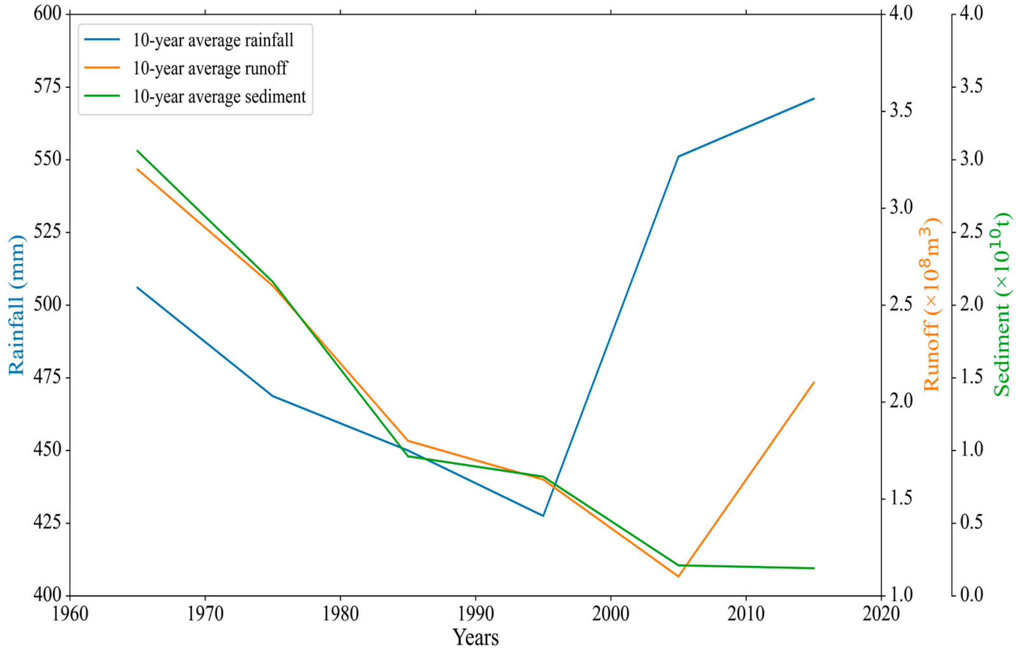

Figure 5. The relationship between runoff, sediment, and rainfall in the Sanchuan River Basin.

3.4. Analysis of Main Soil and Water Conservation Measures, Runoff, and Sediment in the Sanchuan River Basin

The soil and water conservation work in the Sanchuan River Basin began in the 1950s, with the main measures including embankments, small silt dams, afforestation, and grass planting. By the end of the 1960s, only 112 km^2 of land had been treated, accounting for 4% of the total area, and little watershed management work had been carried out. Starting in the 1970s, in addition to the early soil and water conservation measures, large-scale silt dams, small reservoirs, and river channel improvements were also constructed. After 15 years of large-scale centralized comprehensive management, by the mid-1990s, the remaining areas of the four major soil and water conservation measures in the Sanchuan River Basin were 3.34, 0.39, 9.42, and 0.32 hm^2, respectively, which had significant increases compared to the early stages of governance (Table 1). Since the beginning of the 21st century, the areas of the four major soil and water conservation measures have further increased. So far, the preservation rate of terraces and grasses has decreased, with only the areas of dams and forests continuing to increase. The reason for this may be that some terraces have been damaged by rainfall due to their age. With the implementation of projects such as dredging and the reinforcement of silt dams, the dam capacity has been expanded and consolidated, and the forest areas have been increasing year by year.

Table 1. The preservation areas of soil and water conservation measures in different years (hm^2).

Years	Terraces	Dams	Forests	Grasses
1960s	0.43	0.18	0.60	0.30
1970s	1.29	0.11	1.68	0.10
1980s	0.87	0.16	6.44	0.50
1990s	3.34	0.39	9.42	0.32
2000s	4.70	0.74	10.05	0.71
2010s	4.91	0.88	18.94	1.49

The annual runoff discrete degree was 9.33 in the early stage of governance, 4.72 in the centralized management period, 1.96 in the stable period, and 6.47 in the effective manifestation period, which indicates that the interannual variation in runoff in the early stage of governance was significant, with the annual runoff discrete degree being about two times that of the centralized governance period and 4.76 times that of the stable period, during which the interannual variation in annual runoff further decreased. During the period of effectiveness, although the interannual variation in annual runoff increased, it was only 70% of the early stage of governance (Figure 6).

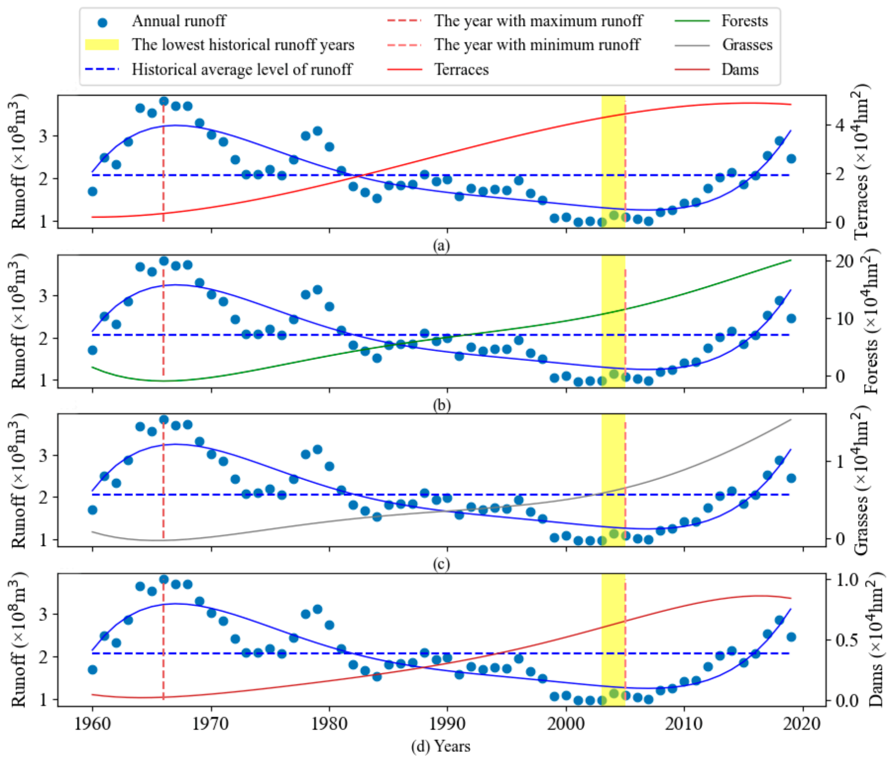

Figure 6. Changes in the soil and water conservation measures and runoff. Note: (**a**), (**b**), (**c**) and (**d**) respectively depicted the changes in runoff with the implementation of terrace, forest, grass, and dam measures during the study period.

As shown in Figure 6, the runoff recorded in 2016 reached the historical average runoff level (2.1×10^8 m^3). In 2019, it reached the maximum historical average runoff level, which was equivalent to the runoff level (2.96 × 10^8 m^3) in 1967. At the maximum historical average runoff level, the areas covered by terrace, forest, grass, and dam measures were only 0.34, 0.08, 0.01, and 0.03 hm^2, respectively. Between 2000 and 2010, the runoff in the Sanchuan River Basin reached the minimum historical average level (1.34 × 10^8 m^3 in 2005). At the minimum historical average runoff level, the areas covered by terrace, forest, grass, and dam measures were 4.55, 9.73, 0.67, and 0.69 hm^2, respectively. Therefore, it can be inferred that the threshold years for regulating runoff through various soil and water conservation measures in the Sanchuan River Basin are 2003–2005. Before 1967, the areas of terrace, forest, grass, and dam measures all showed a slightly increasing trend. After 1967, the four major soil and water conservation measures all showed a significant growth trend. After 2005, the terraces and dams showed a slight increase followed by a stable trend, while forests and grasses showed a significant growth trend, which was also the main reason for the increase in runoff.

The annual sediment discrete degree was 2.09 in the early stage of governance, 0.86 in the centralized governance period, 0.29 in the stable period, and 0.20 in the effective manifestation period, which indicates that the interannual variation in sediment in the early stage of governance was significant, with the annual sediment discrete degree being about 2.43 times that of the centralized governance period, 7.21 times that of the stable period, and 10.45 times that of the effective period; additionally, the interannual variation in annual sediment continued to decrease (Figure 7).

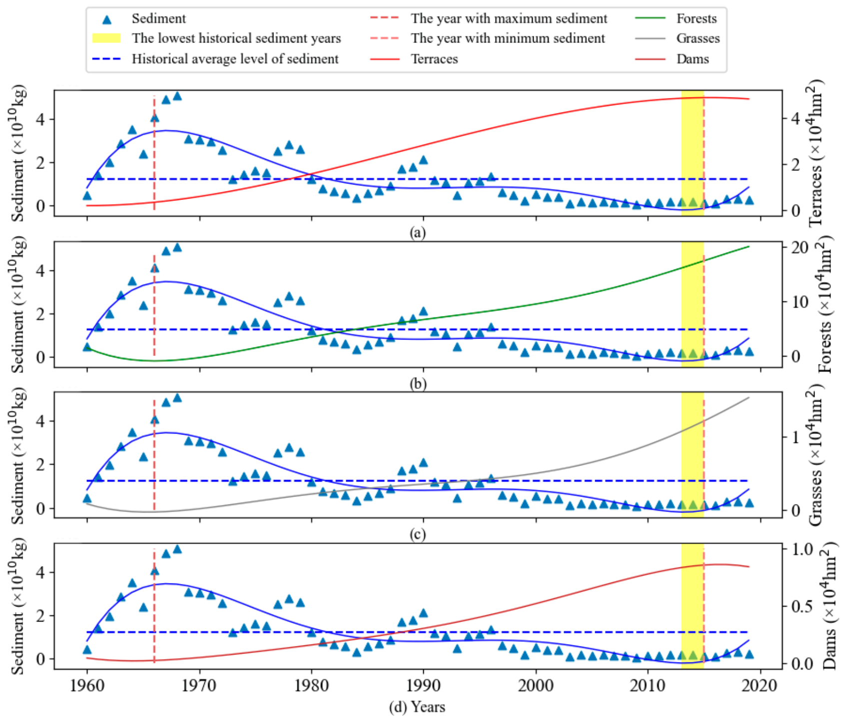

Figure 7. Changes in the soil and water conservation measures and sediment. Note: (**a**), (**b**), (**c**) and (**d**) respectively depicted the changes in sediment with the implementation of terrace, forest, grass, and dam measures during the study period.

It can be seen from Figure 7 that the historical average sediment level was 1.23 × 10^{10} kg. In 2015, it reached the minimum historical average sediment level (1.31 × 10^8 kg). At the minimum historical average sediment level, the areas covered by terrace, forest, grass, and dam measures were 4.85, 17.91, 1.20, and 0.83 hm^2, respectively. Therefore, it can be inferred that 2013–2015 are the threshold years for regulating sediment by various water and soil conservation measures in the Sanchuan River Basin. From 1980 to 2000, the sediment in the Sanchuan River Basin reached a longer stationary period (0.90 × 10^{10} kg). The year with the maximum historical average sediment level was the same as the year with the maximum historical average runoff level, and the sediment at this time was 8.25×10^{10} kg.

3.5. Analysis of Runoff and Sediment Reduction Effects of Soil and Water Conservation Measures

Based on the scatter plot and polynomial regression curve of runoff and sediment in the Sanchuan River Basin, the timeline of the conversation measures was divided into six periods, namely the initial treatment period (1960–1979), the centralized treatment period (1980–1996), the stable period (1997–2009), the effectiveness period (2010–2019), the historical average maximum period (1965–1967), and the historical average minimum period (2003–2005), in order to analyze the runoff and sediment reduction effects of terraces, forests, grasses, and dams in different periods (Table 2).

Table 2. The runoff and sediment reduction effects of various soil and water conservation measures in different periods.

	Periods	Terraces	Forests	Grasses	Dams
Runoff reduction effect (m^3/hm^2)	1960–1966	−23,310	−49,416.30	−11.49	0
	1967–1979	3964.52	2238.26	2250.80	3628.44
	1980–1996	1526.36	811.57	3953.48	1073.14
	1997–2005	205.90	556.07	89.07	107.32
	2006–2009	−5980.95	−137.55	−275.09	−1570.26
	2010–2019	−28,561.10	−3472.16	−1184.39	−4855.19
Sediment reduction effect (kg/hm^2)	1960–1966	−7,046,164.06	−14,937,592.58	−4,505,855.20	0
	1967–1979	874,810.72	493,893.52	496,660.15	800,650.40
	1980–1996	108,428.76	57,652.07	280,846.17	76,233.35
	1997–2015	168,092.56	71,242.37	46,180.59	85,276.81
	2016–2019	−3,668,907.75	−723,884.57	−263,522.70	−957,468

Note: indicates the increase in runoff or sediment under the influence of the soil and water conservation measures during a period.

It can be seen that, in the early stage of governance, various soil and water conservation measures had a poor effect on reducing runoff and sediment, because the areas covered by various soil and water conservation measures during this period were relatively small, and large-scale governance projects had not yet been carried out in the Sanchuan River Basin (Table 2). During the period from 1967 to 1979, the runoff and sediment reduction effects of various soil and water conservation measures were the largest and entered the centralized treatment period. The runoff and sediment reduction effects of various soil and water conservation measures then decreased, laying a solid foundation for the runoff and sediment reduction effects of various soil and water conservation measures observed during the stable period. The runoff reduction effect of various soil and water conservation measures further decreased during the stable period (1997–2005), while the sediment reduction effect increased during the stable period (1997–2015) compared to the centralized control period. Since 2006, the runoff and sediment reduction effects of various soil and water conservation measures have been negative, indicating that the runoff has been increasing during this period. However, the sediment reduction effects of various soil and water conservation measures continued until 2015. Since 2016, the sediment content in the Sanchuan River Basin has increased. Therefore, the threshold years for the runoff and sediment reduction effects of soil and water conservation measures in this basin should be set in 2013–2015, with average areas covered by conservation measures totaling 4.85×10^4, 17.80×10^4, 1.15×10^4, and 0.82×10^4 hm^2.

4. Discussion

4.1. Analysis of the Impact of Rainfall on Runoff and Sediment

The methods for analyzing rainfall time series are usually the M-K test, Pettitt method, etc., which are not suitable for dealing with complex sequences with multiple mutation points [32].

Wang et al. used wavelet functions to study the complex structure of multi-time scale rainfall changes, indicating that rainfall changes have both short and long periodicity [33]. Yang et al. conducted a Fisher test on the rainfall time series of the Sanchuan River Basin from 1956 to 1986, which showed a quasi periodic variation of 10 years [34]. This study used the method of calculating the 10-year average rainfall to analyze the trend of 60 years' worth of rainfall data in the Sanchuan River Basin. The results showed that the 1990s was a turning period of the rainfall in the Sanchuan River Basin. Similar conclusions were drawn by Yang et al. [34] and Kang et al. [35]. Yang et al. [34] pointed out that the special geographical conditions of the Sanchuan River basin and current climate change are the two major factors contributing to its rainfall variation. The main reason is the continuous drought and lack of rainfall during this period. The annual rainfall in the 2000s was 8.9% and 28.9% higher than that in the 1960s and 1990s, respectively, indicating a significant increase in rainfall compared to both the preceding highest (1960s) and lowest (1990s) historical average rainfall periods [36]. Compared to the 1990s, the runoff and sediment in the Sanchuan River Basin continued to decline in the 2000s, indicating that human activities had a greater impact on runoff and sediment than climate change during this period, which is consistent with the results of Duan et al. [37]. With the increase in rainfall, the runoff of the Sanchuan River Basin began to increase in the 2010s, while the sediment slightly decreased compared to the 2000s, indicating that with the large-scale ecological environment construction in the Sanchuan River Basin, a good situation of clear water and less sediment had emerged [38].

4.2. Analysis the Runoff and Sediment Reduction Effects of Soil and Water Conservation Measures

The runoff and sediment changes in the Sanchuan River Basin are the combined effects of climate change and human activities, and rainfall and runoff changes are closely related [39]. The intervention of human activities has further intensified the trend in runoff evolution, and the type and intensity of human activities directly determine the degree of runoff evolution [40]. The soil and water conservation measures in the watershed ensure surface runoff can easily transform into underground runoff through their impact on water cycle elements such as infiltration and evaporation [41]. Before 1970, the scale of soil erosion control in the Sanchuan River Basin was relatively small and the effectiveness of various soil and water conservation measures was weak; in the late 1970s, especially after 1979, the areas covered by soil and water conservation measures increased significantly, from 3.17 hm^2 in 1979 to 14.59 hm^2 in 1996 [42]. This just explains why the soil and water conservation measures in the initial treatment period (1967–1979) and the centralized treatment period (1980–1996) had the greatest benefits in reducing runoff and sediment during different treatment periods [43]. The soil and water conservation measures in the Sanchuan River Basin are mainly composed of forest and grassland, with a combined coverage rate of 72.26% by 2023 [37]. The significant increase in forest and grass coverage can reduce the kinetic energy of raindrops, increase surface permeability, enhance ecological water storage capacity and evaporation, and have a significant effect on reducing runoff and sediment. There was a notable increase in runoff during the stable period (1997–2009), which contrasted with significant sediment reduction benefits. After 2000, due to the limited growth of terraces and dams, the areas covered by forest and grass increased significantly, from 10.76 hm^2 in 2000s to 20.43 hm^2 in 2010s. Although there had been an increase in rainfall during the 2000s, reaching the level recorded in the 1970s, there was an increase in runoff and a decrease in sediment in the Sanchuan River Basin. It can be inferred that the large-scale conversion of farmland to forests is an important factor that cannot be ignored in reducing runoff and sediment after 2000, resulting in less sand and a clearer river.

4.3. Suggestions for Optimizing Soil and Water Conservation Measures Under the Goal of Water Resource Management

Research on soil and water conservation measures aimed at reducing runoff and sediment thresholds in the Yellow River Basin is still in its infancy. Many studies have shown that the flood and sediment reduction effects of soil and water conservation measures with a certain threshold, rather than an unlimited effect, and that engineering measures have a certain time limit for sediment reduction [44,45]. In this study, different soil and water conservation measures showed a gradually decreasing trend in their runoff and sediment reduction effects as the area covered by these measures increased. Human activities have changed the size of river runoff, which not only ensures the production and domestic water supply for local residents, but also affects the natural water cycle of the watershed [46]. Therefore, based on the water resources situation under the threshold conditions of reducing runoff and sediment in the soil and water conservation measures of the Sanchuan River Basin, effective suggestions can be provided for the rational allocation of future soil and water conservation measures.

This study first used the ten-year average method to analyze the trend in runoff and sediment changes, and then used multiple regression methods to analyze their trends, avoiding the low fitting degree of other fitting methods and thereby making the results highly interpretable. Then, based on the fitting equation, the changes in runoff and sediment during different treatment periods, as well as the increase in the area covered with terrace, forest, grass, and dam measures, were calculated to determine the runoff and sediment reduction effect of the unit increases in soil and water conservation measures. This study determined the maximum and minimum values of runoff and sediment changes under the influence of soil and water conservation measures, determining the regulation threshold years as 2013–2015, whose runoff and sediment reduction effects of each soil and water conservation measure were terrace > dam > forest > grass. Zhang reached similar conclusions through M-K test analysis of runoff and sediment in the Sanchuan River Basin [36]. In addition, by comparing the configuration of soil and water conservation measures in different treatment periods, it was found that before the threshold years, terraces and dams played the primary roles in reducing runoff and sediment, whereas after that, forest and grass played the main roles in reducing sediment. The results can provide a scientific basis for the allocation of soil and water conservation measures in the future.

5. Conclusions

Through the analysis of the rainfall, runoff, sediment, and soil and water conservation measurement data in the Sanchuan River Basin from 1960 to 2019, this study reached the following conclusions:

(1) The trend in flood season rainfall and annual rainfall in the Sanchuan River Basin is consistent. The 1990s was a turning period for the flood season rainfall and annual rainfall in the Sanchuan River Basin. The 2000s was a turning period for the runoff in the Sanchuan River Basin, while the sediment entered a stable period after 2000.

(2) The best periods for reducing runoff and sediment were the initial treatment period (1967–1979) and the centralized treatment period (1980–1996). The runoff and sediment reduction effects of each soil and water conservation measure during the initial treatment period (1967–1979) were terrace > dam > grass > forest, while during the centralized treatment period (1980–1996), the runoff and sediment reduction effects of each soil and water conservation measure were grass > terrace > dam > forest.

(3) The runoff reduction effect of various soil and water conservation measures during different treatment periods reached its peak in 2003–2005, while the sediment reduction benefit reached its best in 2013–2015. Based on the comprehensive benefits of runoff and sediment regulation, 2013–2015 are considered to be the threshold years for various soil and water conservation measures, with the measures covering respective average areas of 4.85×10^4, 17.80×10^4, 1.15×10^4, and 0.82×10^4 hm^2.

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