

Article

Not peer-reviewed version

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

[Ding Xinhui](#)^{*}, [Liu Xiaoying](#), [Liu Guangguan](#), [Xiao Peiqing](#)

Posted Date: 28 June 2024

doi: 10.20944/preprints202406.1991.v1

Keywords: runoff reduction effect; sediment reduction effect; threshold



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article

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

Xinhui Ding ^{1,*}, Xiaoying Liu ², Guangquan Liu ² and Peiqing Xiao ³

¹ College of Resources & Environment and History & Culture, Xianyang Normal University, Xianyang 712000, China;

² China Institute of Water Resources and Hydropower Research, International Research and Training Center on Erosion and Sedimentation, Beijing 100048, China; xyliu@iwhr.com (X.L.); liugq@iwhr.com (G.L.)

³ Yellow River Institute of Hydraulic Research, Yellow River Conservation Commission, Zhengzhou 450003, China; peiqingxiao@163.com

* Correspondence: dingxh0615@163.com

Abstract: Researches on the runoff and sediment reduction effects of soil and water conservation measures are being on the rise, which is of great significance for carrying out strategic on soil and water conservation in the Yellow River Basin. Through the analysis of various soil and water conservation measures, runoff, sediment, and rainfall datas in the Sanchuan River Basin from 1960 to 2019, we use the lagrange multiplier method to determining the threshold year of soil and water conservation measures on runoff and sediment processes. The preliminary conclusion is as follows: The trend of flood season rainfall and annual rainfall in the Sanchuan River Basin is consistent. The 10-year average rainfall in each periods indicates that before 2000, it gradually decreased and then significantly increased. The 10-year average runoff showed a gradual decrease before 2010, followed by a sudden increase, while the 10-year average sediment has shown a decreasing trend years by years, especially after the centralized treatment period. Terrace and dam measures show a trend of first decreasing, then increasing, and then approaching stability during different treatment periods, while the trend of forest and grass measures is slightly decreasing and then increasing rapidly. 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 2005, while the sediment reduction benefit reached its best in 2015. Based on the comprehensive benefits of runoff and sediment regulation, 2015 are considered as the threshold year for various soil and water conservation measures, with each measure areas being 4.86×10^4 , 17.91×10^4 , 1.20×10^4 , and $0.83 \times 10^4 \text{ hm}^2$, respectively. The research results will have certain reference significance for the high-quality development of soil and water conservation in the Yellow River Basin.

Keywords: runoff reduction effect; sediment reduction effect; threshold

1. Introduction

The Sanchuan River, located in the western of Shanxi Province, is a significant source of runoff and sediment for the Yellow River. Its landscape is characterized by intertwining ridges and gullies[1–3]. Before governance measures were implemented, the bare ridges resembled monk's heads while the gullies were distributed like chicken claws, with steep slopes resembling upside-down mountains[4–6]. According to erosion division standards for the Loess Plateau, it can be categorized into river basin areas, stone and soil mountain areas, and loess hilly gully areas[7,8]. The soil erosion in the loess hilly and gully areas is very serious, with an average erosion erosion coefficient ranging from 10000 to 20000 t/km²·a[9].

To address water scarcity issues and combat frequent droughts in this region over the past decades, extensive efforts have been made by the government focusing on basic agricultural irrigation and water conservancy construction including water storage, diversion techniques as well as conservation strategies which have yielded significant results[10–12]. Mechanized terraces has been a key research focus of the State Yellow River Water Conservancy Commission involving large

bulldozers constructing level terraces wider than 10 meters on slopes between 5° to 25° since 1988[13–15]. Due to its speediness and high quality while also demonstrating strong capabilities in retaining water and conserving soil, this approach has accelerated basic farmland construction leading to increased production potential with clear benefits[16,17]. In addition, innovative efforts such as biological contour level terrace developed by Liulin County in 1987, which integrates "biological protection engineering" alongside nurturing biological resources within comprehensive management practices, aiming at solving challenges associated with soft contour terraces through development of new land preparation models[18–20]. Furthermore, drought-resistant collection projects have been implemented aiming at increasing farmers' income through suitable crop selection based on local conditions, along with various rainwater collection models designed for efficient use across different landscapes[21–23]. Large-scale water and soil conservation measures have been carried out since 1970s in Sanchuan River basin, resulting in positive outcomes related to water retention and sediment reduction effects[24–26].

In order to clarify the effect 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 are usually used for analysis. Hydrographic analysis is mainly based on the comparison of typical datas measured by hydrological stations during different treatment periods, establishing a correlation between sediment discharge and treatment degree, and thus calculating the sediment reduction effects[27]. Due to the large discreteness of runoff and sediment datas, the calculation results of the hydrological method can't show a long-term trend of runoff and sediment[28,29]. This study takes datas from the Houdacheng Hydrological Station in the Sanchuan River Basin from 1960 to 2019, first uses a optimized polynomial for the variation of runoff and sediment, and then calculates 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 intend to provide valuable insights for guiding future management strategies of the Sanchuan River Basin.

2. Study Area

The Sanchuan River Basin is located in the middle of the section from Hekou to Longmen in the middle reaches of the Yellow River, and belongs to the Lvliang area of Shanxi Province. There are three tributaries in the watershed, namely Beichuan, Dongchuan, and Nanchuan, spanning 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 km²(Figure 1). The basin is located in the northern part of the semi-arid region in the Yellow River Basin, with obvious continental climate characteristics, distinct four seasons, and concentrated rainfall. Moreover, the rainfall in flood season is mostly in the form of heavy rain and rainstorm, which is easy to form flood and produce a lot of sediment.

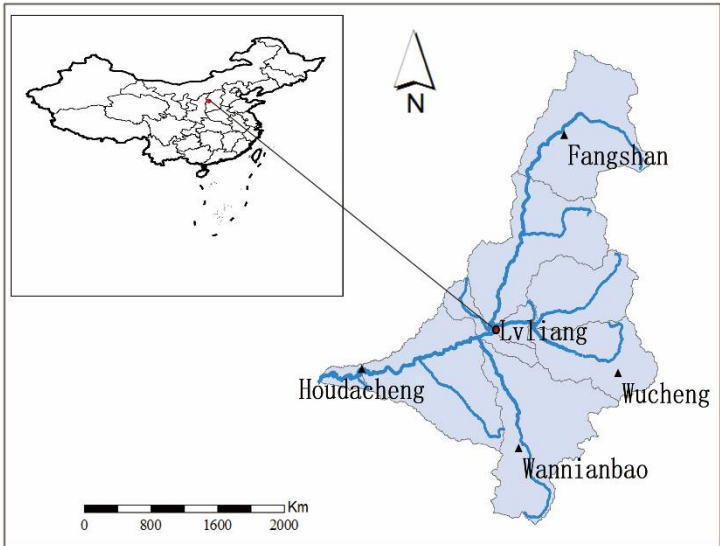


Figure 1. The location of rainfall and hydrological stations in the Sanchuan River Basin in Shanxi Province.

The soil and water conservation work in the Sanchuan River Basin began in the 1950s, with main measures including embankments, small silt dams, afforestation, and grass planting. By the end of the 1960s, only 112km² of land had been treated, accounting for 4% of the total areas, and small watershed management work had been carried out. Starting from the 1970s, in addition to the early soil and water conservation measures, large-scale silt dams, small reservoirs, and river channel improvement were also constructed. By the mid-1980s, a total area of 786.44km² had been treated, accounting for 28.4% of the total soil erosion areas. After 15 years of large-scale centralized comprehensive management, by the mid-1990s, the remain percentages of the four major soil and water conservation measures in the Sanchuan river basin were 66.7%, 57.8%, 25.9%, and 86.1%, respectively (Table 1). Since 21st century, the areas of the four major soil and water conservation measures has further increased. So far, the preservation rate of terraces and grasses has decreased, with only the area of dams and forests continuing to increase. The reason for this may be that some terraces have been damaged by rainfall due to their ages. With the implementation of projects such as dredging and reinforcement of silt dams, the dam capacity has been expanded and consolidated, and the forest areas has been increasing year by year.

Table 1. The preservation areas of Soil and water conservation measures in different years hm²

Years	Terraces	Dams	Forests	Grasses
1960s	0.429	0.179	0.595	0.301
1970s	1.287	0.106	1.682	0.095
1980s	0.865	0.155	6.437	0.498
1990s	3.336	0.389	9.418	0.324
2000s	4.698	0.744	10.049	0.713
2010s	4.91	0.875	18.94	1.49

3. Data Sources and Processing

The Houdacheng Hydrological Station in the downstream of the Sanchuan River Basin has comprehensive runoff and sediment data, so it can be analyzed and calculated the runoff and sediment regulatory benefits of its soil and water conservation measures. The rainfall data is recorded from 29 observation stations in the Sanchuan River Basin. Considering the continuity and completeness of the data sequence, as well as the distribution of stations in the loess hilly and gully areas and rocky mountainous areas, the rainfall datas are obtained from meteorological stations in Gedong, Wucheng, Wannianbao and Houdacheng in the Sanchuan River Basin based on

hydrological data of the Yellow River, using the Thiessen polygon method to obtain the basin surface rainfall, and perform interpolation on the ArcGIS platform. According to the historical runoff distribution of the Sanchuan River, it 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 datas on the four soil and water conservation measures are sourced from literatures on CNKI, and the missing years are supplemented using Lagrange interpolation method.

3.1 Lagrange Multiplier Method

The runoff, sediment, and rainfall datas are polynomial best fitted using Python programming, and the average runoff and sediment are calculated for different periods, marking the maximum runoff (sediment) year, minimum runoff (sediment) year, and historical average runoff (sediment).

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

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

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

The necessary condition for function $F(\mathbf{x}, \boldsymbol{\lambda})$ to have an extremum is:

$$\frac{\partial F}{\partial x_i} = 0 \quad \text{and} \quad \frac{\partial F}{\partial \lambda_j} = 0 \quad i=1,2,\dots,n; j=1,2,\dots,p \quad (2)$$

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

4. Results

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

Due to the runoff and sediment directly generated by rainfall mainly occur during the flood season, the runoff and sediment transport from July to October are selected for comparison. Figure 2 shows that the changes in average annual rainfall and flood season rainfall in different years of the watershed, 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 60s, 70s, 80s, and 90s of 20th century. However, the average flood season rainfall has significantly increased after 2000, even higher than the average flood season rainfall of 1960s. Compared with the 1960s, the average annual rainfall in the 70s, 80s, and 90s of 20th century 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%, 25.1% and 33.7%, 32.3%, respectively. Therefore, the overall trend of annual rainfall and flood season rainfall is consistent, 2000 was a turning point in the annual rainfall and flood season rainfall of the Sanchuan River Basin.

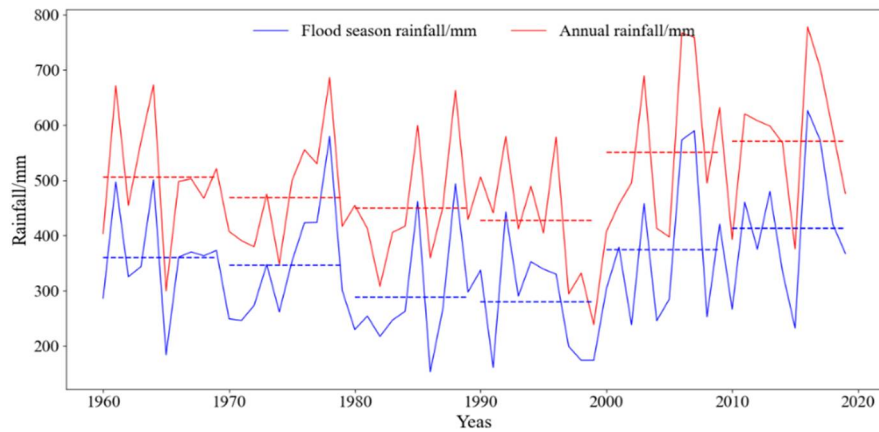


Figure 2. Flood season rainfall and annual rainfall variation in the Sanchuan River Basin.

4.2. 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 1960s was obtained (Fig.3). It can be seen that the trend of the average runoff and sediment is consistent before 2010, decreasing years by years; the average runoff has increased significantly since 2010, almost reaching the level of 1970s, while the average sediment has slightly decreased compared to the first decade of the 21st century. Compared with 1960s, the average runoff of 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 entering two thousand years. Compared to the previous ten years, the runoff increased by 92.9% in the latter ten years, only decreased by 33.2% compared to the 1960s, which is equivalent to the level of runoff in 1970s; the sediment remained relatively stable in the first two decades of 21st century comparing to 1960s, with a decrease of 93.1% and 93.7% respectively.

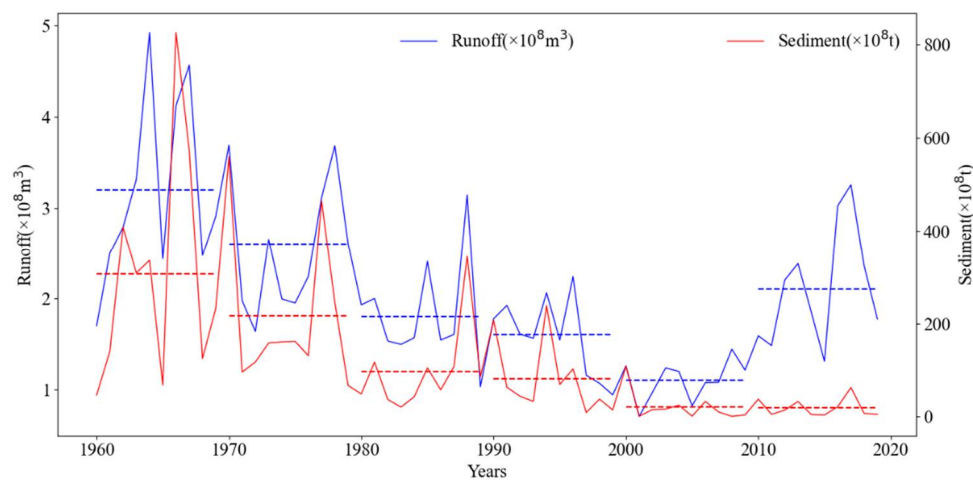


Figure 3. Changes of the runoff and sediment in the Sanchuan River Basin.

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

Based on the 10-year average values calculated from rainfall, runoff, and sediment datas 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 1970s was greater than that in 1960s, while the decrease in rainfall in 1970s was smaller than that in 1960s. This indicates that soil and water conservation measures during this period have 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. There was a slight increase in rainfall in the period of effect manifestation (2010-2019), with a significant increase in runoff compared to stable period, while sediment showed a slight decrease compared to stable period. Under the influence of various soil and water conservation measures, their effects of regulating runoff and reducing sediment are gradually becoming apparent.

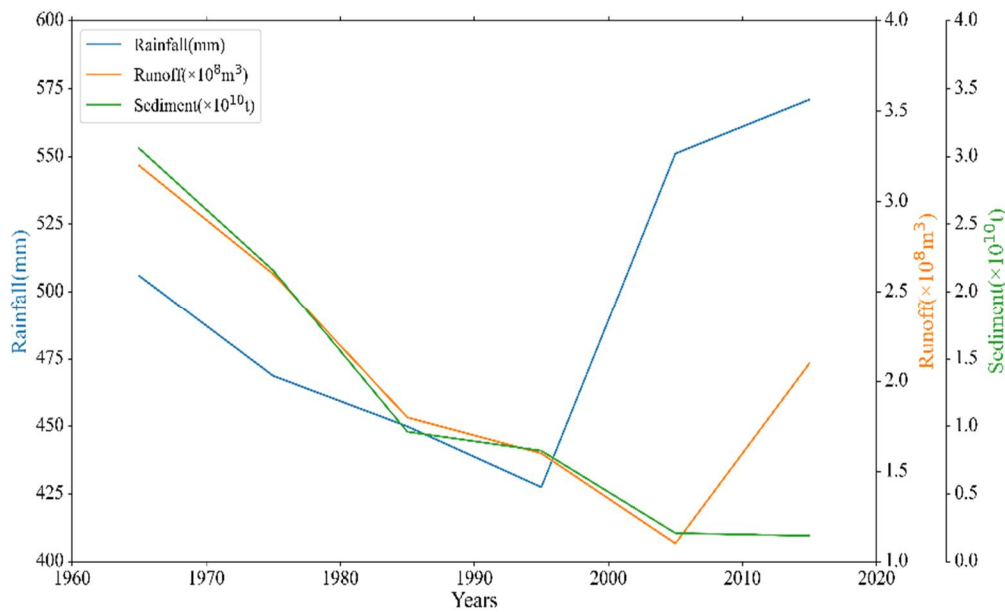


Figure 4. The relationship between runoff, sediment and rainfall in the Sanchuan River Basin.

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

The annual runoff discrete degree is 9.33 in the early stage of governance, the centralized management period is 4.72, the stable period is 1.96, and the effective manifestation period is 6.47, which indicates that the interannual variation of runoff in the early stage of governance is significant, with the annual runoff discrete degree being about 2 times that of the centralized governance period, and 4.76 times that of the stable period, the interannual variation of annual runoff further decreases. During the period of effectiveness, although the interannual variation of annual runoff has increased, it is only 70% of the early stage of governance. The runoff in 2016 has reached the historical average runoff level ($2.1 \times 10^8 \text{ m}^3$). In 2019, it has reached the maximum historical average runoff level, which is equivalent to the runoff level ($2.96 \times 10^8 \text{ m}^3$) in 1966(Figure 5). At the maximum historical average runoff level, the areas of terrace, forest, grass, and dam measures were only 0.34, 0.08, 0.01, and 0.03 hm^2 , respectively. From 2000 to 2010, the runoff in the sanchuan river basin reached the minimum historical average level ($1.34 \times 10^8 \text{ m}^3$). At the minimum historical average runoff level, the areas of terrace, forest, grass, and dam measures were 4.55, 9.73, 0.67, and 0.69 hm^2 , respectively. Before 1966, the areas of terrace, forest, grass, and dam measures all showed a slight increase trend. After 1966, 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 is also the main reason for the increase in runoff.

The annual sediment discrete degree is 2.09 in the early stage of governance, the centralized governance period is 0.86, the stable period is 0.29, and the effective manifestation period is 0.20, which indicates that the interannual variation of sediment in the early stage of governance is 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,

the interannual variation of annual sediment continues to decrease(Figure 6). The historical average sediment level is 1.23×10^{10} kg. In 2015, it has reached the minimum historical average sediment level (1.31×10^8 kg). At the minimum historical average sediment level, the areas of terrace, forest, grass, and dam measures were only 4.85, 17.91, 1.20, and 0.83 hm², respectively. 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 is the same as the year with the maximum historical average runoff level, and the sediment at this time is 8.25×10^{10} kg.

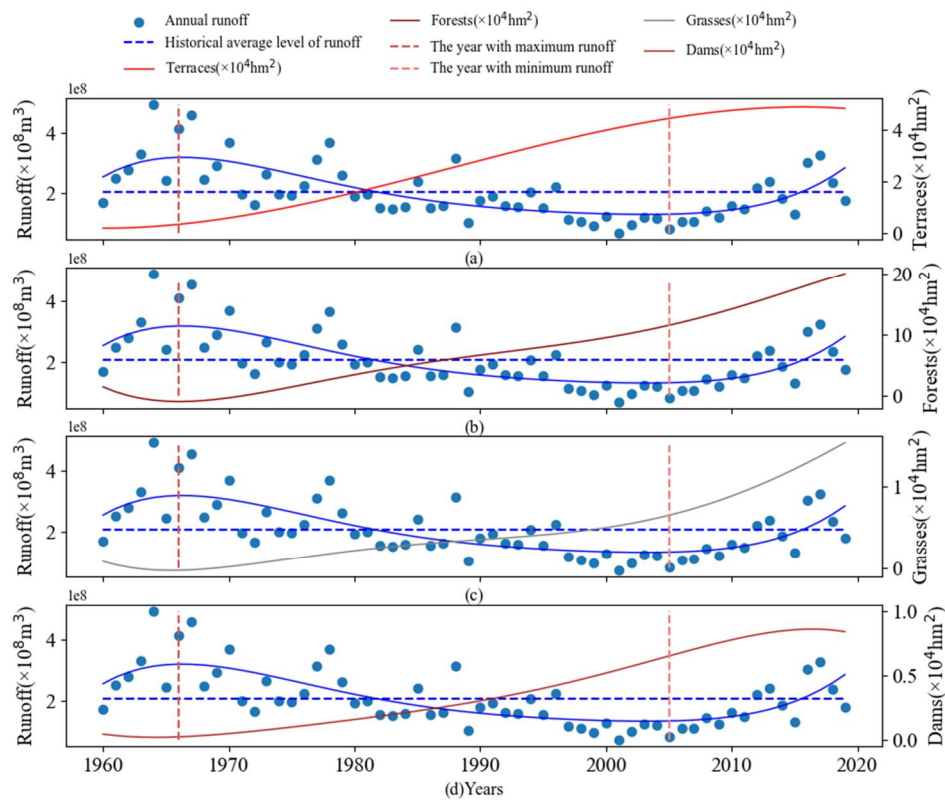


Figure 5. Changes of the soil and water conservation measures and runoff.

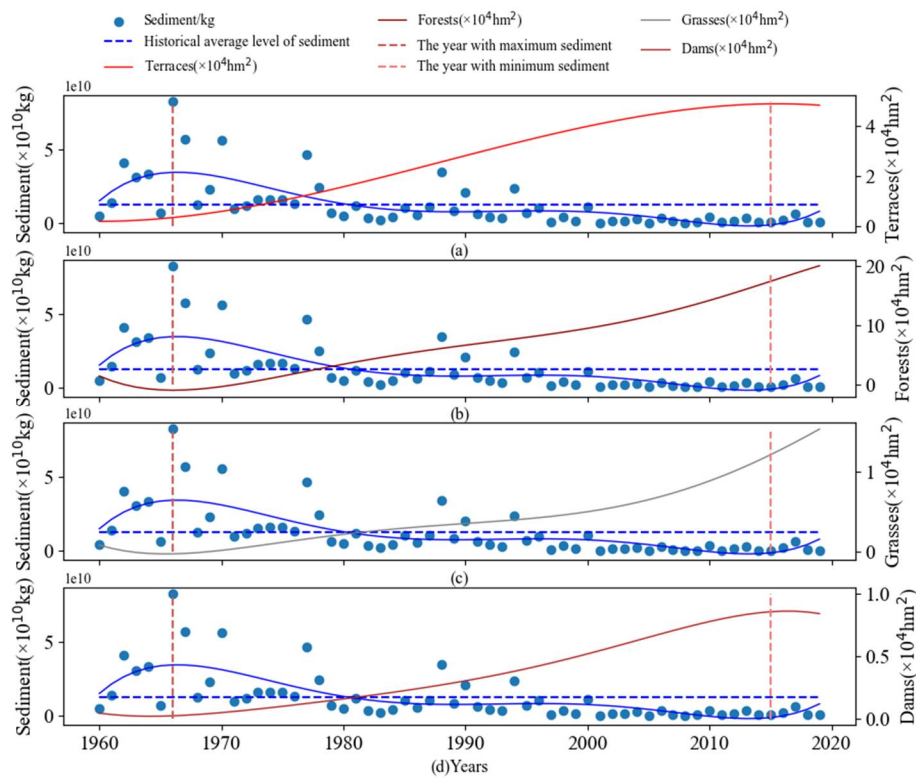


Figure 6. Changes of the soil and water conservation measures and sediment.

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, it is divided into 6 periods, namely the initial treatment period, centralized treatment period, stable period, effectiveness period, historical average maximum period, and historical average minimum period to analyze the runoff and sediment reduction effects of terraces, forests, grasses, and dams in different periods (Table 2).

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

$$r_e = \frac{(A_i - A_j) \times \frac{\bar{m}}{\sum \bar{m}}}{M_j - M_i} \quad (3)$$

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

It can be seen that in the early stage of governance, various soil and water conservation measures have a poor effect on reducing runoff and sediment, because the areas of various soil and water conservation measures during this period is relatively small, and large-scale governance projects

have not been carried out in the Sanchuan River Basin(Table 2). During the period of 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 decreased, laying a solid foundation for the runoff and sediment reduction effects of various soil and water conservation measures 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 the runoff was increasing during this period. However, the sediment reduction effects of various soil and water conservation measures have continued until 2015. Since 2016, the sediment content in the Sanchuan River Basin has increased. Therefore, the threshold year for the runoff and sediment reduction effects of soil and water conservation measures in this basin should be in 2015, with areas of 4.86×10^4 , 17.91×10^4 , 1.20×10^4 , and $0.83\times10^4\text{hm}^2$.

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	-23310	-49416.3	-11.48682	0
	1967-1979	3964.521	2238.257	2250.795	3628.437
	1980-1996	1526.356	811.5708	3953.484	1073.14
	1997-2005	205.8951	556.0687	89.06928	107.3191
	2006-2009	-5980.95	-137.551	-275.09	-1570.26
	2010-2019	-28561.1	-3472.16	-1184.39	-4855.19
Sediment reduction effect(kg/hm ²)	1960-1966	-7046164.06	-14937592.58	-4505855.2	0
	1967-1979	874810.72	493893.52	496660.15	800650.4
	1980-1996	108428.76	57652.07	280846.17	76233.35
	1997-2015	168092.56	71242.37	46180.59	85276.81
	2016-2019	-3668907.75	-723884.57	-263522.7	-957468

¹ - indicates the increase in runoff or sediment under the influence of the soil and water conservation measures during some period.

5. Discussion

It is better that the R² of the polynomials fitted to the runoff and sediment datas in the Sanchuan River Basin is closer to 1. According to data statistics, R² within the range of 0.5-0.8 is also acceptable[30]. However, due to the high dispersion of datas in the early stage of governance, the R² of the fitted polynomial is often greatly affected. In this study, both runoff and sediment datas were fitted using a fifth-order polynomial, with fit goodness of 0.78 and 0.77, respectively. The fit goodness for terrace, forest, grass, and dam datas was 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.

The methods for analyzing rainfall time series are usually M-K test, Pettitt method, etc., which are not suitable for dealing with complex sequences with multiple mutation points. 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 [31]. This study used the method of 10-year average rainfall to analyze the trend of 60 years rainfall data in the Sanchuan River Basin, the results showed that before 2000, annual rainfall gradually decreased and then significantly increased. Similar conclusions were drawn by Yang et al. [32] and Kang et al. [33].

The discreteness of runoff and sediment sequences is higher than that of rainfall data,. This study first uses the ten-year average method to analyze the trend of runoff and sediment changes, and then uses multiple regression methods to analyze their trends, avoiding the low fitting degree of other fitting methods, 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 terrace, forest, grass, and dam measures, are calculated to determine the runoff and sediment reduction effect of the unit increase in soil and water conservation measures. This study determines the maximum and minimum values of runoff and sediment changes under the influence of soil and water conservation measures, in order to determine the regulation threshold year. The results can provide scientific basis for the configuration of soil and water conservation measures in the Yellow River Basin.

6. Conclusions

Through the analysis of rainfall, runoff, sediment, and soil and water conservation measures datas in the Sanchuan River Basin from 1960 to 2019, preliminary conclusions are as follows:

(1) The trend of flood season rainfall and annual rainfall in the Sanchuan River Basin is consistent. The 10-year average rainfall in each periods indicates that before 2000, they all gradually decreased and then significantly increased.

(2) The 10-year average runoff showed a gradual decrease before 2010, followed by a sudden increase; while the 10-year average sediment has shown a decreasing trend years by years, especially after the centralized treatment period.

(3) 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 2005, while the sediment reduction benefit reached its best in 2015. Based on the comprehensive benefits of runoff and sediment regulation, 2015 are considered as the threshold year for various soil and water conservation measures, with each measure areas being 4.86×10^4 , 17.91×10^4 , 1.20×10^4 , and $0.83 \times 10^4 \text{hm}^2$, respectively.

Author Contributions: Conceptualization, X.L. and X.D.; methodology, X.D.; software, X.D.; validation, X.L., G.L., P.X. and X.D.; formal analysis, X.D.; resources, X.D.; data curation, X.D.; writing—original draft preparation, X.D.; writing—review and editing, X.D.; visualization, X.D.; supervision, G.L.; project administration, X.L.; funding acquisition, P.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Influence and Effect of Soil and Water Conservation Measures Configuration on the Water and Sediment Process in the Watershed Program (Grant No. U2243210, U2243601).

Data Availability Statement: The data supporting reported results can be found on the National Earth System Science Data Center (<http://www.geodata.cn/> (accessed on 10 July 2022)).

Acknowledgments: The authors would like to thank the National Earth System Science Data Center for providing data for this study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lei Z.X., Fu J.Y., Luo J.J., Cao L.. Attribution analysis of runoff changes in the Sanchuan River Basin of Shanxi Province from the perspective of landscape patterns. *Acta Ecologica Sinica*, **2022**, 42(12):4946-4958. (in chinese)
2. Lin B.B., Zhang Y.Q., Wu P.L.. Feature extraction of the Sanchuan River Basin based on DEM in GIS environment. *China Rural Water Resources and Hydropower*, **2013**, (03): 34-37. (in chinese)
3. Wu B.. Research on the Impact of Land Use/Cover Change on the Formation of Mountain Floods in the Gedong Basin of the Sanchuan River. *Taiyuan University of Technology*, **2017**.
4. Nie R.. Evaluation and Analysis of Health Status in the Sanchuan River Basin. *Taiyuan University of Technology*, **2015**.
5. Sun W.Y., Zhang P.. Study on the evaluation model of water and sediment changes in the Sanchuan River Basin on the Loess Plateau. *Journal of Water Resources and Water Engineering*, **2008**, (2): 48-51.
6. Wu Q.. Risk assessment of mountain flood disasters in the Sanchuan River Basin. *Taiyuan University of Technology*, **2018**.
7. Bu, C.F., Cai, Q.G., Ng, S.L., Chau, K.C., Ding, S.W.. Effects of hedgerows on sediment erosion in Three Gorges Dam area, China. *Int. J. Sediment Res.*, **2008**, 23, 119-129.

8. Zhang P., Sun W., Guan Y.. Analysis on Water and Sediment Reduction Effects of Soil and Water Conservation Measures in the Sanchuanhe River Basin of the Yellow River. Iop Conference. 2018, 392. DOI:10.1088/1757-899X/392/4/042023.
9. Wang, S.; Luo, P.; Li, W.; Lyu, J.; Zhou, M. Runoff and Sediment Deposition Characteristics of Gravel-Mulched Land: An Experimental Study. *Land* **2024**, *13*, 445. <https://doi.org/10.3390/land13040445>
10. Fan, J., Yan, L.J., Zhang, P., Zhang, G. Effects of grass contour hedgerow systems on controlling soil erosion in red soil hilly areas, southeast China. *Int. J. Sediment Res.*, **2015**, *30*, 107-116.
11. Fang, H.Y. Impact of landuse change and dam construction on soil erosion and sediment yield in the black soil region, north eastern China. *Land Degrad. Dev.*, **2017**, *28*, 1482-1492.
12. Xiong, M.Q., Sun, R.H., Chen, L.D. Effects of soil conservation technologies on water erosion control: A global analysis. *Sci. Total Environ.*, **2018**, *645*, 753-760.
13. Keesstra, S., Pereira, P., Novara, A., Azorin-Molina, C., Parras-Alcántara, L., Jordán, A., Cerdà, A. Effects of soil management techniques on soil water erosion in apricot orchards. *Sci. Total Environ.*, **2016**, *551-552*, 357-366.
14. Kosmowski, F.. Soil water management practices (terraces) helped to mitigate the 2015 drought in Ethiopia. *Agric. Water Manag.*, **2018**, *204*, 11-16.
15. Schönbrodt-Stitt, S., Behrens, T., Schmidt, K., Shi, X., Scholten, T. Degradation of cultivated bench terraces in the Three Gorges Area: Field mapping and data mining. *Ecol. Indic.*, **2013**, *34*, 478-493.
16. Diyabalanage, S., Samarakoon, K.K., Adikari, S.B., Hewawasam, T. Impact of soil and water conservation measures on soil erosion rate and sediment yields in a tropical watershed in the Central Highlands of Sri Lanka. *Appl. Geogr.*, **2017**, *79*, 103-114.
17. Xu, Y., Yang, B., Tang, Q., Liu, G.B., Liu, P.L. Analysis of comprehensive benefits of transforming slope farmland to terraces on the Loess Plateau: A case study of the Yangou Watershed in Northern Shaanxi Province, China. *J. Mt. Sci.*, **2011**, *8*, 448-457.
18. Maetens, W., Poesen, J., Vanmaercke, M. How effective are soil conservation technologies in reducing plot runoff and soil loss in Europe and the Mediterranean? *Earth Sci. Rev.*, **2012**, *115*, 21-36.
19. Musiyiwa, K., Harris, D., Filho, W.L., Gwenzi, W., Nyamangara, J. An assessment of smallholder soil and water conservation practices and perceptions in contrasting agro-ecological regions in Zimbabwe. *Water Resour. Rural Dev.*, **2017**, *9*, 1-11.
20. Okeyo, A.I., Mucheru-Muna, M., Mugwe, J., Ngetich, K.F., Mugendi, D.N., Diels, J., Shisanya, C.A. Effects of selected soil and water conservation technologies on nutrient losses and maize yields in the central highlands of Kenya. *Agric. Water Manag.*, **2014**, *137*, 52-58.
21. Fang, T.J., Wei, W., Chen, L.D., Saskia, D.K., Yu, Y. Effects of land preparation and plantings of vegetation on soil moisture in a hilly loess catchment in China. *Land Degrad. Dev.*, **2017**, *29*, 1427-1441.
22. Wolka, K., Mulder, J., Biazin, B. Effects of soil and water conservation technologies on crop yield, runoff and soil loss in Sub-Saharan Africa: A review. *Agric. Water Manag.*, **2018**, *207*, 67-79.
23. Wei, W., Feng, X., Yang, L., Chen, L.D., Feng, T.J., Chen, D. The effects of terracing and vegetation on soil moisture retention in a dry hilly catchment in China. *Sci. Total Environ.*, **2019**, *647*, 1323-1332.
24. Wei, Y.H., He, Z., Li, Y.J., Jiao, J.Y., Zhao, G.J., Mu, X.M.. Sediment yield deduction from check-dams deposition in the weathered sandstone watershed on the north Loess Plateau, China. *Land Degrad. Dev.*, **2016**, *28*, 217-231.
25. Lemann, T., Zeleke, G., Amsler, C., Giovanoli, L., Suter, H., Roth, V. Modelling the effect of soil and water conservation on discharge and sediment yield in the upper Blue Nile basin, Ethiopia. *Appl. Geogr.*, **2016**, *73*, 89-101.
26. Cheng, Y.T., Li, P., Xu, G.C., Li, Z.B., Gao, H.D., Zhao, B.H., Wang, T., Wang, F.C., Cheng, S.D.. Effects of soil erosion and landuse on spatial distribution of soil total phosphorus in a small watershed on the Loess Plateau, China. *Soil Tillage Res.*, **2018**, *184*, 142-152.
27. Yang, Q.; Gao, H.; Han, Y.; Li, Z.; Lu, K. Coupling Changes in Runoff and Sediment and Their Relationships with Erosion Energy and Underlying Surface in the Wuding River Basin, China. *Land* **2024**, *13*, 496. <https://doi.org/10.3390/land13040496>
28. Alemie, T.C.; Buytaert, W.; Tilahun, S.A.; Steenhuis, T.S. A Distributed Catchment—Scale Evaluation of the Potential of Soil and Water Conservation Interventions to Reduce Storm Flow and Soil Loss. *Water* **2024**, *16*, 1225. <https://doi.org/10.3390/w16091225>
29. Venishetty, V.; Parajuli, P.B.; To, F.; Nepal, D.; Baker, B.; Gude, V.G. Evaluating Best Management Practice Efficacy Based on Seasonal Variability and Spatial Scales. *Hydrology* **2024**, *11*, 58. <https://doi.org/10.3390/hydrology11040058>
30. Quinino R. C., Reis E. A., Lupércio F., Bessegato. Using the coefficient of determination R2 to test the significance of multiple linear regression. *Teaching Statistics*, **2013**, *35(2)*:84-88. DOI:10.1111/j.1467-9639.2012.00525.x.

31. Wang Z.L., Chen X.h., Yang T.. Analysis of runoff changes and influencing factors in the Dongjiang River Basin over the past 50 years. *Journal of Natural Resources*, **2010**, 25 (08): 1365-1374.
32. Yang G.Y., Zhou Z.H., Qin D.Y., Jiang N.Q., Wang G.Q.. Analysis of the Evolution Law and Motivation of Precipitation and Runoff in the Sanchuan River. *People's Yellow River*, **2007**, (02): 42-44
33. Kang L.L., Wang C.G., Zhang Y.L., Chen J.N.. Changes in precipitation in the middle reaches of the Yellow River over the past 50 years and their impact on runoff. *People's Yellow River*, **2004**, (08): 26-28+46

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.