ANNALS OF ENVIRONMENTAL SCIENCE AND NATURAL RESOURCES

Review Article

Volume 1 | issue 1

On Runoff and Sediment Reduction Effect and Critical Threshold of Soil and Water Conservation in Sanchuan River Basin

Xiaoying Liu[1*] & Qunfang Zheng[2]

[1]*China Institute of Water Resources and Hydropower Research, 20 Chegongzhuang Road West, Beijing 100048, China*

[2]*Beijing Forestry University, Qinghua Road East, 100038, China*

[*]**Corresponding Author:** Xiaoying Liu, China Institute of Water Resources and Hydropower Research, 20 Chegongzhuang Road West, Beijing 100048, China.

Submitted: 23 February 2026 **Accepted:** 28 February 2026 **Published:** 05 March 2026

Citation: Liu, X., & Zheng, Q. (2026). On Runoff and Sediment Reduction Effect and Critical Threshold of Soil and Water Conservation in Sanchuan River Basin. Annals of Environmental Science and Natural Resources. 1(1), 01- 05.

Abstract

The Sanchuan River basin is located in the middle section from HekouZhen to Longmen in the middle reaches of the Yellow River, belonging to the Luliang region of Shanxi Province with a total length of 176.4 km, The area is 4161 km2. Since the 1970s, Sanchuan River basin has carried out large-scale comprehensive management of water and soil conservation, and has been listed as one of the eight national key water and soil conservation control areas. Since 1970s,the amount of new water and soil conservation measures in each decade increased significantly compared with that in the 1960s, and the area of water and soil conservation forest was the largest,with an increase of more than 100 times; The second is terrace land and grass planting, which increased significantly each in the 1980s and1990s compared with the 1960s; Although the area of newly increased terraces decreased in the 1980s compared with that in the 1970s, it increased significantly in the 1990s. Although the number of warping dams cannot be compared with that in the 1960s, the new number increased by 23.8% and 38.8% respectively in terms of the changes in the 1980s and 1990s, which is enough to show the obvious changes.

At the same time, the runoff and sediment volume tend to decrease with the increase of area of soil and water conservation. From the analysis of the observed data at the gauging station, we found that with the continuous increase of the area of various soil conservation measures in different periods, the runoff and sediment reduction shows a trend of change. The area of water and soil conservation measures in the 1970s is not large, but also presents sediment and runoff reduction. However, in the 1980s and 1990s, the intensity of sediment reduction was no longer obvious, which could indicate that the effect of soil conservation measures on sediment reduction may have a certain threshold.

The analysis of the observed data also indicated that among the conservation measures the sediment reduction effect of warping dam is the largest, and it is also increasing year by year, followed by forest land and terrace. The effect of these two measures is similar, and the effect of grassland sediment reduction is the smallest.

The previous research result also indicated the similar possible threefold of soil conservation measures in sediment reduction, like that the forest and grass vegetation and terrace projects have a special threshold in terms of sediment and runoff reduction. At the watershed scale: the natural vegetation coverage rate is more than 60%, the rainfall of about 30~50 mm cannot cause surface runoff and sediment. When the ratio of terrace area in the basin (the ratio of terrace area to slightly above water erosion area) is within the range of 5% to 30%, the ratio of terrace is in direct proportion to the volume of sediment reduction. When the ratio of terrace is greater than 35% to 40%, its sediment reduction effect is basically stable at about 90%.

Key Words: Soil Conservation Measures, Sediment Reduction

Overview of Sanchuan River

The Sanchuan River basin is located in the middle section from HekouZhen to Longmen in the middle reaches of the Yellow River, belonging to the Luliang region of Shanxi Province. Watershed has three tributaries of 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, The area is 4161 km2.

The basin is located in the north of the semi-arid region of Shaanxi, Gansu and Shanxi in the Yellow River basin, with obvious continental climate characteristics, four distinct seasons and concentrated precipitation (Fig.1).

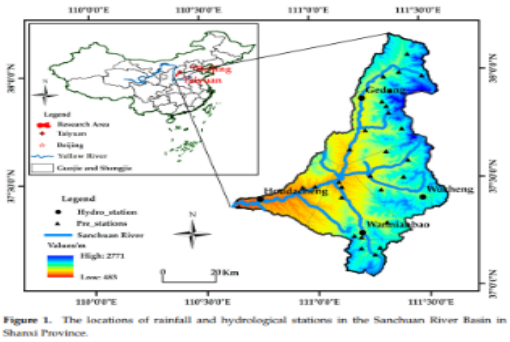

Figure 1. The locations of rainfall and hydrological stations in the Sanchuan River Basin in Shanxi Province.

Figure 1: The location of rainfall and hydrological stations in the Sanchuanhe River Basin in Shaanxi Province

According to the statistics from the year of 2000, the average annual precipitation of the basin is 502.7 mm, of which the flood season (June to September, the same below) reaches 367.7 mm, accounting for 73.1% of the annual precipitation; In addition, the precipitation in flood season is mainly in the form of heavy rain and rainstorm, which is easy to form floods and generate a lot of sediment in the watershed.

The main types of soil erosion in the basin are strong erosion in loess hilly area and slight erosion in soil and rock mountain area, with the areas close to each other 1/2, the former is accounting for 49.7% of the total area; The average regional erosion modulus is 10000 □20 000 t/ (km2 · a) and 1 485 t/ (km2 · a). The rest are river areas with an area of only 154 km2 and an erosion modulus of 800 t/ (km2 ·a).

The reason why the erosion degree of earth-rock mountain area is relatively light is that the vegetation is dense and the coverage rate is high. According to statistics, it is mainly distributed in the basin.

The forest land in the earth-rock mountain area is 138700 hm2, and the forest land coverage rate is 33.4%. In addition, the hillside below the forest line of Luliang Mountains. There are 26900 hm2 of grassland in Liangmao area.

The precipitation change curve in flood season obtained from the data statistics of 17 precipitation stations in the basin. It is obvious that the precipitation in the flood season of the basin in the 1950s and 1960s was relatively high. In the next 30 years, although there were many rainy years like 1988, most of the years were in the relatively low period of alternating precipitation. Especially after the 1990s, it has been dry and rainy. Sediment is also decreasing year by year.

Like other sediment-laden tributaries in the middle reaches of the Yellow River, the Sanchuan River basin has carried out large-scale comprehensive management of water and soil conservation since the 1970s, and has been listed as one of the eight national key water and soil conservation control areas since 1982. The amount of new water and soil conservation measures in each decade increased significantly compared with that in the 1960s, and the area of water and soil conservation forest was the largest, with an increase of more than 100 times; The second is beach land and grass planting, which increased significantly each in the 1980s and1990s compared with the 1960s; Although the area of newly increased terraces decreased in the 1980s compared with that in the 1970s, it increased significantly in the 1990s. Although the number of warping dams cannot be compared with that in the 1960s, the new number increased by 23.8% and 38.8% respectively in terms of the changes in the 1980s and 1990s, which is enough to show the obvious changes (Fig.2).

In addition, Wucheng Reservoir with a control area of 220 km2 and a total storage capacity of 18.5 million m3 was built in the upstream of Dongchuan tributary in October 1972; In October 1973, Nanyanggou Reservoir with a control area of 47.5 km2 and a total storage capacity of 5 million m3 was built in the upstream of Beichuan tributary.

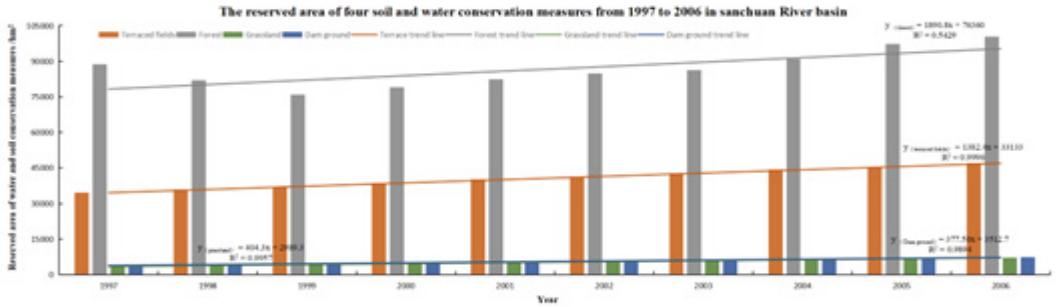

Figure 2: Reserved area of water and soil conservation measures from 1997-2006 in Sanchuan River basin

Analysis and Discussion on the Relationship

According to the relationship between water and soil loss control area and runoff and sediment in different periods (Figure 3), the runoff and sediment volume tend to decrease with the increase of erosion control area.

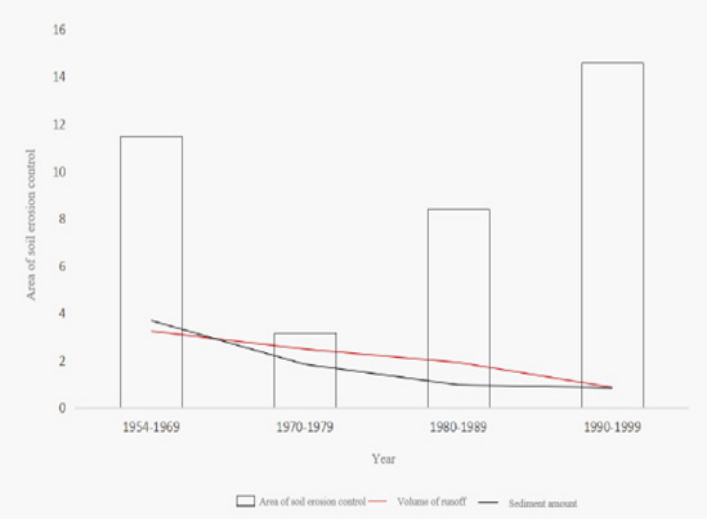

Figure 3: Relationship between soil loss area and runoff and sediment reduction in Sanchuan River at different times

Figure 4 below shows the relationship between the area of measures and runoff and sediment reduction in different periods. With the continuous increase of the area of various soil conservation measures in different periods, the runoff and sediment reduction shows a trend of change. The area of water and soil conservation measures in the 1970s is not large, but also presents sediment and runoff reduction. Whether it indicates the change of rainfall.

However, in the 1980s and 1990s, the intensity of sediment reduction was no longer obvious, which could indicate that the effect of soil conservation measures on sediment reduction had a certain threshold.

Figure 5 shows the role of single water and soil conservation measures in flood reduction in the Sanchuan River basin. Forest and grass measures are more obvious than terraces, grassland measures are the worst in flood reduction, and damsite reservoir measures are the largest in flood reduction. It also proves that damsite engineering measures play a significant role in flood reduction from another perspective. In the future, in view of flood control, we should continue to build dam sites, and with the development of economic construction, the standards for building dams and reservoirs should also be constantly improved.

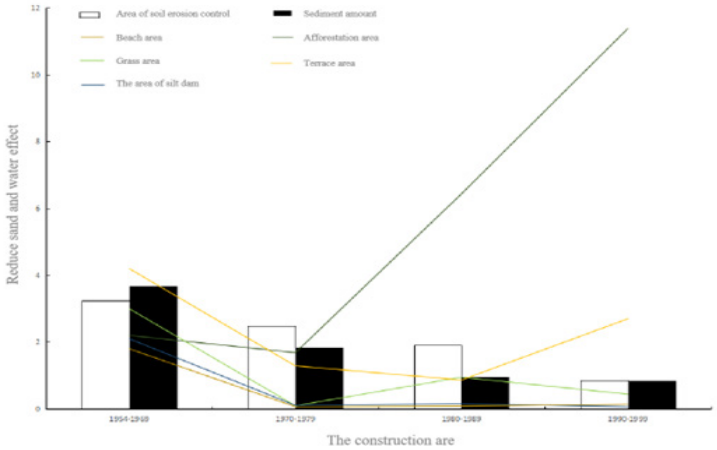

Figure 4: Relationship between the area of single water and soil conservation measures and water and sediment reduction in Sanchuan River in different periods

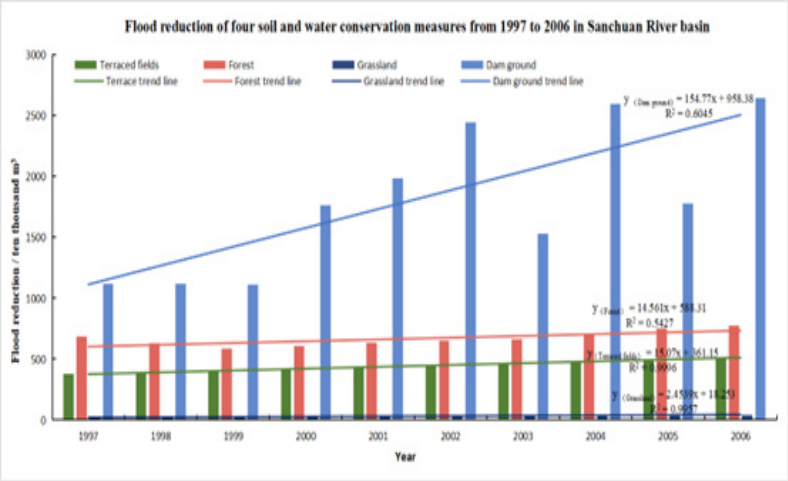

Figure 5: Flood reduction relationship of single water and soil conservation measures in Sanchuan River basin

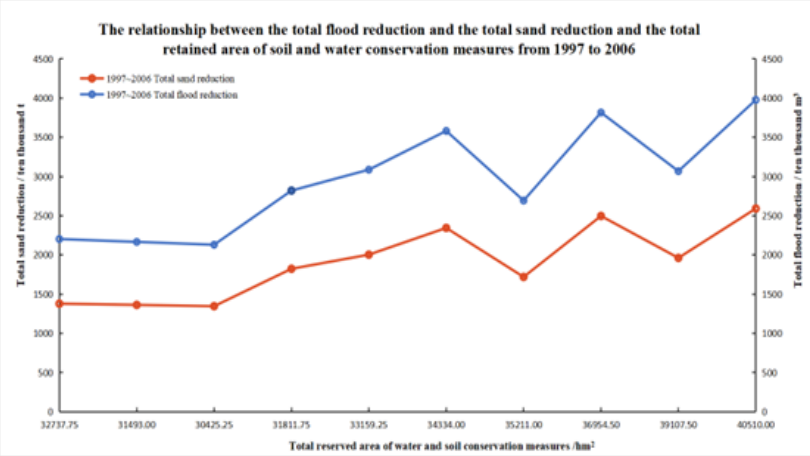

Figure 6: Relationship between reserved area of water and soil conservation measures and flood reduction in Sanchuan Riverbasin

Figure 6 shows the relationship between the total reserved area of water and soil conservation measures with flood and sediment reduction. With the increase of the reserved area, the flood and sediment reduction continues to increase, showing a certain power function relationship.

Figure 7 showing the relationship between the reduction of water and soil conservation measures, indicated that the sediment reduction effect of warping dam is the largest, and it is also increasing year by year, followed by forest land and terrace. The effect of these two measures is similar, and the effect of grassland sediment reduction is the smallest.

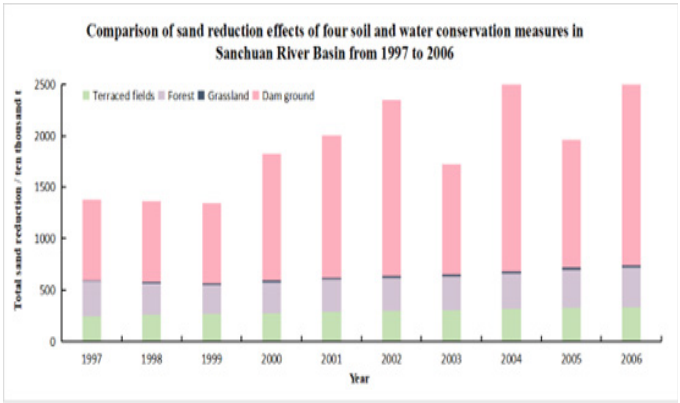

Figure 7: Comparison of sediment reduction effects of single water and soil conservation measures in Sanchuan River basin

In addition, according to the relevant research results (Zhang Xiaoming, 2022), it is believed that the scale differentiation law of water and sediment transport in the watershed under the change of land use/forest vegetation in the Loess Plateau has a good positive correlation between the area and runoff and sediment yield for the small-scale watershed with an area less than 100 km2; For large watersheds, due to the strong sediment transport capacity of gullies, the effect of slope measures on sediment reduction is limited, and the sediment reduction effect of forest vegetation is only reflected by water reduction. When the forest vegetation coverage is less than 45%, the response of runoff and sediment reduction effect to the increase of vegetation is significant.

Secondly, (Hu Chunhong, 2020), forest and grass vegetation and terrace projects also have a special threshold in terms of sediment and runoff reduction. On the slope scale, when the vegetation coverage rate of forest and grass is below 50%~60%, the effect of water and sediment reduction is significant with the increase of vegetation coverage rate; When it is greater than this critical value, the effect of water and sediment reduction will be significantly reduced with the increase of coverage. At the watershed scale: the natural vegetation coverage rate is more than 60%, which can inhibit the rainfall of about 30~50 mm without producing surface runoff and sediment. Terrace measures also has its critical effect. When the ratio of terrace area in the basin (the ratio of terrace area to slightly above water erosion area) is within the range of 5% to 30%, the ratio of terrace is in direct proportion to the extent of sediment reduction. When the ratio of terrace is greater than 35% to 40%, its sediment reduction effect is basically stable at about 90%.

The above analysis in Sanchuanhe and other research results indicated that the the amount of flood and sediment is reduced with the increase of the total reserved area of soil and water conservation measures; the role of dam land in reducing flood and sediment is larger than the terrace and woodland and grassland is relatively least, while the effect of soil and water conservation measures in flood and sediment reduction has certain threshold [1-5].

Discussion and Conclusion

(1) From the perspective of Sanchuan River basin, water and soil conservation measures have an obvious effect on flood and sediment reduction. From the perspective of single measures, the flood and sediment reduction effect of dam land is greater, followed by woodland and terrace, and grassland is relatively least.

(2) From the perspective of the total reserved area of water and soil conservation measures, with the increase of the reserved area, the amount of flood and sediment reduction continues to increase.

(3) The effect of water and soil conservation measures on flood and sediment reduction has a certain threshold, not an infinite relationship. Some research results also show that there is a critical point of runoff and sediment reduction.

Acknowledgments

This research was financially supported by the National Nature Science Foundation of China -Yellow River Joint Fund (U2243210) and National Key Research and Development Project (2016YFC0503704), we appreciate the suggestions of the anonymous reviewer and editor.

References

1. Baver LD (1950) How serious is soil erosion [M]. Proceedings of the soil sciences Society of America 1-5.
2. Hill LW (1977) Forest plantation development influences streamflow. Proc. Soc. Amer. For., Washington, D.C. p. 168-171 Hydrology. Transactions of the ASAE 20: 77-79.
3. Wang Run, Jiang Tong (2000) Review of the European Rhine River Basin Management Action Plan [J] Progress in Water Science 11: 221-226.
4. Yao Wenyi (2011) Analysis and evaluation of water and sediment change in the Yellow River basin [M] Zhengzhou: Yellow River Water Conservancy Press.
5. Liu Xiaoyan (2017) Cause study of sharp decrease of water and sediment in the Yellow River in recent years [M] Beijing: Science Press.