 Benefit Analysis of Silt Storage Dam System for Water and Sediment Interception in the Loess Plateau of China

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Abstract. Silt storage dam system is an integrated system with channel engineering, flood control, sediment reduction, regulation of water resources utilization and other functions. This paper selected the Chabagou watershed as the research object. Through the comparison of runoff and sediment variation before and after the formation of the silt storage dam system under the same magnitude of the flood, analyzed the effects of soil and water conservation on reduction of runoff and sediment.

1. Introduction
Silt storage dam system is an integrated system with channel engineering, flood control, sediment reduction, regulation of water resources utilization and other functions. The function and purpose of silt storage dam system in small watershed is to retain the channel flood and sediment, improve the ecological environment of small watershed, in order to improve the effect of exploitation and utilization of water and soil resources. Dam system construction is one of the water conservancy work "three highlights" project, has been included in the national development plan. In the next 20 years the construction of check dam will reach 163000 in the Loess Plateau. In this region, silt storage dam construction work has entered the most important period.

However, previous studies of silt storage dam in water and sediment reduction benefits were used the research method of “Water conservation method”. Based on the observation data of the test station of soil and water conservation measures of water and sediment reduction effects of soil and water conservation. Calculate the water and sediment reduction benefits of each phase according to the measures of soil and water conservation and to consider the sub item, considering the scouring and silting in river basin soil erosion and sediment yield in the operation and human activities. We can have a clear understanding of silt storage dam in water and sediment conversation in small watershed through this method, but does not embody the silt storage dam system in small watershed comprehensive control of water and sediment reduction benefits.

The author chooses Chabagou watershed as the research object, which located in the middle reaches of the Yellow River branch, through the comparison of runoff and sediment yield situation before and after the silt storage dam formation, combined with the dam basin development of warping dam system, analyzed the benefits of soil and water conservation of water and sediment reduction in this area. To reveal the changes of water and sediment in small watershed of reservoir dam project, in
order to provide scientific basis for revealing the reason of water and sediment reduction in the Yellow River.

2. Study area
The Chabagou Watershed is located at the longitude of 109°47' and latitude of 37°31' and covers an area of 205 km², 24.1 km in length and 7.22 km in width on average. There are one main stream named Chabagou and 11 main branches in the watershed (Fig.1). The outlet station is set up at Caoping, with a drainage area of 187 km². As a result of the continental dry climate, rainfall distribution in the Chabagou Watershed is uneven, 70% concentrating in the three months from July to September and falling mainly in intensive and short rainstorms. With broken terrain, destroyed natural vegetation and agricultural activities, the highly erodible loess in the Loess Plateau tends to generate hyper-concentrated flows in rainstorms, leading to serious soil erosion. The extensive occurrence of hyper-concentrated flows on the Loess Plateau can be regarded as a zonal phenomenon. According to the observations at Zizhou Hydrological Station from 1954 to 1958, the average and largest annual erosion modulus was 15 780 t/km² and 23 670 t/km², respectively. Located in the transitional zone with sandy loess and loess, the study area has been subjected to more intensive soil erosion as a result of silt-sized particle of the loess there besides other causes. To control the serious soil erosion, soil and water conservation measures, such as terraces, forests and grass, check-dams, have been put in practice on the Loess Plateau and developed to a large scale since the 1950s.

3. The development process of silt storage dam
Silt storage dam construction in Chabagou Watershed began in 1953, in the last century 50's, the dam construction of only 25 seats and mostly built in 1958. From the beginning of the last century 60's, the number of silt dam began to increase, the number increased to 124 by 1969. To 80 of the last century, the pace of construction of silt dam began to slow down, only 13 new dams have constructed, mainly concentrated in the repair and reinforcement of silt dam (Fig.2).

The above research results indicate that, the majority of Chabagou watershed dams built in the 60's or 70's of the last century, has made an important contribution to the detention of sediment. However, due to the rainfall in this area has characteristics of high intensity, short duration and concentration. The flood caused by carrying large amounts of sediment beyond the dam impoundment ability, often there will be damage or collapse.
4. Comparison of the flood and sediment

To verify the benefit of comprehensive management of Chabagou watershed dam System, we selected six flood carries on the contrast analysis of similar rainfall of Chabagou Watershed before and after the formation of silt storage dam system. According to the measured data of rainfall, runoff and sediment Chabagou watershed of the six flood reduction are shown in Table 1, table 2 and table 3.

We can see from these tables that, the runoff modulus and sediment transport modulus in 70's than 60's years was decreased. In the case of precipitation in the similar conditions, runoff and sediment transport modulus decreased by 19.9% and 19.1% respectively. Compared to the 90's and 60's, the runoff modulus and sediment transport modulus decreased by 23% and 32.8% respectively; In comparison, the benefits of water reduction by soil and water conservation measures and the benefits of sediment reduction was essentially flat, water and sediment reduction benefits gradually obvious with the continuous improvement of dam system construction. Check dams system in the integrated management of water and soil conservation in small watershed are gradually reflected.

Table 1. The runoff and sediment discharge modulus change of Chabagou watershed (1).

| The flood | Rainfall (mm) | Rainfall duration (h) | Rainfall intensity (mm/h) | runoff $\times 10^3$ m$^3$ | runoff modulus (m$^3$/km$^2$) | Sediment discharge (10$t$) | sediment discharge modulus (t/km$^2$) |
|-----------|---------------|-----------------------|---------------------------|-----------------------------|--------------------------------|-----------------------------|----------------------------------|
| 630603    | 8.6           | 2.7                   | 3.2                       | 43.2                        | 2107.3                         | 20.9                        | 1019.5                           |
| 720731    | 9.0           | 3.0                   | 3.0                       | 34.6                        | 1687.8                         | 16.9                        | 824.4                            |
| reduction (%) |             |                       |                           |                             |                                |                             | 19.9                             | 19.1                             |
Table 2 The runoff and sediment discharge modulus change of Chabagou watershed (2).

| The flood | Rainfall (mm) | Rainfall duration (h) | Rainfall intensity (mm/h) | runoff ($10^3$m³) | runoff modulus ($m^3$/km²) | Sediment discharge ($10^3$t) | Sediment discharge modulus ($t$/km²) |
|-----------|---------------|-----------------------|--------------------------|-------------------|--------------------------|------------------------------|-------------------------------------|
| 600702    | 25.3          | 3.5                   | 7.2                      | 38.7              | 1887.8                   | 25.9                         | 1263.4                             |
| 970729    | 27.6          | 4.0                   | 6.9                      | 29.8              | 1453.7                   | 17.4                         | 848.8                              |

Table 3 The runoff and sediment discharge modulus change of Chabagou watershed (3).

| The flood | Rainfall (mm) | Rainfall duration (h) | Rainfall intensity (mm/h) | runoff ($10^3$m³) | runoff modulus ($m^3$/km²) | Sediment discharge ($10^3$t) | Sediment discharge modulus ($t$/km²) |
|-----------|---------------|-----------------------|--------------------------|-------------------|--------------------------|------------------------------|-------------------------------------|
| 720702    | 24.7          | 3.7                   | 6.7                      | 67.8              | 3307.3                   | 50.5                         | 2463.4                             |
| 990720    | 24.8          | 3.3                   | 7.5                      | 44.4              | 2165.9                   | 34.6                         | 1687.8                             |

5. Conclusion
Chabagou Watershed Dam can effectively reduce the sediment modulus, flood reduction rate reached 30%. This shows that silt dams can be effectively intercept flood, reduce runoff modulus, decrease water effect is greater than 20%. It is worth noting that, silt storage dams decreased significantly during the past decades, most of the original dam has been filled. After 1980s, the dam construction has slowed, and the low design standard, management and maintenance, resulted in sediment release potential in increasing. Therefore, in the future to maintain and consolidate the existing sediment storage dam is very necessary.

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References
[1] Qi J., Cai Q., Fang H., Chen X., Nie B., Cui P. (2010) Effects of soil and water conservation on reduction of runoff and sediment in Chabagou Watershed. Science of Soil and Water Conservation, 8(1): 28–39.
[2] Zhang P., Yao W., Ran D. (2008) Research methods improvement and discussion of the soil and water conservation comprehensive treatment to water and sediment responds. Soil and water research, 15(2): 173–176.
[3] Zhang L., Shi C., Zhang H. (2010) Effects of check-dams on sediment storage-release in Chabagou Watershed. Transactions of the CSAE, 26(2): 64–69.