Study on relationship between underlying surface of typical warping dam and erosion and sediment yield

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Abstract. Under the condition of rainstorm, the underlying surface is an important factor of erosion and sediment yield, and an important embodiment of the process of soil erosion and the law of sediment deposition. This paper analyzes the soil erosion of warping dams with different underlying surface characteristics based on the data of typical warping dams, such as sedimentation amount, sediment retention modulus and underlying surface. The results show that: (1) the average slope of dam55, dam97 and dam011 is 27.55°, 30.79° and 34.68° respectively, and the erosion modulus is 11020t/km², 15204 t/km² and 22579 t/km² respectively; the average slope of dam55, dam97 and dam011 is positively correlated with the erosion modulus, and the correlation coefficient is 0.9889. (2) The sedimentation depth and erosion modulus of dam011 are significantly higher than those of dam55 and dam97. Under the condition of rainstorm, the average slope of watershed is an important factor of soil erosion, which can better reflect and predict the comprehensive intensity of soil erosion.

1. Introduction
The extreme weather in recent years reflects that under the condition of heavy rainfall, mountain torrents still exist in the Loess Plateau, and bring huge economic losses and security problems to the downstream cities. The construction and planning of warping dam is still an important means of flood control and disaster reduction in the future, and also the premise of ecological restoration and sustainable high-quality development. In recent years, many scholars have carried out in-depth research on the underlying surface of small watersheds, mainly including sediment yield mechanism of different landforms under rainfall conditions, soil erosion model construction, effectiveness of soil and water conservation measures and comprehensive evaluation. Zhao Tianyin identified the source of sediment by analyzing the sediment layer of eight rainfall and flood cycles in Qiaozigou small watershed of Luoyugou, Tianshui City, Gansu Province, and divided the sediment source into three sources: farmland, gully slope and gully wall. The results show that the gully wall is the most significant sediment yield in the three stages of 1960-1990. Hou Jiancai studied the theory of rainfall, runoff and sediment in wangmaogou watershed, a typical small watershed in the hilly and gully region of the Loess Plateau by using element tracer technology. The results showed that there was a significant exponential positive
correlation between slope and soil erosion intensity. Within the range of 15° to 26° with the increase of slope, the erosion intensity increased significantly, and through the typical warping dam, the gully and gully were controlled. The relative sediment yield of the valley proved that the inter gully land was the main source of sediment, and the sediment inflow accounted for 66% ~ 70% of the total. It can be seen that the underlying surface is the main source area of erosion and sediment yield in the basin, and the gully land is prone to soil erosion when it rains, and the amount of erosion is different under different slopes. Through the analysis of the underlying surface (slope, slope length and other factors) under different conditions, the mechanism of watershed erosion can be better explained. In this paper, through low altitude aerial photography technology, the typical warping dam (mughulu dam) under different underlying surface conditions is studied, and the soil erosion characteristics of warping dam under different underlying surface parameters are analyzed, so as to provide data support for the erosion and sediment yield mechanism of warping dam.

2. Materials and Methods

2.1. Study area
In this study, Chabagou basin and Zhuangmiaogou basin in the center of 7.26 Wuding River rainstorm were selected as the research objects, and three warping dams (dam55, dam97 and dam011) were selected for comparison. The area of dam controlled basin was less than 1km².

2.2. Materials and Methods
Artificial excavation was used to measure the siltation depth of different sections (in front of dam, in middle of dam and at the end of dam) in the dam site. By using UAV low altitude aerial photography and photoscan software, high-precision DEM (0.2 ~ 0.5m) was generated from the investigation of warping dam control basin. ArcMap was used to extract dam area, dam control basin area, slope and erosion modulus (sediment retention modulus). The slope is divided into 10 grades through natural breaks (Jenks) classification method. Linear regression and correlation analysis were used to analyze the effects of different topography parameters on soil erosion.

3. Results and Analysis

3.1. Slope analysis

![Figure 1. Natural Breaks (Jenks) of slope with slope area and proportion](image-url)
Slope is an important factor of terrain data in basin underlying surface. It can not only reflect the mechanism of sediment yield, but also play an important role in the process of soil loss and erosion. The results of this study(Figure 1) show that the slope distribution in the dam controlled basin is mainly concentrated in 14° to 38° with the highest proportion, and the proportion greater than 38° gradually decreases, while the proportion less than 14° varies with the dam area. In dam011, the overall slope between 14° and 38° is relatively small, the slope greater than 38° is relatively high, and the slope between 0° and 6° is obviously small, which indicates that the dam area in dam controlled basin is small. It can be inferred that the overall slope in the basin is large, and it is easy to produce large amount of soil erosion in rainstorm, and the deposition depth is high, which can be further confirmed by relevant data.

3.2. Erosion modulus

In the Loess Plateau, the main rainfall index affecting soil erosion is the number of high-intensity rainfall, and soil erosion is mainly caused by one or several high-intensity rainfall. The size of erosion modulus depends on the erosion intensity per unit watershed area. Under different terrain conditions, the steeper the terrain is, the easier the soil erosion will occur. The results(Figure 2) show that the average slope of dam55, dam97 and dam011 is 27.55°, 30.79° and 34.68° respectively, the erosion modulus is 11020 t/km², 15204 t/km² and 22579 t/km² respectively, and the average deposition depth in dam is 0.58m, 0.49m and 1.00m respectively. There is a positive correlation between the average slope and the erosion modulus in the dam controlled watershed, and the correlation coefficient is 0.9889. The deposition depth and erosion modulus of dam011 are significantly higher than those of dam55 and dam97. Therefore, under the condition of rainstorm, the average slope of watershed is an important factor of soil erosion, which can better reflect and predict the comprehensive intensity of soil erosion.

4. Discussion

The construction of warping dam has a significant impact on the runoff coefficient and the lag time of the watershed, which can effectively regulate the process of runoff and sediment transport in the watershed. Its blocking effect can significantly reduce the sediment transport ratio of the watershed, and has a regulatory effect on the stability of the gully slope and the soil erosion modulus of the watershed. The sediment retention effect of warping dams under different underlying surface conditions can reflect
the mechanism process of erosion and sediment yield in small watershed, especially the sediment deposition of typical warping dams, which contains a lot of sediment deposition and transport information, and can effectively reflect the real situation of soil erosion in watershed under rainfall conditions. Slope as an important factor of underlying surface, is very important to study the law of soil erosion. Through the analysis of the distribution of different slopes and the correlation between slope and watershed erosion, it can effectively support the mechanism of soil erosion and sediment yield, and provide basic support for the silt retention and flood detention function of warping dam.

5. Conclusion
Based on the analysis of typical warping dam's silting depth, slope distribution and soil erosion modulus data, among them, the overall slope of typical warping dams is compared, and the distribution of different slope ranges is analyzed by using the natural discontinuous classification method, the results show that dam011 dam control basin has the largest overall slope, the smallest dam area, the highest amount of soil erosion in rainstorm and the highest silting depth. There is a positive correlation between the average slope and the erosion modulus in the typical warping dam controlled watershed, and the correlation coefficient is 0.9889. Under the condition of rainstorm, the average slope is an important factor of soil erosion, which can better reflect and predict the comprehensive intensity of soil erosion.

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