Landslide of Surface Layer on the Slope and Estimation of Basin Sediment Yield

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Abstract: Through various rainstorm tests, the erosion processes of a slope was observed and the impacts of various topographic features, soil composition and vegetation on sediment yield were analyzed. The result indicated: (1) the excess rain is the main reason of the soil erosion of bare lands; and the sediment yield is related to the accumulated precipitation; (2) the sharp increase of soil pore water pressure is the instrinsic force to cause the soil dilapidation of surface layer, whereas the falling soil flow becomes the root of sudden increase of basin sediment yield. Finally, the relationship among the basin sediment yield, precipitation characteristics and basin characters, was analyzed, and the proposed formulation was vertified by the field data of sediment yield in Gushanchuan Basin.
Keywords: surface layer dilapidation, precipitation characteristic, basin character, basin sediment yield

1 Introduction

For a basin with an area more than 10 km^2, gully erosion is the main style of soil erosion. With the increase of the basin area, the sediment concentration could reach very high. Thus, the hyperconcentrated and muddy flow may frequently be observed. In making project plan for sediment disaster prevention in a basin more than 10 km^2, how to determine the amount of sediment yield becomes the key issue. The design sediment yield can be determined by the sediment discharge corresponding to a certain design frequency precipitation. Therefore, the estimation of basin sediment yield provides a scientific reference for determining disaster prevention strategy.

To study the impact of rainfall processes on the sediment yield on a slope, various tests were carried out in a flume with adjustable slope, and length = 6 m, width = 2 m,and depth = 1.3 m. The gradations of sediment mixture are d_{90} = 0.60 mm, d_{50} = 0.23 mm, d_{10} = 0.006 mm.The slope of the flume can be adjusted from 20° to 40°; soil thickness is 60 cm, and the dry density is 1.5 g/cm^3—1.7 g/cm^3. Six kinds of topographic conditions are adopted: plane, ascent, descent, gutter, ridge and catchment, and two kinds of surface layer conditions are used: bareness and non-slub cloth covering. The precipitation intensity in tests is 20 mm/h—80 mm/h. The erosion process, sediment yield, displacement of soil mass, and pore water pressure were measured during experiments.

2 Effects of various factors on slope dilapidation

(1) Effects of precipitation on slope dilapidation

When precipitation intensity is more than infiltration capacity, slight erosion will occur, when runoff appears on the bare slope. If the precipitation duration is long enough or a strong rainstorm occurs, the pore water pressure will continuously increase to lead to the dilapidation of surface layer. The sharp increase of soil pore water pressure is the intrinsic force to cause the soil dilapidation of surface layer. The dilapidation is mainly related to rain intensity and accumulated precipitation, also related to basin geographic environment.

(2) Effects of the shape of a slope on dilapidation[2]

The statistic analyses on the field data are the main methods in the previous research on the dilapidation of surface layer on a slope. Based on statistic results, most dilapidations occurred on the slope more than 30°. The probability of dilapidation was affected by slope shapes such as plane, ascent, descent, gutter, ridge and catchment. Test results indicated that the type and position of landslide are also related to slope shapes. For example, landslides were observed in the case of the slope more 30°, whereas dilapidations couldn't be seen for the at the positions that slope gradients were more than 30° in a serial slope less than 30°. The occurrence probabilities of landslides on different slope shapes can be summarized as: the descent type＞the ascent type, the plane type＞the catchment type, and the gutter type is equivalent to the ridge type.

(3) Effects of vegetation on dilapidation[3]

Non-slub cloth covering the slope was used as the vegetation in the tests. Non-slub cloth has a good ability to hold water and soil during the precipitation, because of the good touch between the non-slub cloth and surface soil. There is no any erosion occurred on the surface, no matter how strong the precipitation intensity is. This result shows vegetation has a good function for water and soil conservation, and therefore can mitigate the degree of water erosion. However, the dilapidation still occurred in the end on the surface whose gradient was more than 30°. Comparing with the bare surface, the vegetation can efficiently delay the dilapidation, but the gravitation erosion is still inevitable. On the other hand, the phenomenon that no hydraulic water erosion occurs on the surface covered by the vegetation during precipitation process may result in a larger scale falling than that on the bare surface.

(4) Effects of soil types on dilapidation

Based on statistic dilapidation probability of the surface layer on a slope is closely related to the soil type. The field data show that more than70% of landslides appeared on soil slopes, only 25% occurred on the slopes of strong-airslake rock and other rocks. Moreover, rock falling can hardly result in flow and has a little influence on basin sediment yield. Most surface layer fallings are independent to the slope height and the thickness of a falling is about 1m. The tests indicate that the soil-type slope would not fall if both the propertation of clay and dry density of soil mass are high, because the rain can hardly infiltrate into the soil and no pore water pressure can be formed in the soil mass. Howerer if the surface runoff is relatively big and the degree of hydraulic erosion on bare soil is severe, the total sediment yield would be high.

3 Estimation of basin sediment yield

Basin sediment yield is related to precipitation characteristics and basin environment characters. For the basins that have similar environment characters, their sediment yields are mostly related to the precipitation. So the relationship between basin sediment yield and precipitation can be established with precipitation characteristics. Taking the Gushanchuan basin as an example, the sediment yield peak occurred in 1977. The total precipitation was not very high in flood season that year, but the maximum daily precipitation was very high, about several times of normal year. It is obvious that the sediment yield peak of Gushanchuan basin is mainly resulted from several storms. Sediment yield was also related to the annual precipitation in some degree. Thus, it is reasonable to take the maximum daily precipitation and mean annual precipitation as the characteristic parameter of precipitation in the formulation of sediment yield forecasting. The basin normal annual sediment yield is related to environment characters including vegetation covering rate, surface layer composition(composition) and slope form or gully density. The formulation can then be written as follows:

$$w_y = k\left(\frac{s_1}{s}\frac{m_y}{M_y}\right) + \eta\left(\frac{s_2}{s}\frac{m_1 - M_1}{M_1}\right)w_y \tag{1}$$

where

w_y, M_y are the predicted sediment yield and mean annual sediment yield;

m_y, M_y are the annual precipitation and mean annual precipitation;

m_1, M_1 are the maximum daily precipitation and mean annual maximum daily precipitation;

s_1/s is the proportion of bare area and basin area;

s_2/s is the proportion of slope area whose gradient is more than 30° and basin area;

η is related to annual rainstorms number, $\eta = 1.8$ for Gushanchuan basin;
k is a parameter, $k = 1.2$ for Gushanchuan basin.

Gushanchuan basin is famous for its heavily sediment-laden and grit streams in whole Yellow River basin. The slope is composed of sand loam, in which the quantity of grain less than 0.01 mm is only 5%~10%. Its erosion resistance is weak. In Gushanchuan basin, the mean annual precipitation is 400 mm, the mean annual maximum daily precipitation is 50mm and the vegetation rate is slightly less than 20%. The slope area that in which the gradient is more than 30° is about 60% of the total basin area. Based on observed data of annual precipitation and maximum daily precipitation from 1957 to 1986, the following Figure shows a comparison between the calculated annual sediment yield and the observed values.

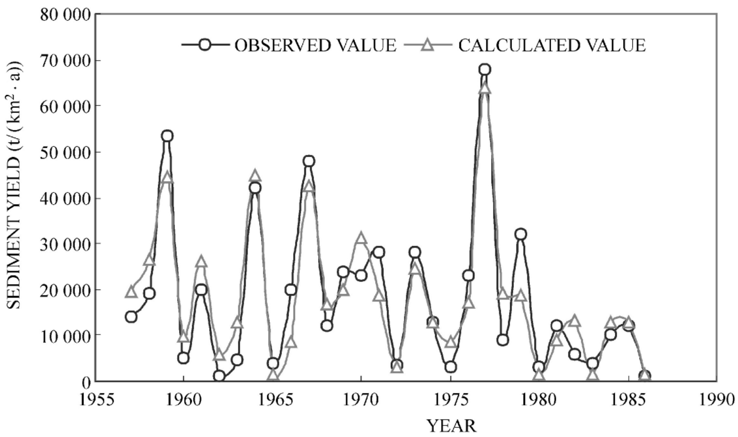

Fig. Comparison between the calculated annual sediment yield and the observed values

4 Conclusions

The basin mean annual sediment yield is related to the mean annual precipitation, vegetation, soil constituent, gully density, and so on. Moreover, the annual sediment yield is also related to the annual precipitation, precipitation intensity and storm number, etc. The paper investigated the hydraulic erosion quantity on the bare area and the potential falling quantity of the soil slope whose gradient is more than 30°. The verification of the proposed formulation for the sediment yield prediction by using observed data in Gushanchuan basin shows that a good correlation coefficient, 0.8,is reached. So the formulation can be applied to other similar basins.

References

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