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Study on Soil Erosion Law of Highway Spoil Ground

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Abstract. In this study, a typical spoil ground was selected in the test area, and runoff plots were set up. Through rainfall tests and statistical analysis of the data, the soil erosion law of the spoil ground was studied. The results show that under different rainfall intensities, the soil bulk density is positive to the runoff rate. Correlation indicates that the increase of soil bulk density and runoff rate increase; the increase of soil bulk density increases the soil's impact resistance, and the erosion rate decreases with the increase of bulk density.

1 Introduction

As a foreign structure, the road is attached to the natural environment, and has a drastic impact on the hydrological response of the watershed and the process of soil erosion [1]. Uncovered pavements, excavated slopes, filled slopes, and highway spoil grounds have significantly altered the original landforms, thereby altering the natural hydrological process and the law of soil erosion. In recent years, the study of road soil erosion has attracted the attention of many scholars at home and abroad. Its research mainly focuses on uncovered pavement [2-5], excavated slope and filled slope [6-8]. The study of soil erosion law in highway spoil grounds has received widespread attention. Highway spoil ground is an indispensable product in highway construction. At the same time, highway spoil ground accounts for 6% of the total number of spoil grounds generated in China's construction activities. Therefore, soil erosion from highway spoil grounds affects road soil Erosion assessment and estimation of sediment yield in a river basin are both important.

Studying the soil erosion laws and runoff and sediment production laws of highway spoil grounds can provide theoretical basis and necessary parameters for estimating soil erosion in spoil grounds. At the same time, it can supplement and improve road and soil erosion estimation models to provide technical support for regional soil and water loss assessment. In addition, the study can also improve the calculation accuracy of catchment sediment yield by catchment hydrological models.

2 Overview of the test area

The study area is located in Hunan Province, China, and belongs to the mid-subtropical monsoon climate. The average annual temperature is 18.3 °C, and the average annual rainfall is 1238.4 mm, mainly concentrated in May to July. The project selected 6 highway spoil grounds with different high-speed projects and different stacking years in the vicinity of Changsha City, Hunan Province, set up runoff plots, and conducted artificial rainfall tests.

3 Experimental methods

3.1 Slope runoff and sediment data collection

In order to find out the rules of runoff and sediment production on highway spoil grounds, artificial rainfall experiments were conducted. A total of 6 plots were selected in the experiment, of which 5 plots were loose earthwork in the spoil plot, and 1 was the construction road in the spoil plot. The properties are shown in Table 1. Runoff plots are processed as follows. First, steel plates that can be bonded to each other are used to form a rectangular area with a certain area directly below the rainfall sprinkler heads. In order to prevent runoff from leaking in the plot, the steel sheets are inserted 10 to 15 cm below the ground. A V-shaped water collecting tank is installed at the bottom to collect muddy water samples.

The experimental rain intensity was 0.6, 1.22, 1.74, 2.33, 2.79 mm / min, and a total of 30 games were performed (6 5). In each rainfall process, the time starts immediately after the start of the rainfall, and one muddy water sample is collected immediately after the start of the runoff, and then every 2 minutes. The sampling volume varies from 1 to 10 L depending on the rain intensity. When the sampling volume is greater than 1 L, first stir the muddy water sample up and down for 1 min to make the sediment content more uniform, and then take out 1 L to calculate the mud. Sand content and sediment content were determined by the drying method. The duration of rainfall varies depending on the rate at which the runoff is stabilized. Each rainfall lasts for 20 to 30 minutes after the runoff stabilizes.

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Table 1 Main properties of each Plot

	Plot a	Plot b	Plot c	Plot d	Plot e	Plot f
Plot width (m)	2.1	2.1	2.1	2.1	2.1	2.1
Plot length (m)	10.0	10.0	10.0	4.2	3.8	10
Soil bulk density (g cm^{-3})	1.37	1.22	1.27	1.41	1.24	1.66
Plot slope (%)	19.4	30.6	46.6	57.7	78.1	30.6
Grit content (%)	18.4	19.7	17.4	20.4	16.9	17.2
Powder content (%)	65.2	62.7	69.1	64.4	68.5	70.1
Clay content (%)	15.9	16.6	12.5	14.7	13.6	12.0

3.2 Data statistical analysis method

Since the soil bulk density and slope of the plot have certain effects on runoff and erosion, in order to distinguish the impact of the two factors (bulk density, slope) on the erosion rate, this paper uses partial correlation coefficients to explore the relationship between the erosion rate of a single factor:

$$r_{xy,z} = \frac{r_{xy} - r_{xz}r_{yz}}{\sqrt{1-r_{xz}^2}\sqrt{1-r_{yz}^2}} \tag{1}$$

Where rxy, z is the partial correlation coefficient of x and y with z as the control variable; rxy is the correlation coefficient of x and y; rxz is the correlation coefficient of x and z; ryz is the correlation coefficient of y and z.

This paper uses rainfall erosivity (R) as a factor to fit the amount of soil loss. The calculation method is the same as that in the empirical formula RUSLE. In order to revise the plots of different slope lengths to the same slope length, so as to compare the erosion rate, the formula is used to uniformly modify the slope soil loss of each plot to a slope length of 10 m.

$$L = (\frac{\lambda}{22.13})^m \tag{2}$$

Where λ is the horizontal projection of the slope length, and m is 0.5 in this paper. This article uses the model effective coefficient (ME) to check the fitting effect of the model. The calculation method is:

$$M_{\mathrm{E}} = 1 - \sum(Q_i - Q_{ci})^2 / \sum(Q_i - Q_m)^2 \tag{3}$$

ME is the model effective coefficient; Qi is the measured value of the i-th sample; Qci is the calculated value of the i-th sample; Qm is the average value calculated by the model.

Data processing includes regression analysis, partial correlation analysis, paired T test, nonlinear fitting, and numerical solution of nonlinear equations. All statistical analyses were performed using Matlab.

4 Analysis of soil erosion regularity in highway spoil ground

4.1 Influence of rain intensity on soil erosion rate

The tendency of the soil erosion rate of loose soil (Plot a ~ e) to change with rain intensity is similar, and basically all increase with the increase of rain intensity as a power function (Figure 1). Compared with loose soil placement, the soil erosion rate of the construction pavement (Plot f) under heavy rain is increased less. This is because after the loose soil particles on the surface of the pavement are eroded, the bottom soil bulk density is larger, the impact resistance is stronger, and the soil Erosion rates are relatively insensitive to changes in rainfall intensity and will depend on soil conditions.

There are two anomalies in the soil erosion rate of Plot f: the maximum soil erosion rate under a rain intensity of 1.74 mm / min, and the average soil erosion rate produced by a rain intensity of 2.79 mm / min is less than that under a rain intensity of 2.33 mm / min. Soil erosion rate. The above-mentioned anomalies are caused by the differences in the road surface of the spoil ground during the experiment, which indicates that loose soil particles on the road surface caused by disturbances such as machinery and vehicles have an important impact on road erosion.

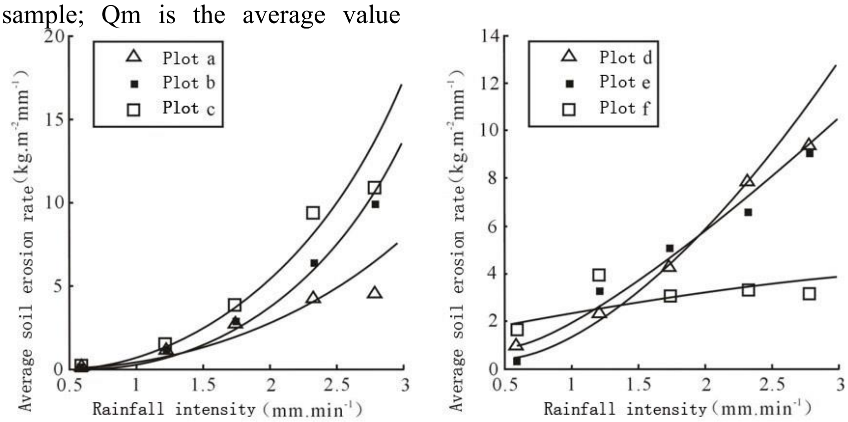

Figure 1 Relationship between rain intensity and average soil erosion rate

4.2 Influence of bulk density on soil erosion rate

The relationship between soil bulk density and average erosion rate is relatively complicated (Table 2): under light rain intensity (0.6 ~ 1.74 mm / min), the bulk density has a significant positive correlation with soil erosion rate, that is, the larger the bulk density, the stronger the soil erosion. However, under heavy rainfall (2.33 ~ 2.79 mm / min), the bulk density is negatively correlated with the soil erosion rate. At light rain intensity, the runoff of the plot with larger bulk density increased significantly. At the same time, the increase of bulk density also reduced the critical threshold of erosive rainfall, which resulted in the increase of soil erosion with the increase of bulk density. Under heavy rainfall, the surface of the soil body quickly reached saturation, and the super seepage flow occurred, and the relative infiltration amount was relatively small, so the runoff did not change significantly with the increase of the bulk density. The increase of the bulk density will inevitably increase the soil's impact resistance. Therefore, under heavy rain conditions, the erosion rate decreases with the increase of the bulk density.

The significance degree of the correlation coefficient (Table 2) shows that the effect of bulk density on soil erosion rate under light rain intensity is more significant, and its effect becomes less obvious when the rain is stronger than 1.74 mm / min.

Table 2 Partial correlation coefficient between soil bulk density and average soil erosion rate

Rainfall intensity（mm/ min）	0.6	1.22	1.74	2.33	2.79
Soil bulk density (g/ cm)	0.968**	0.811*	0.407	-0.530	-0.784
P value	0.006	0.047	0.472	0.304	0.105

Note: where slope is the control variable

4.3 Influence of slope on erosion rate

In order to eliminate the influence of bulk density on erosion rate to the greatest extent, according to the above analysis, when the rain intensity is 1.74 mm / min and 2.33 mm / min, the correlation between bulk density and soil loss rate is the least significant (P values are 0.472 and 0.304, respectively, table 2) Therefore, the results of these two sets of simulation experiments were selected to analyze the influence of slope on erosion rate. In order to carry out a unified analysis of the experimental results under different slope conditions, the raw data must be standardized. Specifically, Plot a soil loss is used to remove soil loss on other slopes, and standardized data corresponding to the slope is established. The slope-standardized loss relationship is plotted as shown in Figure 21, and the statistical relationship is obtained by the correlation (Equation 4):

$$S = 2.032\sin\theta + 0.639 \quad (4)$$

Among them, S is the soil loss after the road spoil ground is standardized, and θ is the slope of the plot.

In order to facilitate comparison with slope farmland, the slope farmland slope formula is also revised to Plot a slope, and the revised slope factor SLiu is obtained. The results show that the variation law of the slope factor (S) of the spoil ground is quite different from that of the traditional cultivated land. Although the trends tend to increase as the slope increases, the slope of the slope factor on slope farmland is significantly larger than the slope of the spoil ground. If the steep slope formula of cultivated land is directly used to estimate the slope factor of the spoil ground, the estimated value will be too large.

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