ATLANTIS PRESS

Advances in Engineering Research, volume 129

6th International Conference on Energy, Environment and Sustainable Development (ICEESD 2017)

Research on Characteristics of Soil and Water Loss under Different Slope Conditions

Kun Wang[1,a], Xin Cong[2,b], Jing Xu[3,c], Zhenghe Xu[4,d*]

[1]University of Ji'nan, Ji'nan, China

[2]University of Ji'nan, Ji'nan, China

[3]Beijing forestry university, Beijing,China

[4]University of Ji'nan, Ji'nan, China

[a]email:1015157780@qq.com, [b]email:2536356451@qq.com,
[c]email:1426461661@qq.com,[d]email:xu4045@126.com

Keywords: Runoff plot; Slope; The depth of runoff; Amount of soil erosion; Soil and water loss characteristics

Abstract. With the expansion of production and construction projects in recent years, water and soil erosion in the southern mountain area of Ji'nan has been increased significantly. In order to protect the important supply area of Ji'nan spring water, it is necessary to study the characteristics of soil and water loss and its control measures in the southern mountainous areas. Based on the runoff and sediment data of the runoff plots in Jixi Soil and Water Conservation Monitoring Experiment Station, soil erosion characteristic under the different slope were analyzed combined with the rainfall, soil and vegetation factors. The study showed that: (1) the runoff depth and soil erosion increased with the increase of slope gradient, the maximum value appeared at 20~25 degrees slope; (2) The mean value of runoff depth in different slope was obviously correlated with rainfall intensity, the runoff depth increased with the increase of rainfall intensity; Soil erosion quantity is affected by the surface vegetation and soil characteristics besides rainfall characteristics, it increased with the increase of rainfall intensity and decreased with the increase of vegetation coverage. And the degree of soil and water loss of slope can obviously weaken by carrying out the vegetation measures.

Introduction

The function of keeping water and soil in the southern mountainous area in Ji'nan plays an important role in the development and utilization of water resources in Ji'nan. Because of steep slop,barren soil, small vegetation coverage and the destructive effect from a large number of development projects on soil in recent years, the degree of soil erosion has been intensified. The complex and varied topography and geomorphology of mountainous area is the key factor influencing the characteristics of runoff and sediment from hill slope,and slope gradient is one of the important topographic factors affecting runoff and erosion of slope[1-3]. The study analyzed the effects of different slope gradient on the surface runoff and soil erosion under the natural rainfall condition in differrnt runoff plots, to provide scientific reference for comprehensive control of soil and water conservation of Ji'nan and other basins.

Basic Situation of Runoff Plots

For researching the characteristics of soil erosion in southern mountain area of Ji'nan City, the Bureau of Hydrology built five runoff plots with 5 degrees, 10 degrees, 15 degrees, 20 degrees and 25 degrees in Jixi Soil and Water Conservation Monitoring Experiment Station in 2013.The slops are to the north, its projection length are 10m and the width are 5m. The laying soil is cinnamon soil from southern mountainous areas, and its thickness is 50cm. These plots are planted with 4 kinds of grass including trifolium repens, ryegrass, bermuda grass and festuca arundinaceain in June 13, 2013, we try to avoid human interference in the process of plant growth. And in 2015, low shrub (Vitex, Lespedeza)

were added after herbaceous vegetation covered stably to form the artificial runoff plots with the combination of grass and shrub.

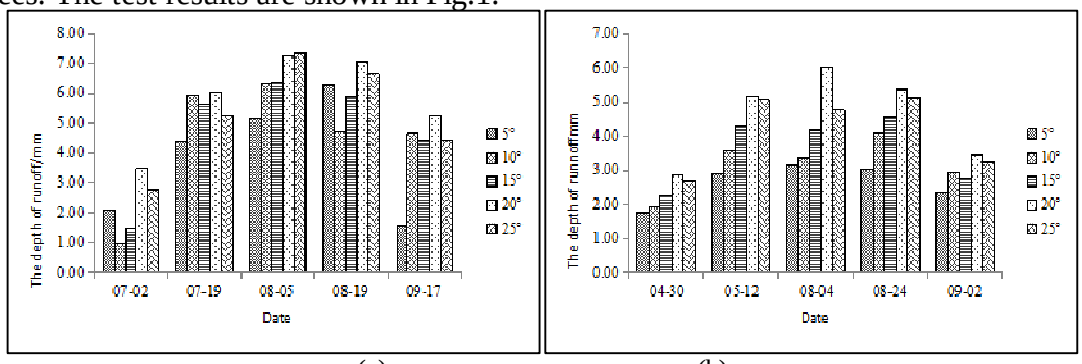
Data Acquisition and Research Methods

Runoff plots were used to the experiment in June 1, 2014, and a total of 10 runoff generation from 2014 to 2015 were monitored. Runoff yield were measured at the end of rainfall and runff, sediment sampling was carried out at the same time. And then, the runoff yield was converted into runoff depth according to the projected area. Sediment in each plot were taken for 2 times repeatedly, the weight of dry sand were determined using drying method and calculated the sediment concentration and the amount of soil erosion[4-5]. Precipitation, air temperature, soil temperature and soil moisture data were obtained from automatic weather station on the side of the runoff plots, data is recorded once per 15min.

Based on the correlation analysis between the characteristics of runoff and sediment at five different kinds of slops and the characteristics of corresponding rainfall and vegetation, the characteristics of soil and water loss under changing slope were deeply discussed. This study selected the characteristic factors of rainfall intensity, the amount of rainfall and vegetation coverage, conducted comprehensive analysis of the response features of soil erosion under different slope changes in various factors to explorate the main influencing factor which lead to soil erosion. The changing characteristics of the amount of runoff and soil erosion with increasing slope were analyzed based on the 10 times production process of runoff and sediment in flood season.

Results and Analysis

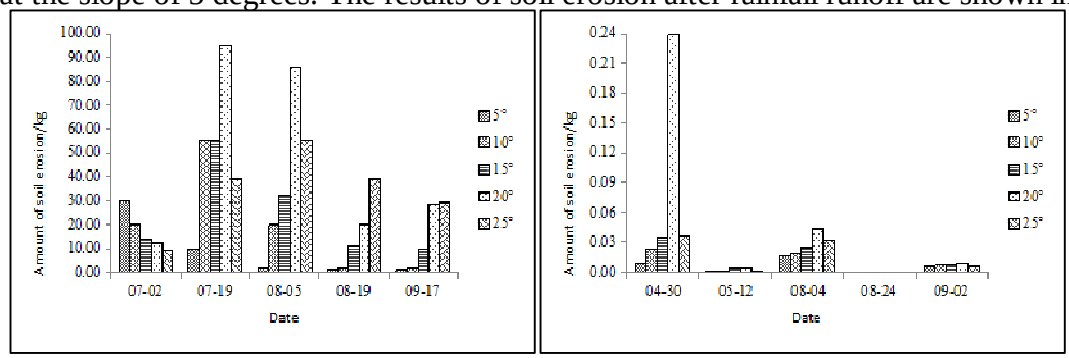
Effect of Different Slope on Runoff. The rainfall and underlying surface conditions of runoff plots with different slopes are consistent in the previous runoff process, so the main factor affecting runoff is slope gradient. The effect of slope gradient on runoff and sediment yield is mainly affected by rainfall infiltration. Under the same rainfall conditions, if the slope gradient increaes, the runoff yield will also raise because the increasing water velocity of slope and the weakening infiltration[6-8]. Among the 10 process of rainfall runoff, the minimum runoff depth appeared in 10 degrees plot 2 times , the 5 times appeared in the area of 5 degrees, the maximum depth of runoff occurred in the 20 degrees 9 times, there is 1 time appearing in the 25 degrees. Therefore, we can know about that there is a positive correlation between runoff depth and the slope gradient. In 5 degrees and 10 degrees slope, the effect of infiltration is obvious and it is not easy to generate runoff. While in the 20 degrees slope, it is prone to cause runoff yield under excess infiltration phenomenon because the gravity component perpendicular to the slope of rainfall and runoff become less, the flow rate increases, and the infiltration weakens. According to the analysis about the data during 2014-2015, the maximum runoff gradient is 20 degrees. The test results are shown in Fig.1.



(a) (b)

Figure 1. Runoff depth characteristic under different slopes(a:in2014 b: in 2015)

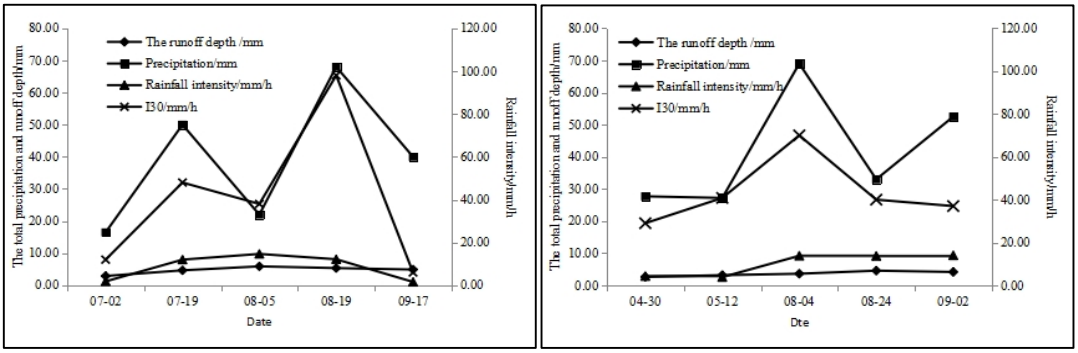
Effect of Different Slopes on Soil Erosion. The rainfall and underlying surface conditions of runoff plots with different slope are consistent in the soil erosion process, so the main factor affecting soil erosion is slope change. On the stable slope, with the slope gradient increasing, the soil erosion increases with the increase of runoff rate, but the raindrop splashing erosion force weakens which makes the quantity of erosion decrease[9-10]. In this study, through the analysis of the results of rainfall runoff in 2014, we can know that: soil erosion increased with slope gradient; the maximum erosion quantity appeared at 20 degrees or 25 degrees slope, the minimum value appeared in the slope of 5 degrees; In July 2nd, the amount of soil erosion with the slope variation are contrary to others, this is because the runoff plots began to conduct repeated sprinkler irrigation in early July after artificial seeding in June 13th, the soil is bare and it leads to physical crust of soil surface after irrigation. In 2015, soil erosion increased with the slope increasing except for the test in August 24th which didn't produce sediment yield. The maximum erosion amount appeared at 20 degrees, and the minimum value appeared at the slope of 5 degrees. The results of soil erosion after rainfall runoff are shown in Fig.2.



(a) (b)

Figure2. Soil erosion characteristic under different slope (a:in2014 b: in 2015)

Effects of Rainfall Characteristics on Soil Erosion. The degree of soil erosion is different under different rainfall characteristics including the total precipitation, average rainfall intensity and I_{30} (maximum rainfall intensity in 30min). This study made a comparative analysis between the average values of runoff depth under five slopes and the corresponding values of rainfall characteristics in each test. The results showed that the variation of runoff depth was consistent with the rain intensity, and partly consistent with the change trend of the total precipitation and $I_{30.}$ Therefore, these experiments show that rainfall intensity plays a key role in the change of runoff depth. Correlation between runoff and rainfall characteristics are shown in Fig.3.

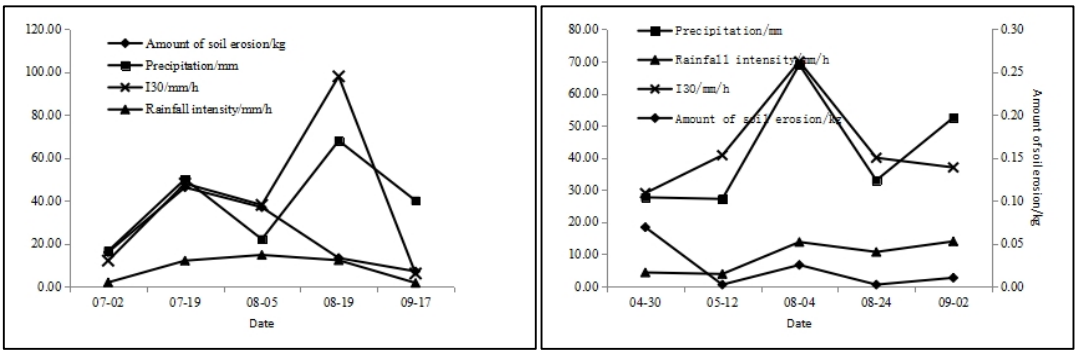


(a) (b)

Figure 3 Correlation between runoff and precipitation characteristics(a:in2014 b: in 2015)

In addition, this study made a comparative analysis between the average values of soil erosion amount under five slopes and the corresponding values of rainfall characteristics in each test. The results showed that the amount of soil erosion increasesd with the increasing of rainfall intensity, total precipitation and I_{30} in the early stage, and then its change trend was consistent with the trend of rainfall

intensity after the maximum value appeared(Fig.4). Therefore, the correlation between soil erosion and rainfall intensity is the strongest, which is not related to other factors.



(a) (b)

Figure 4 Correlation between soil erosion and rainfall characteristics(a:in2014 b: in 2015)

Effect of Underlying Surface Characteristics on Soil Erosion. To eliminate the interference of rainfall factors. The data of two groups with similar rainfall characteristics in August 5, 2014 and in May 12, 2015 were selected to research the relationship between runoff/soil erosion and slop gradient(the vegetation coverage in the year of 2014 was 34.7%, and the vegetation coverage in the year 2015 was 46.6%). The results are shown in Fig.5.

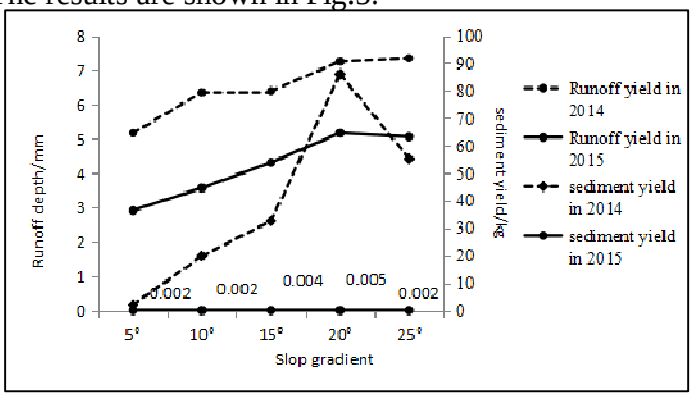


Figure 5 The relationship between slope and runoff/soil erosion in different surface conditio

From the Fig.5, we can know that the runoff yield and sediment yield of each slope in 2015 were lower than 2014 under different vegetation coverage conditions. From the overall trend, vegetation coverage increased, runoff yield and sediment yield decreased, and the change of sediment yield is particularly obvious. Therefore, soil erosion can be significantly weakened by planting plants on the slope.

Conclusions

Through the analysis of the effect of different slopes factors (5 degrees, 10 degrees, 15 degrees, 20 degrees and 25 degrees) on runoff and sediment yield, soil loss characteristics of slope were studied in mountainous area of southern Ji'nan, we can draw the following conclusions:

(1)In the early stages of the runoff plots construction, the soil was loose and bare, and soil erosion rate increased with the decrease of the slope. So we should pay attention to the protection of bare slope. With the stability characteristics of soil, runoff and soil erosion of 5 degrees and 10 degrees slope became small, and the maximum depth of runoff and soil erosion occurred mainly in the 20 degrees slope, followed by 25 degrees slope. Therefore, 20~25 degrees slops can be regarded as the critical gradient of soil erosion in the mountainous area of southern Ji'nan.

(2)Through comparative analysis of the average runoff depth and the soil erosion yield in different slopes, the results show that the depth of runoff has good correlation with the average rainfall intensity, and the change tendency is consistent with the total precipitation and I_{30} only in part of tests; Soil erosion and rainfall intensity has a certain relevance and the correlation with the total precipitation and I_{30} is not obvious.

(3)Based on two times of rainfall with similar intensity, runoff and sediment content under different underlying surface conditions were analyzed. Results show that runoff depth and soil erosion decrease with the increase of vegetation coverage, and vegetation has important significance for soil and water conservation.

Acknowledgements

This paper is supported by National Natural Science Foundation of China(31400619), Ji'nan water environment ecological management technology reasearch and promotion project (SHMS2015-301) and Ji'nan sponge city southern pilot area water quality monitoring and assessment technology (2016JSFW02Z0307).

References

[1] H.R. Zhao, F.L. ZHENG. Effect of slope gradients on erosion from a red soil hillslope under different rainfall intensity. Journal of Soil and Water Conservation, Vol. 25 (2011) No.3, p.40-43.(in Chinese)

[2] O. RIBOLZI, J. PATIN and L.M. BRESSON, et al. Impact of slope gradient on soil surface features and infiltration on steep slopes in northern Laos. Geomorphology, Vol. 1 (2011) No.127, p.53-63.

[3] M. MAHMOODABADI, S.A. SAJJADI. Effects of rain intensity, slope gradient and particle size distribution on the relative contributions of splash and wash loads to rain-induced erosion. Geomorphology, Vol. 15 (2016) No.253, p.159-167.

[4] J.J. HE, Q.G. CAI, and S.B. LIU. Effects of slope gradient on slope runoff and Conditions. Chinese Journal of Applied Ecology, Vol.23 (2012) No.5, p.1263-1268.(in Chinese)

[5] H.B. WANG. Study on the Relations between characters and sediment yield and runoff from plots with different soil and water conservation measures. Research of Soil and Water Conservation, Vol.18 (2011) No.5, p.63-66.(in Chinese)

[6] Z.Z. SHEN, P.L. LIU, and Y.S. XIE, et.al. Study of plot soil erosion characteristic under different underlying horizon. Bulletin of Soil and Water Conservation, Vol. 26 (2006) No.3, p.6-9.(in Chinese)

[7] J Vermang, L.D. Norton,and J.M. Baetens, et.al. Quantification of soilsurface roughness evolution under simulated rainfall. Transactions of the ASABE, Vol. 56 (2013) No. 2, p.505-514.

[8] S.H. ZHANG. Effects of land use / cover change in different slops on agricultural non point source pollution in Dianchi watershed based on GIS and SWAT model. (MS. Yunnan Normal University, China 2014), p.69.

[9] X.Q. ZHANG, L.B. GU, and K.L.ZHANG, et.al. Impacts of Slope Gradient on Runoff and Sediment in Northwest Guizhou . Journal of Soil and Water Conservation, Vol. 29 (2015) No. 4, p.18-22.(in Chinese)

[10] K. AUERWALD, P. FIENER, and W. MARTIN, et al. Use and misuse of the K factor equation in soil erosion modeling: an alternative equation for determining USLE nomograph soil erodibility values. Catena, Vol. 118 (2014), p.220-225.