The Effect of Soil Erosion on Rock Fragment Content in Beijing Hilly Area

Fu Suhua[1] **,** ***Liu Baoyuan***[1] and ***Duan Shuhuai***[2]

[1] Beijing Normal University, Beijing, 100875
[2] Beijing Soil Loss Conservation Center, Beijing, 100073

Abstract: Since soil loss varies with the different land use. It leads to problem of different rock fragment content in top layer in the Beijing hilly area. In this paper, The data of cropland plot, the fallow plot and the wasteland plot at Miyun county, Beijing were used. The topsoil samples and section samples were taken at the upper slope, middle slope and lower slope of the plots. The soil samples were sieved. Then the rock fragment, whose diameter is over 2mm in the sample, was weighted. The percentage of rock fragment in the sample was calculated. The results show that the percentage of rock fragment at fallow plot is the largest and the percentage of rock fragment at wasteland is the smallest. The percentage of rock fragment in the sample of the waste land was known as a normal value, and the soil texture index was expressed with the ratio of the percentage of rock fragment at other land use to the one at waste land. The indexes of fallow land, conventional tillage and wasteland were 2.96, 2.07 and 1, respectively. The results can be applied for land use plan and soil degradation evaluation.

Keywords: Beijing hilly area; land use; rock fragment content; soil erosion

1 Introduction

Today soil erosion is almost universally recognized as a serious threat to man’s well being. Soil degradation is a major result of soil erosion. Soil texture exerts great influences on those soil physical, chemical and biological properties that are important in plant growth. Therefore, soil texture is often looked as one of indexes to evaluate the degree of soil degradation[1, 2]. Research results at granite area in south of China showed that soil experienced apparent soil coarsening from no degraded soil to strongly degraded soil[1]. Zhangmingkui’s results[3] showed that the changes of soil fertility were remarkably connected with soil texture, especially the content of clay particle after the land has experienced return from cropland to wasteland for a long time. In fact, if soil particle composition is suitable, it will bring good soil structure. The soil with favorable structure has suitable quantity and size of the pores and has greater water infiltrate rate, nutrient concentrations, water retained and fertility retained. Therefore plant root can more easily penetrate soil. With soil coarsening, some nutrients in soil are lost. It leads to land productivity decline and environmental pollution. Many researchers have been carried out studies on it[4—9]. To protect man’s living environment, we must control effectively water and soil loss and retard soil from soil coarsening and soil degradation. In addition, with soil coarsening, the increase of rock fragment content will affect infiltration and soil erosion. Poesen et al[10, 11] has been done some researches on it and some of the research results have been applied in soil erosion model[12]. Therefore, it is very important for precise prediction of soil erosion model to study on soil coarsening.

Shixia watershed, a hilly area, is located in north east of Miyun reservoir. The cultivated horizon is very shallow. Because of human activity, soil erosion in the watershed is very serious. At fallow land, soil erosion of a single storm is 4,122t/km^2. It is greater than the rate of soil formation (65t/ km^2) and the tolerable soil loss in north stony mountainous area (200t/km^2). Serious soil erosion results in following problems: the cultivated soil becomes shallow, soil texture becomes coarse and sandy soil becomes more serious. According to field observation, different land use has different soil erosion and has profound influence on soil coarsening. But little quantitative research has been concerned about. So the purpose of this paper is to quantitatively research the degree of soil coarsening affected by land use. The result can serve as understanding variations of soil texture, evaluation of soil degradation degree and land use plan.

2 Material and method

Woodland, wasteland and cropland are the main land use in Shixia watershed. The rate of the three kinds of land use to total watershed area is 44.1%, 13% and 6%, respectively. Soil support practices such as narrow terrace and pit were used in more than 80 percent of woodland. Soil texture of woodland has been disturbed by human activity. So it is difficult for woodland to analyze the characteristic of soil coarsening. Therefore, plots for fallow land, wasteland and cropland were used to analyze the effect of different land use on soil coarsening in Shiixa watershed, Miyun County (Table 1). The plots were constructed in 1993. There are 8 year data for runoff and sediment. At the beginning of plots constructed, there was the same soil texture.

The field soil samples were taken at the middle sites of upper, middle and lower section of the plot. The profile samples and topsoil samples were taken. The topsoil samples were taken from a iron pane with 40 cm in length, 40 cm in width and 1 cm in height. The pane was plugged in soil. The soil in pane was taken with knife. 9 topsoil samples were obtained. The soil depth is generally less than 15cm in Shixia watershed. So the profile samples in 0 cm—5 cm and in 5 cm—10 cm were used. Near to the sites of topsoil samples taken, profile soil samples were taken by shovel and knife. There were 18 profile samples. Each field sample was about 1,500g. The field samples were spread on a drying tray, broken down clods by hand and placed in drying cabinet until air dry. Three subsamples were taken from the every field sample. Every subsample was about 200g—300g. Every subsample was sieved on 2 mm sieve. The fine particles passing 2mm-sieve were transferred to a beaker, evaporated, dried at 105℃, cooled and weighed to obtain mass of fine particle (m1). The coarse particles left on the 2 mm sieve were transferred to a bottle, heated on hotplate until no any residue adhered to rock fragment. The contents of the bottle were transferred, through a 2mm sieve, to a 500ml cylinder. The residue on the sieve was washed thoroughly with water. The sieve contents were transferred to a beaker, evaporated, dried at 105℃, cooled and transferred on 2 mm sieve. Sieve by hand and weigh the mass of coarse particle (>2mm) (m2) and the mass of fine particle (<=2mm) (m3). The residue in bottle was dried at 105℃, cooled and weighed (m4). The percentage of rock fragment was calculated by the ratio of m2 to m1+m2+m3+m4. The average of three subsamples was looked as the percentage of rock fragment of field sample.

Table 1 Basic parameters of plots(1)

No.	Degree (°)	Length (m)	Width (m)	Aspect	Soil depth （cm）	Soil loss (1993) （t/km^2）	Soil loss (1993—1099) (t/km^2)	Land use
4	14.6	10	5	North-east	10	1,125	1,453	Fallow(2)
1	16.8	10	5	South	7	1,263	1,311	cropland(corn)
5	14.6	10	5	North-east	5	998	153	wasteland

Note: (1) Soil in plot is skeletal cinnamon soil
(2) Plot management: In the spring of first year, the plot was plowed and placed in seedbed condition. From the second year, the plot wasn't tilled again. The plot was kept free of vegetation

3 Results

3.1 Effect of soil erosion on soil coarsening

According to field observation, soil texture in topsoil is profound difference between two adjacent plots with different land use. There is more rock fragment at fallow plot than at wasteland (Fig. 1 and Fig. 2). The experiment results also showed that the rock fragment contents for different land use both in topsoil and in soil profile have apparent difference. The rock fragment contents from large to small are fallow land, cropland and wasteland. This is caused by different soil erosion for different land use. At fallow land, in the first year that the plot was constructed, both splash erosion and runoff erosion were more serious than the other two land use plots. The fine particles were washed off and coarse particles were left. The fallow plot was tilled only in the first year. Once there are enough large coarse particles in topsoil to protect the soil, only fine particles were carried out by water. The cropland plot was tilled every year and there were new fine particles provided. So the soil loss at fallow land plot is less than that at cropland plot (Table 1), whereas the degree of soil coarsening at fallow land plot is more serious than that at cropland plot (Table 2). Comprised with fallow land plot, the plant at wasteland plot protects topsoil in two aspects. On the one hand, Rainfall is easier to infiltrate at wasteland plot, it brings low runoff and water transport capability. On the other hand, the plant residue in topsoil decreases sediment available for runoff. So the sediment carried by runoff at wasteland plot is less than that at fallow land plot. Therefore, the characteristic of soil coarsening at wasteland plot is not very apparent. Comprised with fallow land plot, the corn was planted at cropland plot. The interception decreases the rainfall energy splashing soil surface. So the splash erosion at cropland plot is less than that at fallow land plot. There is less sediment available for runoff at cropland plot. But there are more bare surfaces for cropland than for wasteland. So when runoff is the same, the soil erosion at cropland plot is more severe than at fallow land plot. At the same time, if rainfall is the same, the runoff at fallow land plot and cropland plot is more than that at wasteland plot. Thus, the degree of soil coarsening from strong to light is fallow land, cropland and wasteland. Provided the percentage of rock fragments in the sample of waste land was known as a normal value, and soil texture index was expressed with the ration of the percentage of rock fragments for other land user to the one in waster land, then the indexes of fallow land, crop land and waster land at 0cm—1cm are 2.96, 2.07 and 1, respectively.

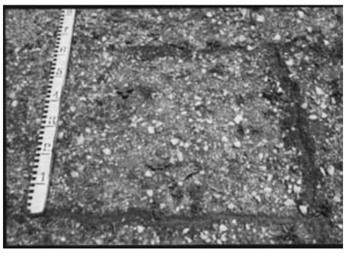

Fig. 1 Rock fragment of surface soil at fallow plot

Fig. 2 Rock fragment of surface soil at waste land plot

Teble 2 Rock fragment content with different land use(%)

Soil horizontal	0—1		0—5		5—10	
cm	content	ration	content	ration	content	ration
fallow	66.1	2.96	38.3	1.72	33.2	1.65
cropland	46.3	2.07	31.7	1.42	21.5	1.07
wasteland	22.3	1	22.4	1	20.1	1

3.2 The characteristic of soil coarsening along with soil profile

The rock fragment contents for the same profile in 3 different sections were averaged and were looked as the percentage of rock fragment for the profile. At wasteland plot, the percentage of rock fragment in different profile was almost the same, no any characteristic of soil coarsening along with the soil profile existed (Table 3). At fallow land plot and cropland plot, there was soil coarsening in different profile. The rock fragment contents from large to small were 0 cm—1 cm, 0 cm—5 cm and 5 cm—10 cm (Table 3). At wasteland plot, plant and residue protect the soil in two aspects. First, runoff at wasteland plot is less than those at fallow land plot and cropland plot. So runoff brings low water transport capability. Second, soil erodibility decrease because of plant and residue protection. So the soil under topsoil is free from rainfall erosion. Hence, there is no apparent difference in different profile at wasteland plot. At fallow land plot, soil coarsening in profile is caused by concentrated flow that results in rill formation. So some of fine particles in 0cm—10cm were carried out by water. Moreover, there are more fine particles carried out by water near the topsoil. Therefore percentage of rock fragment in 0cm—1cm soil horizontal was the largest. For cropland, maybe soil coarsening was caused by tillage.

Table 3 Rock fragment content with different land use and different soil depth(%)

Soil	Fallow land		cropland		wasteland	
（cm）	content	ration	content	ration	content	ration
0－1	66.1	1.99	46.3	2.15	22.3	1.11
0－5	38.3	1.15	31.7	1.47	22.4	1.11
5－10	33.2	1	21.5	1	20.1	1

In 0 cm—5 cm soil horizontal, the percentage of rock fragment at fallow land plot was the largest and that at wasteland was the smallest. Whereas in 5—10 soil horizontal, the percentage of rock fragment at fallow was the largest, and the rock fragment contents at cropland plot and wasteland plot was almost the same. It showed that soil horizontal eroded by water varied with different land use. At fallow land plot, the soil horizontal in 5 cm—10 cm has been eroded. It mainly caused by concentrated flow that results in rill formation. At cropland plot, the soil horizontal in 0 cm—5 cm has been eroded. It was affected by tillage. At wasteland plot, only topsoil has been eroded by water because plant and residue protect soil.

3.3 Rock fragment content in different slope section

The percentage of rock fragment in 0 cm—1 cm profile was used to analyze the difference in different slope section. For a plot, the percentage of rock fragment in different slope section was different. That is, the degree of soil coarsening varies with slope section (Table 4). From top to lower section, the percentage of rock fragment increased. The result is different from Zhang mingkui and Young wude’s findings[15, 16]. In their studies, the degree of soil coarsening from strong to light was upper section, middle section and lower section. This is because the scale that we researched is different. In our study, the slope is plot slope, and the slope length is very short (10 m). Moreover, the slope degree in upper, middle and lower section is uniform. Once runoff happens, concentrated flow formed rapidly. From upper to lower section, water transport capability increases. Hence there are more fine particles carried out by water in lower section than in upper section. So there is more apparent characteristic of soil coarsening in lower section than in upper section. Zhang mingkui and Yong wude *et al.*, studied on a complete slope in a watershed. The slope length is very long. Moreover, the slope degree in upper, middle and lower section has profound difference. Generally the slope degree in lower section is small. Once runoff happens, in upper section, the fine particles were carried out by water and coarse particles were left. Part of fine particles from upper section deposit in the middle section and the others continue to be carried by concentrated flow to lower section. In lower section, because of low slope degree, water transport capability is less than sediment content. So the sediment from upper and middle section generally deposits. Thus there were apparent characteristic of soil coarsening in upper section than in lower section.

Table 4 Rock fragment content with different soil depth(%)

section	Fallow land		cropland		wasteland	
	content	ration	content	ration	content	ration
upper	54.0	1	41.4	1	16.2	1
middle	68.8	1.27	46.0	1.11	24.1	1.49
lower	75.6	1.40	51.4	1.24	26.7	1.65

4 Conclusion

Varying soil loss resulted from different land use leads to problems of soil coarsening to different degrees. The degree of soil coarsening from strong to light is fallow land, cropland and waste land. Provided the percentage of rock fragments in the samples of waste land was known as a normal value, and the soil texture index was expressed with the ratio of percentage of rock fragments for other land use to the one in waste land, the indexes of fallow land, crop land and waste land at 0 cm—1 cm are 2.96, 2.07 and 1, respectively.

The characteristic of soil coarsening is different from different slope section. The soil texture indexes from high to low are lower slope, middle slope and upper slope.

The characteristic of soil coarsening in profile varies with different land use purposes. The percentage of rock fragment in different soil horizontal at wasteland is almost the same. So the profile at waster land is free from soil coarsening. At fallow land and crop land, the percentage of rock fragment in 0 cm—1 cm is far more than those in 0 cm—5 cm and 5 cm—10 cm. Therefore, soil horizontal that is vulnerable to soil erosion varies with different land use. At waste land plot, only topsoil exists soil erosion. Soil in 0 cm—5 cm has been eroded at crop land and soil in 5 cm—10 cm has been eroded at fallow land.

Acknowledgments

The project is funded by Beijing Science Technology Project and National Nature Science Foundation of China for Distinguished Young Scholars (49725103).

References

[1] Shi deming *et al*., Study on soil degradation indexes in South of China [J]. Journal of Soil and Water Conservation, 2000. **14**(3): 1-9.

[2] He yurong. Soil degradation and control in South mountainous area of China [J]. Journal of Mountain Science, 1996. **14**(2): 110-116.

[3] Zhang mingkui. Relationship between resilience of eroded red soil and soil character [J]. Journal of Soil and Water Conservation, 2000. **14**(3): 52-56.

[4] Li guanglu. Study on soil degeneration on Southern Plateau[J]. Yunnan Environmental Science, 2000. S1, 89-92.

[5] Larney, F J *et al*., Early impact of topsoil removal and soil amendments on crop productivity[J]. Agronomy Journal. 2000.**92**(5):948-956.

[6] Larney, F J *et al*., Management for agricultural, forestry and urban uses- soil quality and productivity responses to simulated erosion and restorative amendments[J]. Canadian jiournal of soil science, 2000, **80**(5):515-523.

[7] Biot, Y and Lu X X. Loss of yield caused by soil erosion on sandy soils in the UK[J]. Soil Use and Manage, 1995, **11**(4): 157-162.

[8] Poesen, J W, and Ingelmo-Sanchez F. Runoff and sediment yield from topsoils with different porosity as affected by rock fragment cover and position[J]. Catana, 1992, 19, 451-474.

[9] Poesen, J *et al*., Concentrated flow erosion rates as affected by rock fragment cover and initial soil moisture content[J]. Catena, 1999, **36**(4):315-320.

[10] Morgan R P C, *et al*., The European soil erosion model (EUROSEM): a dynamic approach for predicting sediment transport from fields and small catchments[J]. Earth Surface Processes and Landforms. 1998, 23: 527-544.

[11] Hudson N W. Soil conservation[M]. Iowa: Iowa State University Press 1995.

[12] Soil and Water Conservation Service of Hydraulic Bureau. Criterion of soil erosion classifying [S]. Hydraulic Bureau in China. Beijing: Hydraulic and Power Science publication. 1997.

[13] Yang wude, *et al*., Impact of soil erosion on soil fertility and land productivity[J]. Chinese Journal of Applied Ecology, 1999, **10**(2): 175-178.

[14] Zhang mingkui. Character and resilience of eroded sandy soils in Zhejiang Provience[J]. Journal of Soil and Water Conservation, 1999, **5**(2): 75-79.