The Relationships between Soil Erosion and Human Activities on the Loess Plateau

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Abstract: The Loess Plateau lies in the North of China and is one of the most serious regions of soil erosion in the world. Severe loss of soil and water not only has its devastating effect on farming, forestry, stock-breeding and ecological environment of the area concerned, but also is the root of poverty for local people. The Loess Plateau has a long cultivation history, hence population growth, vegetation degeneration and plugging constitute the chief reason for serious soil and water loss on Loess Plateau. This paper analyses the relationships between soil erosion and human activities, and discusses some effective methods adopted in China in soil erosion control, research directions and future perspectives on Loess Plateau.
Keywords: soil erosion, human activities, Loess Plateau

1 Introduction

The Loess Plateau situated in northern China covers the drainage basins in the middle reaches of Huanghe. It starts from the western piedmont of Taihang Mountains in the east, reaches the eastern slope of the Wushao and Riyue mountains, connects the northern part of the Qinling Mountains in the south and borders the Great Wall in the north, covering an area of about 380,000 km The region is overlain extensively by Quaternary loess in great thickness, hence the name Loess Plateau. The continuous loess covering on mountains, hills, basins and alluvial plains of differing height ranges from 100m—300m in thickness. The Loess Plateau is one of the source places of the Chinese nation with an agricultural development history of 4,000—5,000 years, therefore, human activities exert great influence on the soil formation and evolution (CHEN Yongzong *et al*., 1988).

2 Soil erosion problem on loess plateau

The area with erosional amount greater than 5,000t $\cdot km^{-2} \cdot a^{-1}$ covers about 145,000km in the region, being 37.1% of the Plateau's area; that greater than 10,000t $\cdot km^{-2} \cdot a^{-1}$ covers about 50,000km^2, or 12.8% of the Plateau's area. The silt produced accounts for about half of the annual average silt discharge of the Huanghe River, the distributional areas are concentrated in the upper reaches of Malian River, drainage area above Jinfoping of Beiluo River, area from Yanhe River to Huangpuchuan, and Qiushuihe drainage basin west of Shanxi. The areas subject to most intense erosional silt delivery are almostly located in the loessic hilly-gully area.

3 Cause analysis of soil erosion and land degradation

Modern global soil erosion issue is inseparable from human activities, the development of soil erosion has become a world principal environmental problem, some scholars hold that artificial acceleration of erosion has become the cancer of land (R, Lal, 1988). In a country like China which has a long history of cultivation, the problem has become even more protruding. Soil and water loss is serious on modern Loess Plateau where erosion landforms featuring by barren land, ravines and gullies can be found everywhere. Particularly the surging silt-laden Huanghe under conditions of rainstorm induced floods usually presents irresistable natural force. Human destruction on vegetation can happen in a short while or extremely short while, however, aggravation of human induced soil erosion would be several hundred times serious than natural erosion. The cause of black buran happened in United States in 1934 was the destruction of forest and vegetation and reclamation, resulting in a shocked outcome of losing fertile topsoil in a short while. The discussion on cause for intense soil erosion and land degradation on the Loess Plateau is of crucial importance to the identification of control and management measures of the region.

3.1 Impact of human activities on intense soil erosion process and eco-environmental evolution Since historical period

A vast amount of historical data proved that there used to have extensive flatland, few ravines and gullies, lush forests and grass as well as clear river water on Loess Plateau in history (SHI Nianhai, 1981). Zhu Kezhen, a well-known Chinese climatologist indicated (Zhu Kezhen, 1973) that climate in Huanghe drainage basin 5,000 years ago fitted the North Asia subtropics of present day Changjiang drainage basin with a temperature of around 2℃ higher than present. The black loamy soiland xxxx profile in the loess deposits developed around 7,000 years ago indicated that the climate then related to soil formation process was warmer and more humid than today's when erosion was slight due to luxuriant forest and grass vegetation. Since 3,000 years BP, the climate tended to be dessicated, entering into a transional period of relative intense loess deposition and erosion. What is more important is human activities were entering into a more and more prosperous period, natural vegetation was seriously disturbed due to farming practices and overgrazing and soil erosion tended to be drastically developed.

In light with UNEP and FAO investigation data, two thirds of land on Earth was once covered by forests, being as large as 7.6 billion hm^2, but today only 2.64 billion hm^2 were left over; 80% of Asia's farmland were originated from forests. Population growth was the root cause for farmland expansion, and farmland expansion was at the expense of damaging natural vegetation, so the natural erosion was evolved into human accelerated erosion, aggrevating eco-environmental deterioration. China has a long farming history and the Huanghe drainage basin as the source place of Chinese national culture witnessed earlier development history of farming and animal husbandry. Since the 6th century to the 15th century, population on the Loess Plateau had been around 25% of the country's total. Afterwards, population continued to increase and reached over 40 million in 1840. 1949—1986 experienced a drastic population growth period, an increase of 1.2 folds. Polulation growth bounds to cause expansion of cultivated land, aggravating destruction of forest and grass vegetation. Desertification expansion, reduction of forest belt, soil erosion and vicious circulation of eco- environment resulting from devastation of reclamation without restraint stimulated the increase in drought and flood occurrence frequency. China witnessed 110 flood events and 95 drought events from the 7th to the 20th century, of which several droughts occurred 2.7 times averagely every centennial in the first seven centuries and 10.8 times every centennial in the late seven centuries.

Once natural eco-equilibrium was sabotaged by human activities, impacts of natural factors of precipitation and topography on soil erosion would be relatively precipitous. Human accelerated erosion has not only increased sediment delivery to the Huanghe River but caused drastic decline of soil quality. Experiment and observation indicated that after 20 years reclamation of the forestland, the content of organic matter in topsoil has approached to C Horizon and dropped from 27.15g • kg^{-1} to 5.45g • kg^{-1}, an annual average decline of 3.8%. After reclamation of forestland, relative humidity of atmosphere dropped by 0.68%—1.5% averagely in 5 years, soil temperature rose by 9.4℃, 8℃, 5.3℃ and 3.5℃ respectively from ground surface to 5cm, 10cm and 20cm horizons (Tang Keli *et al*., 1991).

3.2 Current status of vegetation and vegetation to human aggravation of erosion development

Most part of the Loess Plateau is confined to the warm temperate semi-humid, semi-arid climatic zone, part to mesothermal semi-arid climatic zone, and the northwestern part of the Plateau to mesothermal arid climatic zone. The corresponding natural vegetation zone consists of forest belt, forest steppe belt, steppe belt and desert steppe belt.

There are relative more vegetation types on the Loess Plateau. Up to now, over 500 species of herbs, more than 250 species of woody plants, over 300 species of resources plants, but the available resources of various plants are limited. In fact, natural vegetation of forest and grass on the Loess Plateau has been seriously devastated and the existing ones are only in sporadic distribution on some of the mountains, even in summer when plants are in luxuriant state, the vast land still appear yellow. The forest coverage in the region is only 7.1%, 6 percentage less than the country's average level. The existing forests are mainly distributed in the southeastern part of the Plateau, on rocks or earthen rocky mountains. In the vast expanse of loess hilly areas and loessic Yuan, only sporadic trees are distributed in the vicinity of villages and towns and sparse grass and shrubs are on non-cultivated land. Ziwulingwas the only place with forest vegetation better preserved on loess overlain area of the Loess Plateau, however, forest vegetation was also seriously damaged in the past several decades, and forest boundary line has been retreating at an annual average rate of 0.5km. Since the region's forest vegetation was so deficient that aggravated development of soil erosion is inevitable. Grassland area accounts for 30.5% of the total land area, of which 60% has already degraded or decertified. Most of the ridge and gentle slopes, even valley slopes in the loess hilly area have been reclaimed. Consequently, gully erosion and gravity erosion was induced and accelerated due to serious slope erosion. In the case vegetation in most part of the region on the Loess Plateau was devastated, nature balance got disordered, obviously, human accelerated erosion play the leading roleerosion rate far exceeded natural erosion.

It is known to all that the mechanism of vegetation restraining erosion is first of all, the interception of plant foliage, then the function of wash durability and surface runoff reduction of withered twig and dead leaf layers, and lastly fixation of plant root system and amelioration of soil physio-chemical properties to increase anti-erodibility and wash durability of soils. Meanwhile, plants are unfavorable for soil erosion development by improving environmental quality and providing wild-animal habitats.

Vegetation interceptability is influenced by factors like vegetation type, canopy density, precipitation volume and precipitation intensity. The significance of anti-erosion of vegetation interceptability lies in to reduce actual rain interdepted on the ground so as to reduce soil erosion. For instance, in gully drainage basin of Huanglongshan temple, the avarage rainfall during floody season is 322mm—390mm, the annual intercepting amount of trees (Pinus tabulaeformis Carr., Populus davidiana Dode) and shrubs (Lespedeza bicolor Turcz, xxxxx) is 46mm—99mm, the intercepting rate is 12.5%—26.7% (Liang Jianmin *et al*., 1980). In other words, precipitation here reduced by 12.5%—26.7% compared with treeless drainage basins, hence naturally mitigating runoff wash; meanwhile, vegetation interception can also prevent raindrop splashing on and raindrop disturbance to thin flow layer of water on the slopes and such kind of disturbance is the major driving force on slope runoff erosion (Hudson N. W., 1971). Result of our rainfall simulation experiment (Cai Qiangguo, Chen Hao, 1989) indicated that rate of splash erosion of 50% coverage has already been reduced by over 70% in contrast to coverless ground. The experiment actually implies that in terms of merely rainfall induced splash erosion, when vegetation coverage reaches around 50% on gentle slopes, soil splash erosion has already been greatly reduced.

The functions of wash durability and surface runoff reduction of withered twig and dead leaf layers vary with each vegetation type. According to measurement of secondary forest area in Ziwuling of borderland between Shaanxi and Gansu provinces by Cheng Jimin (1987), the maximum amount of water absorbed by withered twig and dead leaf layer is related with factors of dry weight, thickness, bulk density and storage. Water content of Populus davidiana Dode is 124.5%, equivalent to a 10mm precipitation. In other words, no runoff can be resulted during a 10mm—20mm precipitation event in forest area of Populus daviviana Dode on Ziwuling Range. Experimental research indicated that withered twig and dead leaf layer plays a great role to rainfall runoff infiltration. In forest area of Ziwuling the infitration rate of surface layer (0cm—15cm) in the initial 30 minutes can reach 17.4mm $\cdot$min^{-1}, being 2.6 times of the farmland, stable infitration rate, 12.5mm $\cdot$ min^{-1}, 4.3 times that of farmland (Cha Cuan *et al*., 1992). Result of field artificial rainfall experiment (rainfall intensity 1.28mm $\cdot$ min^{-1}, rainfall duration 38.6min) indicated that under high intensity rainfall conditions, all the 38.6mm precipitation fallen on the forestland infiltrated, and only 8.6mm infiltrated on the farmland. Therefore, it is very important to soil and water conservation by preserving withered twigs and dead leaves under forests.

Li Yong and others (1993) studied and obtained vegetation control soil erosion module on the Loess Plateau, i.e., a combination of herbs, shrubs and woody plants. Root systems of herbal plants can prevent surface washing whereas shrubs and woody plants can raise anti-erodibility of deep stratum (>50cm) soil mass, the function is particularly obvious on steep slope with greater grade (normally greater than 30 degrees). Herbal plant generally functions insignificantly in preventing creeping of surface layer soil mass and sometimes promotes water infiltration into soils because of root system, resulting in increase weight of soil mass, reducing soil resistance to shearing and accelerating steep slope topsoil creeping. To prevent shallow layer sliding, it is essential to rely on extensional force of root systems of woody plants and deep-rooted shrubs.

In order to synthetically explain the anti-erodable effect of plants, we conduted runoff experiment on small plots. The runoff plots were located on the ridges of Wangjiagou Guandao in Lishi of west Shanxi Province, the surface materials were Lishi loess of middle Pleistocene, ground gradient was 22 degrees and five plots were located. Polymerized grasses with coverage of 0%, 20%, 40%, 60% and 80% respectively were planted. Observations of natural precipitation of these plots were conducted along with several groups of rainfall simulation experiments (Zeng Boqing *et al*., 1990). Results of both items were basically similar, when vegetation coverage was 20%—40%, soil and water reduction rate was 54%—79%, when vegetation coverage was 60%—80%, soil and water reduction rate was 77%—95%, indicating a very apparent effect of polymerized grass vegetation on soil erosion. Another group of data on natural precipitation observation indicated that after steep slope farmland (18—30 degrees) was abandoned for grass planting, the quantity of soil eroded was reduced by 77.6% annually. In addition, we also set up five experimental troughs and cultivated Awnless Brome in them, the actual coverage were 0%, 34%, 60%, 75%, and 100% respectively and two types of rainfall simulation experiments were carried out with rainfall intensity being 0.81mm $\cdot$min^{-1} and 1.3mm $\cdot$min^{-1} separately. Results showed that when rainfall intensity was 0.81mm $\cdot$ min^{-1} and rainfall duration was 30 minutes, rainfall runoff on slopes with coverage of 60% and 100% reduced by 68% and 89% respectively than on bare land; erosion induced sediment yield reduced by 95% and 98% respectively. Even for a heavy rainstorm with an intensity of being 1.3mm $\cdot$ min^{-1}, runoff reduction being 52% and 89% respectively, the erosion induced sediment yield would be 89% and 98% respectively. When grass coverage reached 75%, the resultant runoff would be reduced by over 75% and silt yield by 95% in contrast to bare land. In the case of stable infiltration, 80% of the rainfall would be infiltrated into soil with a stable infiltration being 4 times of bare land, silt content in slope runoff reduced by an order of magnitude compared with bare land, a powerful demonstration of the role of grass vegetation (Cai Qiangguo, Wu Shuan *et al*., 1992).

In order to estimate effect of soil and water conservation of artificial pastures, five years runoff and silt observational data for 12 types of pastures (average vegatated degree being 73) grown on steep slopes (28 degrees) were calculated on an average basis. In terms of the annual runoff depth (mm) and erosion module (t $\cdot$ km^{-2}) of the 12 types of pastures compared with bare land, water and silt reduction efficiency of artificial pasture was 47.5% and 74.7% respectively. In Wangjiagou drainage basin of west Shanxi, comparison of the observstional data of the grass reservation facilities installed in the natural runoff experimental plots on Hongtu gully slopes for eight years (1959—1966) with observational data of Hongtu gully slopes where random grazing was allowed, one can find that runoff and erosion amount was reduced by 93.7% and 97.4% respectively after several years' grass reservation (Cai Qiangguo, Lu Zhaolin *et al*., 1992).

Numerous research (Shi Nianhai *et al*., 1985; Wang Shouchun, 1990) indicated that there used to have fine vegetation on the Loess Plateau in human history, though Huanghe River was silty since ancient times, the erosion intensity was no doubt much lower than the present, the increasingly serious erosion was resulted from man's devastation of vegetation.

3.3 Impact of ploughing on accelerated soil erosion

When people discuss the cause for such a serious soil erosionon Loess Plateau, they normally consider the extremely weak ability of loess in resisting water erosion as an important reason. Of course the anti-erodibility of loessial soils is lower than other loamy soils, yet result of runoff washing experiments carried out on Malan loee slopes indicated that virgin loess on gentle slopes (15 degrees) without being disturbed by ploughing still have better ability to resist runoff washing. The experimental method we adopted was to release water to wash small troughs digging on natural waste slopes where farming was given up for many years. The ground surface was covered with sparse weeds and soil was late Plestocene loess. The cross section of the experimental trough digging on ground surface was inverse triangle, 20cm deep, opening was 30cm—38cm wide and included angle on the bottom was about 60 degrees. Water used for the experiment was clear water from pond, the entrance flow discharge was 1800, 1200,500 and 250ml • sec^{-1}, the experimental trouugh was 10m, 20m, 30m and 40m. Experimental results indicated that the maximum entrance flow (1800ml • sec^{-1}) and the maximum silt content of the longest trough (40m) was less than 0.6kg • m^{-3}, an indication of slight erosion of the internal walls of the trough. However, this by no means to say that it was caused by inadequate erosional energy of the trough water flow. The actual measurement indicated that the maximum flow velocity initially as water was releasing might exceed 1.2m • sec^{-1}, even water flow reached balanced state after energy dissipated by erosion, the flow velocity could also reach 1.0m • sec^{-1}. In the laboratory and field rainfall simuilation experiments for farmland rill erosion study, the maximum surface water flow velocity measured by the same method was no more than 0.1m • sec^{-1}, the maximum flow velocity in the rills seldom exceeded 0.3m • sec^{-1}. This can be inferred that the energy the water flow in the rills possessed was by far the greastest in comparison with the energy on slopes of the sloping farmland and energy of water flow in the rills under similar conditions. However, silt content in rill water measured in our laboratory and field experiments was normally 100 kg • m^{-3}—200 kg • m^{-3}, the highest can exceed 500 kg • m^{-3} (Cai Qiangguo, Wang Guiping *et al*., 1998), several hundred times higher than the maximum silt content at cross section of the rill flow, different soil structure was mainly accountable for such a great difference.

Numerous observations indicated that better soil structure with greater resistence to shearing and higher wash durability of water flow was normally formed on derelict land for many years, wasteland, grassland and forestland. Root systems of plant and soil fixation of organisms are also important factors to increase wash durability of soils. Just because of this, erosion induced silt content on wasteland and derelict land for many years is much lower than that on sloping farmland, rarely forming rill erosion. Rainfall runoff washing experiment revealed that even in the case of high intensity rainfall, water-borne silt content of derelict land plots was only 44% of that of sloping land plots, erosional amount was only 7.2% of the latter. In Ansai County of north Shaanxi, a comparative measurement on abandoned farmland for five years and the farmland was carried out after a heavy rainstorm (both on 66m-long slopes of 27 degrees). Vegetation coverage of abandoned farmland was 50%, no rills were formed following the rainfall event. Coverage of farmland was 30%, both rills and shallow furrows occurred, erosion rate reached 15,380t • km^{-3}. It is thus clear that soil anti-erodibility of abandonded farmland is much higher than farmland under other similar conditions. According to experimental and observational data, different land use methods exert great influence on soil anti-erodibility. Wash durability of soil in grass reservations is the strongest, yellow locust comes the second, abandoned farmland in the third place, and farmland, the weakest. The experiment also showed that even after three years, wash durability of the abandoned farmland can also be increased substantially in contrast to farmland. So, farming abandonment can greatly mitigate soil erosion intensity, the effect of wash durability of rehabilitated ground vegetation following abandonment would be much better.

Different land types were selected in Wangjiagou drainage basin where we measured loess resistence to shearing by using Pitcon four-bladed vane shear meter (Luk S.H., H.Chen, Q.G.Cai *et al*., 1990). We found that time change of soil resistence to shearing mainly depended on climatic conditions, affected by ploughing while spatial change was affected by land use patterns and topographic conditions. Soil resistence to shearing on compact farmland was only 33% of that on non-farmland, soil resistence to shearing on newly ploughed farmland was only 23% of that on non- farmland. Newly ploughed land, especially ploughed loess will apparently result in drop of soil erodability. Ploughing is normally carried out before rainy season on the Loess Plateau, leading to intense soil loss because of highly concentration of substantial energy of rainfall on the newly ploughed soil. Comparative measurement was carried out on newly ploughed sloping wheat field (grade, 3 degrees, slope length, 60m) right after a heavy rainstorm. Result indicated that erosion rate of non- ploughed wheat field was 17,492t • km^{-2}, rill and shallow furrow erosion of newly ploughed wheat field was 36,754t • km^{-2}, differing 2.1 times from each other. Farmland ploughing in rainy seasons is a very important reason for intense rill erosion. Investigations showed that average depth of rill erosion (3.02cm) happened on ploughed wheat stubble fiels was 7.9 times that on non-ploughed wheat stubble field (0.38cm) and 10.1 times of wheat residue covered field (0.3cm). Average depth of rill erosion (3.55cm) on buckwheat field was 9.3 times that of non-ploughed wheat stubble field, and was 11.8 times that of wheat residue covered field. Average depth of rill erosion (1.89cm) of potato field was 5.0 times that of non-ploughed buckwheat field, and was 6.3 times of wheat residue covered field (Zheng Fenli *et al*., 1989). Although compation of topsoil bulk density of forestland was small, its wash durable property was 13 times higher than tillage layer of farmland while anti-erodibility of artificially mixed forest soil was greater than pure forest just as experiment indicated.

The above experiments indicated that in case the entire structure of loess was not disturbed, its erodibility would not be so easily reflected. Loosening topsoil by artificial ploughing is an important way to devastate the entire structure of loess. So if ploughing was reduced on the Loess Plateau then soil erosion rate could be greatly reduced.

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