Soil erosion and rill system evolution based on field observations in Kongshan Hill, South-west Jiangsu Province, China

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Abstract—**Water erosion is the main type of soil erosion in hills of south-west Jiangsu Province, China where the severe soil erosion happed in the hill slope covered by brown-yellow or red earth during the summer monsoon season. In this study the authors selected a man-made bare slope as the study site which was divided into 4 sub-watersheds in the northern slope of Kongshan Hill, South-west Jiangsu Province. Based on a five-year rill system and slope soil erosion observations in the study area, the rill system evolution and the soil erosion was observed and discussed. The study indicates that the human activities in the hill slope playing important role for the severe soil erosion. The natural vegetation recovery process was usually after the stage of severe soil erosion and the vegetation recovery started with decline of the intensity of slope morphological processes.**

INTRODUCTION

Rills are created when water erodes the topsoil on hillsides, and so are significantly affected by seasonal weather patterns. They tend to appear more often in rainier months [1]. Although rills are small, they transport significant amounts of soil each year. Some estimates claim rill flow has a carrying capacity of nearly ten times that of non-rill, or interrill areas. In a moderate rainfall, rill flow can carry rock fragments up to 9 cm in diameter down slope. In 1987, scientist J. Poesen conducted an experiment on the Huldenberg field in Belgium which revealed that during a moderate rainfall, rill erosion removed as much as 200 kg (in submerged weight) of rock [2]. Unfortunately, the considerable effect rills have on landscapes often negatively impact human activity. Rills have been observed washing away the surface soils. They are also very common in agricultural areas because sustained agriculture depletes the soil of much of its organic content, increasing the erodibility of the soil

Soil erosion is the fundamental earth surface process and has an important significance in the fields of morphological study and farmland management. Recently investigation revealed almost 40 percent of China's territory, or 3,569,200 square kilometers of land, suffers from soil erosion, and 1.6 million square kilometers scoured by water and 2 million square kilometers by wind were the official data in China. Soil erosion has become the severe environmental problem in China and every year the total erosion volume was estimated about 4.52 billion tons[3]. The soil erosion caused the reservoir sedimentation, farmland soil layer thinning, and the nutrients declining. In south-west China, there are almost 100 million people will lose the land they live on within 35 years if soil erosion continues at its current rate, a nationwide survey found and the Crops and water supplies are suffering serious damage as earth is washed and blown away across a third of the country [4]. Water erosion is the main way of soil erosion in eastern China, where the severe soil erosion happed in the hill slope covered by brown-yellow or red earth during the summer monsoon season. Soil erosion in China has been interested by many foreign and domestic researchers in the past century [5-6]. In the past decades, many papers and books related to soil erosion in China were published. In North China, the dust wind erosion and the soil erosion in the Loess Plateau are the main study contents. In the farming lands, soil erosion and tillage controls was the main topic of different researches [7]. The Cesium-137 measuring method has been widely used to evaluate the soil erosion in China in the past decades [8]. Apart from the field observations and laboratory experiments, the GIS and modeling were widely used in regional soil erosion analysis [9-10].

In China few studies were about rill system and soil erosion in small field survey based on year to year land surface morphological observation and discussion on rill system evolution in a small scale settings. In this paper, a no more than 100 square meters area and five-year observations data (from 1990 to 1995) demonstrate the process of soil erosion and rill system evolution initiated by the slope runoffs after the human excavating parts of the top soil in the study area.

GEOGRAPHICAL SETTINGS OF STUDY AREA AND METHOD

The study area is located in the eastern suburb of Nanjing city. The geographical site is located on the bottom of the slope of Kongsha Hill, South-west Jiangsu Province, China (Figure 1).

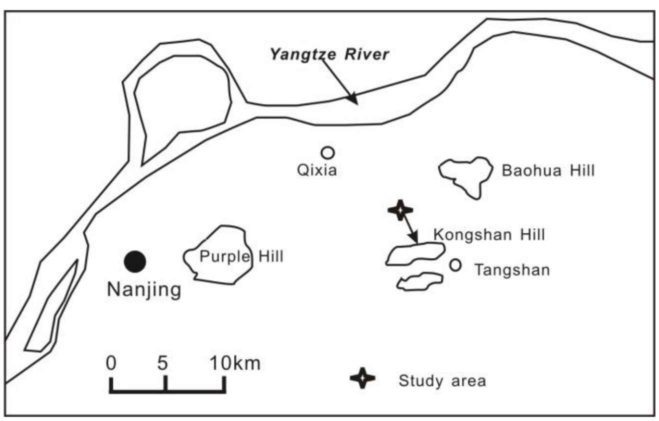

Figure 1 Location of the study area

The Climate environment in the study area is the typical subtropical monsoon. During the summer season, warmer and wetter period is usually with heavy rain storms. The Dongshan station is close to the study area and monthly rainfall in 2007 was shown in Figure 2.

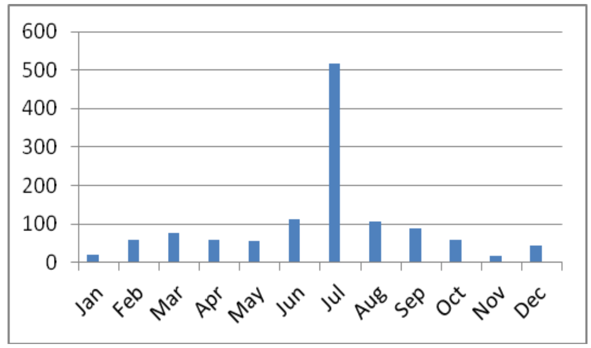

Figure 2. Monthly rainfalls distribution in 2007 (mm)

Human activities strongly influenced the landscape of the Kongsha Hills, such as the limestone mining and the road construction. For the purpose to study the soil erosion and rill system changes, we selected an area in the bottom of the hill slope. The study area was covered with deep earth and the upper 20 cm surface soil was eliminated by human excavating in the first year of spring season. The study area covered an area of 80.0 square meters including four small watersheds named A, B, C, and D. The study area was not disturbed from 1990 to 1995, so the natural processes including the soil erosion, the rill system evolution, the vegetation recovery were observed in the later a few years. The five-year observations were carried out in each September after the summer heavy rain seasons. The rill system changes, the surface erosion and the vegetation changes (plant types and land cover percentage) were measured annually in the field. In the first year, the four watersheds (A, B, C and D) features shown in table 1. The A and B were observed detailed in the later a few years. The upper parts of the slopes of the watershed were corresponded with the landforms of steep scarps.

TABLE 1. FEATURES OF THE WATERSHEDS IN THE FIRST YEAR

Water sheds	Aera (m^2)	Upper slope	Middle slope	Lower slope	Rill number Level-1	Rill uumber Level-2	Rill number Level-3	Rill number Level-4
A	25.0	30-50°	13-20°	8-13°	3	6	8	20
B	25.0	30-50°	15-30°	10-15°	2	7	15	29
C	14.0	30-50°	15-20°	15-20°	2	7	8	/
D	14.0	30-50°	5-10°	5-10°	2	6	10	/

RESULTS

Rill system evolution

Rills formation is intrinsically connected to the steepness of the hillside slope. Gravity determines the force of the water, which provides the power required to start the erosional environment necessary to create rills. Therefore, the formation of rills is primarily controlled by the slope of the hillside. Slope controls the depth of the rills, while the length of the slope and the soil's permeability control the number of incisions in an area. Each type of soil has a threshold value, a slope angle below which water velocity cannot produce sufficient force to dislodge enough soil particles for rills to form [11].

In the study area, the rill system was appeared in summer season of the first year after the slope surface soil excavated and the rain season. With the slope surface changed and the soil erosion, rill systems developed in the small watershed A and B with one main channel (level-1) and more small rills of level-2, level-3 and level-4. In Table 1 there were 3 and 2 level-1 rills respectively, except one main rill (level-1), the others were the small rills with the outlets directly out of the watershed. Most parts of the small watershed A and B had the rill system respectively. The five-year observation demonstrated on the evolution of the rill system. An example was watershed B, its rill systems development was shown in table 2. From the first to the third year, the rill system was quickly developed with the severe soil erosion in the upper part of the small watershed. The rills of level-3, level-4 and level-5 disappeared in the later time of the five-year observation. The field observation indicated that in the small scale the rill system experienced the evolution processes from complex to simple.

TABLE 2. RILL SYSTEM EVOLUTION PROCESS FROM SMALL WATERSHED B

Year	Rill system: rill number and cutting depth(cm)				
	Level-1	*Level-2*	*Level-3*	*Level-4*	*Level-5*
First	2/16cm	7/22cm	15/18cm	29/12cm	Abundant [a]
Second	2/10cm	7/18cm	10/13cm	16/8cm	Abundant [a]
Third	2/8cm	7/12cm	6/7cm	0	Few
Forth	2/6cm	7/9cm	0	0	None
Fifth	2/5cm	7/5cm	0	0	None

a. refers to very small rills

Soil erosion

In the study area, soil erosion was very severe in the first few years. Because of human excavating parts of the top soil, there were no vegetation at the beginning. Slope overflow induced by gravity was the main power for the formation of rill system and soil erosion. According to the five-year observations dada, the soil erosion on the man-made bare slope in Kongshan Hill was experienced a very quick processes especially in the first 3 years. The maximum erosion site was located the divide parts between the small watershed edges (watershed A, B and watershed C, D) with the average cutting rate of 50 cm/a in the first 3 years. In the small watershed A and B, the average surface cutting rates were about 10-20cm/a in the same period. So the soil erosion rate was much higher than the estimated value before the observations. In the watershed divide, the slope was steeper. So the slope mass movement was active especially in the rain storm period, which caused the quickly decline of elevation of the watershed divide (Figure 3)..

Slope evolution of the small watershed

Based on the field observations in the watershed B, the slope evolution of the small watershed was reconstructed and shown in the Figure 3. In the diagram the lines with numbers indicates the slopes of different year since the beginning. The thickness of the layer with yellowish brown soils was about 2.0 meters at the first year. Below the yellowish brown soil layer was the layer of diluvium gravels.

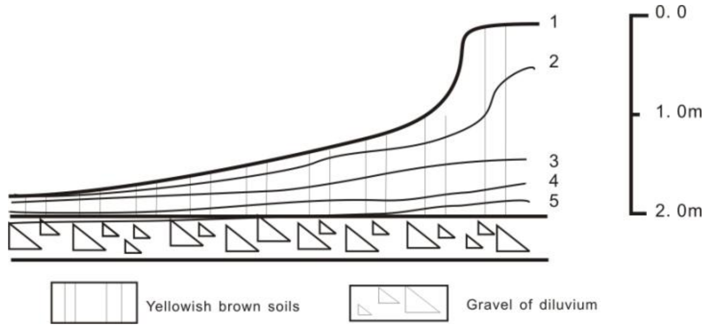

FIGURE 3 SLOPE EVOLUTION OF THE WATERSHED B

In the earlier 3 years the profiles of the slope of the watershed changed rapidly (Figure 3). The initiate upper part of the slope was more steeper and with the landform of the scarp. So the slope mass movement accelerated the soil erosion, which caused the decline of the watershed divide. In the earlier 3 years the decline of the divide was about 1.5 meters. The profile of the slope became more gentle. There was a tendency of soil erosion in the study area: the more gentler the profile of the slope, the more fewer soil erosion.

It was a interesting finding that the layer of deluviun gravels had the function prevent the erosion of surface cutting. When the upper layer of yellowish brown soil was vanished. The surface of the watershed was partly composed of gravels. The gravels protected the slope surface and slowed down the slope water erosion.

Vegetation recovery process

Vegetation coverage plays an important role in the prevention of soil erosion [12]. The natural process of vegetation recovery was also surveyed during the five-year observations [13]. With the development of the slope of the small watersheds in the study area, the slope became gentler. The grass seeds in the adjacent area were blown to the study watershed. The five-year observation also found the changes of natural vegetation recovery processes in the small scale. The following table 3 showed the changes of vegetation recovery in the watershed A and watershed B.

TABLE I. YEARLY VEGETATION RECOVERY PROCESS IN WATERSHED A AND B

Year	Vegetation recovery process (percentage of vegetation cover)	
	Watershed A	*Watershed B*
First	0	0
Second	10%	15-20%
Third	50%	60-70%
Forth	70-80%	80-90%
Fifth	90%	100%

According to the survey of the vegetation species, the plant main quickly occupied the man made bare slope was the flowing vegetation species: *Artemisia arigyi Levl. et Vant.*, *Artemisia Japonica Thunb*, *Kunmerowia Striata Schindl.*, *Lespedeza tomentosa Seib.*,*Carex, sp.*, *Cleistogenes chinensis Keng*. The pecies of *Atemisia sp.*was the pilot species occupied the bare land in the first time and also the main plant covering the small watersheds.

The vegetation covered land was protected by the plant, which was benefit to the reduction of soil erosion. The observation found in the watershed B, there was a small scarp in nor more than one centimeter scale between the vegetation covered land and bare land.

CONCLUSION

Based on five-year observations of rill system, soil erosion and the vegetation recovery in the study area, the rill system evolution, soil erosion, slope evolution and vegetation recovery were discussed in a small scale settings. That study revealed some interesting results in this study.

(1) Rill system evolution demonstrated that the rill system in the small scale settings had the grades of five levels. With the soil erosion process and the profile changes of the slope, rill system changed from more complex to simple. The lower level rills vanished.

(2) Soil erosion was much intensive in the study area. The maximum erosion rate in the watershed divide reached to 50 cm per year during the first 3 years. and most part of the watershed experienced the strong soil erosion in the study area with the erosion rate of 10-20 cm per year in the first 3 years. The composition of the watershed strata included the layer of diluvium gravels. When the depletion of the upper soil, the diluvium gravels had the function to prevent the soil erosion. It suggested that the earlier controlling the erosion, the better results for preventing the soil erosion in a small scale.

(3) The watershed of the rill system had specific morphological profile from the head to the mouth of the rill system. The general tendency of the slope evolution was controlled by the erosion baseline. The slope became gentler with the process of soil erosion.

(4) The natural vegetation recovery in the small bare slope was finished in 3 to 4 years. *Atemisia sp.*was the pilot species occupied the bare slope in the first time during the process of soil erosion and slope evolution. The grass vegetation prevented the soil erosion in the scale of centimeter level.

Acknowledgment

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