An Experimental Study on the Relationship between the Developing Process of the Drainage Geomorphology and the Sediment Yield*

Cui Lingzhou, Li Zhanbin, Guo Yanbiao and ***Han Lin***

State Key Laboratory of Soil Erosion and Dryland Farming on Loess Plateau, Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shanxi, 712100, China

Abstract: Based on the general model of the drainage geomorphology that is in the initial developing stage, the developing process of the drainage geomorphology and the dynamic character of sediment yield of the different developing stage of the drainage geomorphology were studied under the condition of the artificial simulated rainfall. The results showed that the developing process of the drainage geomorphology can be defined three stages—early stage, active stage and stable stage according to the dynamic character of sediment transport rate. During the early stage, the drainage geomorphology development takes on the obvious process that is from the inordinate phase to ordinal phase, and the variation of sediment transport rate and time of different rainfall intensity presents power function. During the active stage, the drainage geomorphology development becomes further acute. The difference of the variation of sediment transport rate and time of different rainfall intensity is distinct. The variation of sediment transport rate and time of 0.5mm/min and 2.0mm/min presents power function separately, and that of 1.0mm/min presents exponent function. During the stable stage, the drainage geomorphology development becomes slow, and the variation of sediment transport rate and time of different rainfall intensity presents quadratic polynomial function.

Keywords: the drainage geomorphology, the developing stage, sediment yield

1 Introduction

Drainage area is the basic unit of rebuilding and controlling the eco-environment of the loess plateau. The law of its sediment yield and soil loss controlling are always focus that the scientists of soil and water conservation study recently. As the important factor of impacting the drainage sediment yield, Geomorphology character basing on the modern geological environment is the long-time interaction of the material of drainage surface, rainfall and runoff. At the same time, through the transport of sediment and water and energy consuming, the development and evolution of drainage area is finished, and the erosion geomorphology landscape that is broken and its gully are formed freely. During this course, the changing geomorphology shape also has the restricted mechanism to the sediment yield, and makes the sediment yield produce different degree response by some kinds of means such as intensity and velocity. So the drainage geomorphology and the sediment yield form a complex, dynamic and coupling system that is dependent and restricted each other through the rainfall.

To the study on this system, the foreign scholars carried out a large of initiate work[1,2,3], for example, W. M. Davis, according to the theory of erosion circulation, put forwards the model of geomorphology developing stage. R. E. Horton, using quantity analysis methods, put forwards "Horton four law", and basing on R. E. Horton's idea, A. N. Stranhler put forwards the principle of dividing the level of drainage network system. In China , Ai Nanshan[6,7]etc, believes that the small drainage system has the conditions of forming the dissipation structure, introduced the method of thermodynamics entropy conception to the erosion drainage research and put forwards the quantitative index to divide an open drainage geomorphology growth stage model using the critical erosion integral value(Ei). Ma Xinzhong etc[9],using the ways and theory of dissipation structure, analyzed the dynamic mechanism of the drainage

* supported by the innovation project of Chinese Academy of science(KZCX1-10-04), and the foundation of State Key Lab of Soil Erosion and Dry Farmland on Loess Plateau(2000B002).

system ,built the model of erosion evolution and the variation equation of erosion modulus along the drainage area of the drainage geomorphology system in the loess upland ravine zone. Jin Desheng[11,12] , through the response model of Developing Process of the Drainage Geomorphology, using simulated rainfall, studied on the non-linear relationship between the sediment yield and drainage network development, drainage network development of the different material componemt and the sediment yield. The results show that drainage network development and the sediment yield are not uniform in time and space, and the process of sediment yield have the character of waving, varying and decreasing. Shi hui etc[10], by simulating experiment, using REE that is the trail material ,studied the sediment yield process of experimental model ,the position of drainage sediment yield and the source of sediment yield.

At present, the field research of drainage mostly emphasize on dividing developing stage of drainage geomorphology and the condition of the material movement in the macroscopical scale in the historical time, and the research span of time and space is large, the simulating study mostly concentrated on the process of sediment yield. However the study on the Drainage Geomorphology characteristic of the different Developing stage, sediment yield law, and the relationship of interacting, dynamic and coupling is few. For this reason, by the simulating experiment, based on the built primary development model of the experimental small drainage and artificial rainfall, we start to carry out the quantitative research of the developing process of small drainage and sediment yield in different growth stage. Through this study, the corresponding research can be more deep developed, and we can provide basic data and theory support for the model predicting sediment yield of small drainagel area.

2 Methods

2.1 The designation of drainage model

Based on analyzing the character of typical small drainage geomorphology in loess plateau and field surveying, macroscopically statistical character of drainage geomorphology was analyzed and generalized. Then the experimental small drainage area in early development stage was designed according to resemble theory. The geometrical index of the experimental small drainage area as following: the surveying projective area is 31.49m^2, length of drainage is 9.1m, maximum width is 5.8m, perimeter is 23.3m, basin relief is 3.15m.The figure 1 is the DEM model of original experimental small drainage area.

2.2 The experimental methods

The experiment is carried out by the simulation rainfall hall of State Key Laboratory of Soil Erosion and Arid farmland in Loess Plateau. The simulated rainfall equipment is spray downwards and the height of sprinkler head is 16m. The soil for experiment is loess in Yanglin. The soil was filled in model after sieved through 1cm sieve pore. On the course of filling, the soil is tamped once every 5cm and measured soil volume weight every 10cm in order to insure that volume weight of filled soil is about 1.39g/cm^3. The preparatory experiment is done after filled soil. Based on summarizing preparatory experiment, it is carried out to fill soil secondly and design newly geomorphology shape. After second filling, it rains about 15 minutes with small rainfall intensity (0.3mm/min) under condition of no flow in order to make model subside and stabilized, the soil moisture uniformity, then begin experiment. Three kinds of rainfall intensity are designed according to typical and representative principle after analyzing completely natural rainfall characteristic in loess plateau. They are 0.5mm/min, 1.0mm/min and 2.0mm/min. Rainfall time is 90min(60min), 60min(45min) and 30min. According to characteristic of drainage development, rainfall time can be adjusted. There are 25 times rainfall altogether in the whole experiment course, 0.5mm/min for 11 times, 1.0mm/min for 9 times and 2.0mm/min for 5 times. Before every rainfall experiment, rainfall intensity was modulated and soil moisture was measured. Start time of runoff was recorded after experiment began. Velocity of runoff was measured with dyeing way in main channel and branch channel. The sample of sediment was collected from exit of main channel every 1minute. At the same time, water level was recorded in collecting water pool. After the end of experiment, the volume of every sample was measured with measuring cylinder and dry weight of sediment was measured by drying. Then sediment concentraten was calculated. According to water level of collecting pool that was recorded in experiment course, runoff volume of whole drainage for 1 minute was calculated. Then using sediment concentraten of sample, sediment yield of whole drainage in 1minute for different rainfall intensity can be get.

3 Results and analysis

3.1 The developing stage of drainage geomorphology

The dynamic variety characteristic of average sediment transport rate for every rainfall was showed in Fig. 2. Fig. 2 illustrates that dynamic variety of average sediment transport rate presents generally uniform trend under three different rainfall intensity. From the start variety range and difference of average sediment transport rate under different rainfall intensity. Then variety range increases obviously and average sediment transport rate reached rapidly maximum. After that, it descended slowly and effect of rainfall intensity on drainage sediment yield and geomorphology development strengthened more then fell. According to dynamic variety characteristic of average sediment transport rate of every rainfall, the developing stage of experimental small drainage geomorphology can divide into early stage, active stage and stable stage. The Fig. 3, Fig. 4 and Fig. 5 are the DEM model of the geomorphology of the experimental drainage area of corresponding stage.

3.2 The character of sediment yield

According to dividing result about developing process of drainage geomorphology, we analyzed variety characteristic of average sediment transport rate in different rainfall intensity for every developing stage. The result shows that variety of average sediment transport rate in different rainfall intensity for every developing stage has prominent difference. In developing early stage, variety of average sediment transport rate with time of different rainfall intensity (0.5mm/min,1.0mm/min and 2.0mm/min) is basically consistent, and they present power function.(Fig. 6) .In developing active stage, variety of average sediment transport rate with time of different rainfall intensity is quite different. 0.5mm/min and 2.0mm/min rainfall intensity present power function (Fig. 7 ,8), but 1.0mm/min presents exponent function (Fig. 9). In developing stable stage, variety of average sediment transport rate with time of different rainfall intensity trends consistent. They present quadratic multinomial.

4 Conclusion

(1) The developing process of drainage geomorphology and sediment yield is a dynamic system that is correlative.

(2) The developing process of drainage geomorphology shows obviously stage. According to dynamic variety of sediment transport rate, it can be divided into early stage, active stage and stable stage.

(3) In different stage, variety of sediment transport rate is obviously different for different rainfall intensity. In developing early stage, average sediment transport rate with time presents power function. In active stage, that of 0.5mm/min and 2.0mm/min rainfall intensity present power function, but 1.0mm/min presents exponent function. In stable stage, it presents quadratic multinomial.

References

[1] Horton R.E, 1945. Erosional Development of Stream and Their Drainage Basins, Hydrophsical Approach to Quantitative Morphology, Geol. Soc. America Bull, vol. **56**, pp. 275-370.

[2] Bakker J.P. and Strahler A.N,1956, Report on Quantitative Treatment of Slope-Recession Problem, Congres international de Geographic Rio de Ganoiro.

[3] Schumm S.A, 1956, The Role of Creep and Rainwash on the Retreat of Badland Slopes, Amer, Jour. Sci. vol. **254**. pp. 693-706.

[4] Qian Xiaorong, Chen Shanlin, Ai Nanshan, 1986, The Connection Between Geomorphologic Process of a Small Watershed and Dissipation Structure [j], Bulletin of Soil and water conservation vol. **6**, pp:12-20.

[5] Ai Nanshan, 1987, comentropy in Erosion drainage system [j], Journal of Soil and Water Conservation vol. **1**, pp:1-7.

[6] Jin Desheng, A Study on Fluvial Dynamic Geomorphology and Its Experiment and simulation [J], ACTA GEOGRAPHICA SINICA vol. **44**, pp: 147-156.

[7] Li Qiang, Lu Zhongchen, Yuan Baoyin, 1990, Quantitative study on the developing stage of geomorphology [J], ACTA GEOGRAPHICA SINICA vol. **45**, pp:110-119.

[8] Ma Xinzhong, Lu Zhongcheng, Jin Desheng, 1993, Dissipation structure and erosion evolution of the drainage geomorphology system[J], ACTA GEOGRAPHICA SINICA vol. **48**, pp: 367-375.

[9] Jin Desheng, Guo Qingwu, 1995, An experimental study on developing process of drainage geomorphology [A], Experiments and Simulations in Geomorphology, Ed by Jin Desheng etal, pp:79-101.

[10] Lei Alin, Tang Keli, 1995, Discussion on choosing prototypes in simulated test of soil erosion[J], Journal of soil and water conservation , vol. **9**, pp: 60-65.

[11] Shi Hui, Tian JunLiang, Liu Puling, 1997, Study on relationship of slope-gully erosion and soil and water conservation vol. **9**, pp:30-33.

[12] Jin De-Sheng, ChenHao, Guo Qingwu, An experimental study on influence of material component to non-linear relation between sediment yield and drainage network development [J], ACTA GEOGRAPHICA SINICA vol. **55**, pp:339-448.

[13] Chen Hao, 2000, Relationship between erosion and sediment in drainage basins of Loess Gully-Hilly area[J]. ACTA GEOGRAPHICA SINICA vol. **55**, pp:355-363.

NOTE: The following figures are all what this paper adopts. When you reedit my paper, you may select right position for the corresponding figures Which I have given the serial number.

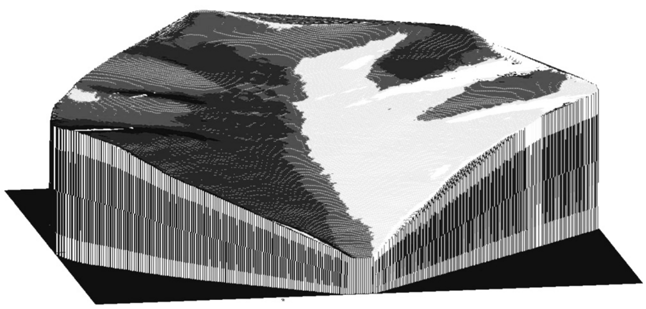

Fig. 1 The DEM model of the original experimental small drainage area for experiment

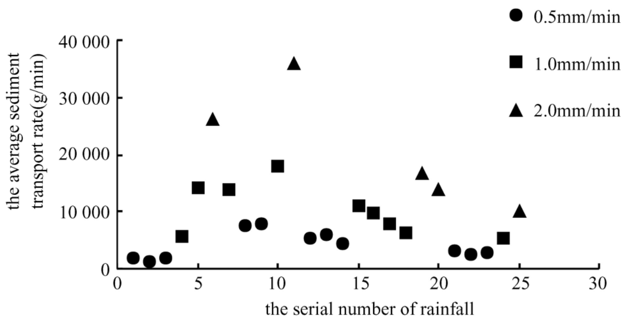

Fig. 2 The dynamic variation of the average sediment transport rate of the every rainfall

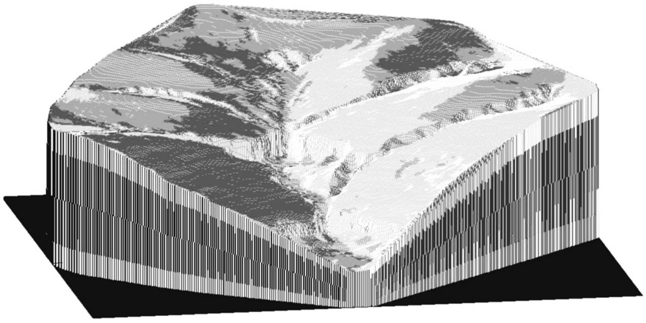

Fig. 3 The DEM model of early stage of the geomorphology of experimental small drainage area

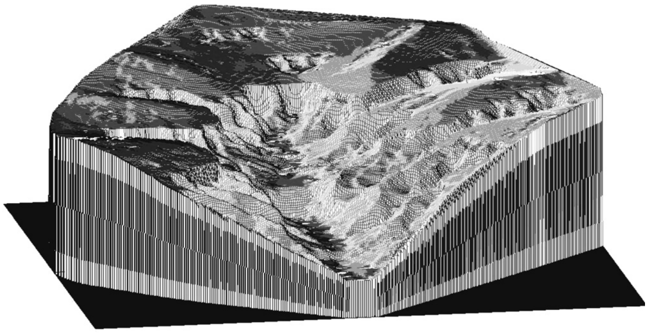

Fig. 4 The DEM model of geomorphology of the experimental small drainage area in active stage

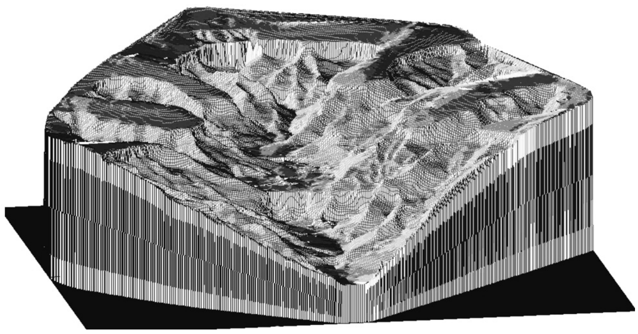

Fig. 5 The DEM model of geomorphology of the experimental small drainage area in stable stage

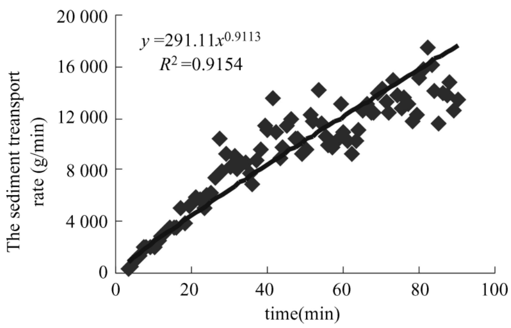

Fig. 6 The variation of sediment transport rate and time of the experimental small drainage area in early stage(0.5mm/min)

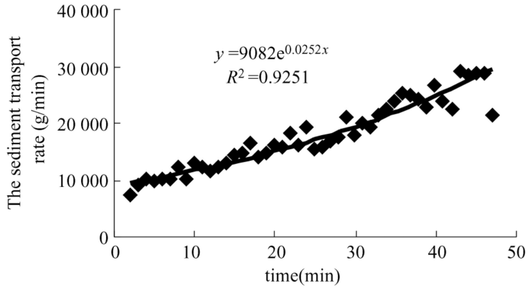

Fig. 7 The variation of sediment transport rate and time of the experimental small drainage area in active stage(1.0mm/min)

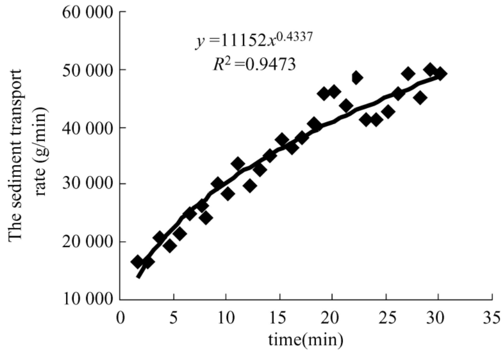

Fig. 8 The variation of sediment transport rate and time of the experimental small drainage area in active stage(2.0mm/min)

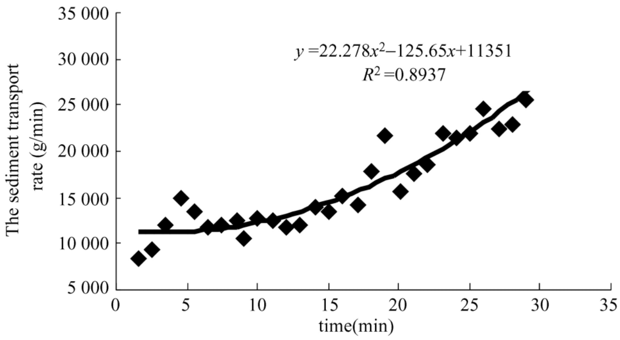

Fig. 9 The variation of sediment transport rate and time of the experimental small drainage area in stable stage(2.0mm/min)