Analysis of soil hydraulic erosion model based on convolution

Xue-Xiong Wu

1Zhejiang Key Laboratory of Water Conservancy Disaster Prevention and Reduction, Zhejiang Institute of Hydraulics & Estuary, Hangzhou, 310020, China
2Zhejiang Guang Chuan Engineering Consulting Co., Ltd., Hangzhou, 310020, China

Abstract: Soil erosion is a very complicated process. This paper uses convolution theory, through the runoff and sediment data of economic forest area natural rainfall conditions of southeast coastal area collected, and divided into several micro slope unit, using convolution model, slope soil erosion analysis. The simulated values were verified with the measured values, the results show that the simulated values and measured values of the average relative error is 40%, the effective model coefficient is 0.614; the simulation value had a significant linear relationship with rainfall and runoff.

1. Introduction

Soil erosion is a very complicated process. In order to describe the effect of soil erosion and its process, scholars at home and abroad have done a lot of research. Wischmeier \cite{1} using the observation data of the eastern United States nearly 30a of the 30 states more than 10000 runoff plots and erosion factors related to statistical analysis, the universal soil loss equation to draw empirical USLE, this model is widely used in the world. Then, the Agricultural Bureau and the Soil Conservation Bureau carried out the revision research on the USLE model, and proposed a revised universal soil loss equation (RUSLE) to make it more widely used \cite{2}. The empirical model is simple, but can not reflect the erosion process. In order to solve the existing empirical models and problems of the restrictions, the United States Department of agriculture has carried out research work WEPP erosion prediction model of soil erosion process based on the model description model of \cite{3} is by far the most relevant physical parameters of water erosion process.

With the development of soil erosion research, Chinese scholars have put forward a variety of empirical statistical models \cite{4-6} through a large number of statistical studies of sediment yield factors. For example, inter gully land and bare land base state of slope soil erosion model as a benchmark, the gully erosion effect has been modified, the calculation established between ditch rainfall erosion and sediment yield equation \cite{7}; Chen Xiaoan \cite{8} through the regression analysis of the relationship between sediment and erosion factors, established the Chabagou watershed time storm erosion slope soil model \cite{9}; Liu Baoyuan based on the observation data in different regions of the country district comprehensive analysis, put forward Chinese soil erosion prediction model is applied to the nationwide. At the same time, the physical process model of soil erosion in China has also been developed. Duan Jiannan \cite{10} by referring to foreign experience and erosion modeling technology, and constructs the mathematical model of slope soil erosion SLEMSEP process according to the actual situation in China, to describe the process of soil erosion in arid area, the quantitative evaluation of the impact of soil erosion on slope and soil changes caused by human activity; Wang Lixian \cite{11} from water erosion dynamic principle using one-dimensional flow model, the approximate model of overland flow and erosion equation coupling that erosion process model of erosion on slope, and in the condition of artificial rainfall test on model adaptation test; dynamic equilibrium of \cite{12} from the Tang Liqun slope
sediment of the rainfall splash erosion, sediment transport and the runoff scouring process with proposed sediment model is complete, and has been used in the Chabagou watershed; leitingwu etc. [13] combined with derivation of hydrodynamics, soil erosion and sediment deposition equation, mathematical model is established to simulate the evolution process of rill erosion, the model has ability to express spatial and time evolution of rill, can reflect the dynamic rill erosion processes. With the further study of erosion process, the soil erosion and sediment yield model with physical process has developed rapidly. Many scholars have established the soil erosion and sediment yield model of each specific color. Most of the models have good applicability in the Loess Plateau. However, similar studies have been carried out in the south of China, and few of them have been applied to the coastal areas of Southeast China. Therefore, the study of the erosion process model suitable for the region can provide a useful tool for regional soil erosion assessment and soil conservation planning.

2. General Situation of Test Area

The experimental area is located in Zhejiang, Yongkang province. It belongs to the low mountains and hills basins in East Zhejiang Province. Its topography and rainfall have certain representativeness. The area is located in the subtropical monsoon climate, mild climate, adequate light, abundant rainfall, average annual rainfall 1429mm, rainfall distribution is uneven in a year, mainly concentrated in 3-9 months, accounting for about 76.5% of the annual rainfall; the test area into the parent material in the quartz sandstone and Quaternary red clay soil, the main types of paddy soil. The zonal vegetation in subtropical evergreen broad-leaved forest. This research takes Yongkang soil and water conservation monitoring stations set up along the slope of the planting of Diospyros kaki as the object, as the discussion of economic forest slope soil erosion prediction of typical examples. District wide 5m (and contour parallel), 20M (long along the slope, the slope of 10 degrees horizontal projection), water collecting and runoff pool below, a pool of 5 built a "V" type diversion weir, one of which is connected with two grade runoff pool, Fangshan persimmon cultivation spacing of about 2.5m * 3.0m.

3. Real time data acquisition

By recording rain gauge rainfall data collection, runoff and sediment by using a self-developed weighing meter for the determination of runoff and sediment. The test collected 2011-2012 years, 22 heavy rainfall conditions of sediment yield data, including 3 games in 2011, 19 in 2012.

4. Water erosion model of slope based on convolution

The slope water erosion model is based on the sediment yield model derived from Wang Guangqian and [14]. The model assumes that the sediment particles move at an average velocity, and the sediment particles are spheres of diameter, and the sediment particles are arranged regularly in rows.

In the unit time, the maximum distance of the observation section is \( s \) by observing the sediment distance of the cross section, and the area occupied by the observation section is \( sV \) in unit time and unit width. Unit time per unit area of erosion sediment quality is the rate of soil erosion, soil erosion due to the transport layer from the top to the foot of the slope is gradually increasing, soil erosion and transport layer thickness hypothesis with the slope length increases linearly, and the increase rate (i.e. after the unit length of slope, the thickness of soil erosion transport layer increased layer, is an empirical parameters, it and soil type, land use and vegetation cover, terrain slope, rainfall intensity and other parameters related). In the unit time, the sediment in the sediment through the observation surface comes directly from the area unit, because the sediment rate is slower than the flow velocity, i.e., soil erosion rate (unit: kg = m-2 • s-1).

That is, due to the single width flow on the slope, there is a relationship between the single width flow and the runoff rate per unit area (for the coordinates under the slope). In the sediment, river basin is divided into several "channel + slope, slope can be calculated for each area and the length of slope, if the slope is simplified to rectangle slope, slope, width, the runoff model can be obtained and measured runoff on slope is, per unit area the runoff rate, through the above relation can be obtained:
The slope erosion per unit time is the rate of soil erosion in the slope of the integral, when slope is simplified as a rectangular slope, the area integral can be simplified into two steps: the first step in the slope of the unit width integral, obtained per unit time per unit width sediment; second step erosion the amount of sediment per unit width multiplied by the width per unit time per unit time of the entire slope (unit: kg/s), the formula is as follows:

\[ E = \frac{\pi}{6} \int_{0}^{L} \frac{\alpha \rho \pi \rho}{42} m D \rho Q^3 A^\frac{2}{3} x^\frac{2}{3} n^\frac{1}{3} J^{\frac{3}{2}} L^2 \]

5. Results and analysis

Under different rainfall conditions, runoff runoff and sediment yield were different in economic forest plots. As can be seen from table 1, on the whole, the larger the rainfall in a single field, the greater the sand runoff in the plot. But the observation result also has the situation of small rainfall and large sediment yield. For example, the amount of sediment produced by fifth fields of rainfall over 67.0mm is higher than that of second 90.0mm of rainfall, and the amount of sediment produced by twenty-first fields is 1.9 times that of the same amount of rainfall (twenty-second fields). Both the fifth and twenty-first rains have antecedent rainfall, and the latter two rains are almost unaffected by antecedent rainfall. It can be seen that the sediment yield is not only related to the rainfall, but also closely related to the antecedent rainfall. When the antecedent rainfall occurs simultaneously, the amount of sediment produced by the same rainfall is close to (eleventh rains and twentieth rains). In addition, the antecedent rainfall and the time interval of this rainfall are different, and their effects on the rainfall sediment yield are also different.

| Rainfall field | Rainfall duration Y-M-D | Rainfall mm | Duration h | Runoff mm | Sediment yield t/km² | Rainfall field | Rainfall duration Y-M-D | Rainfall mm | Duration h | Runoff mm | Sediment yield t/km² |
|---------------|-------------------------|-------------|------------|-----------|----------------------|---------------|-------------------------|-------------|------------|-----------|----------------------|
| 1             | 2011-10-13              | 65.0        | 20.25      | 10.5      | 661.8                | 12            | 2012-06-22              | 89.5        | 30.33      | 33.9      | 2192.1                |
| 2             | 2011-11-18              | 90.0        | 22.47      | 22.0      | 1238.8               | 13            | 2012-06-30              | 34.0        | 5.17       | 3.7       | 263.6                |
| 3             | 2012-04-13              | 34.0        | 16.83      | 9.9       | 538.0                | 14            | 2012-07-15              | 38.5        | 9.50       | 4.8       | 270.9                |
| 4             | 2012-04-29              | 44.0        | 3.85       | 9.0       | 531.9                | 15            | 2012-07-19              | 32.5        | 3.50       | 2.2       | 164.3                |
| 5             | 2012-04-30              | 67.0        | 12.17      | 13.6      | 1301.3               | 16            | 2012-08-07              | 112.6       | 27.00      | 26.6      | 1953.0               |
| 6             | 2012-05-08              | 53.0        | 15.17      | 4.9       | 376.6                | 17            | 2012-08-25              | 15.5        | 1.00       | 0.5       | 26.6                |
| 7             | 2012-05-19              | 46.5        | 9.33       | 7.2       | 471.4                | 18            | 2012-08-30              | 14.0        | 1.00       | 0.3       | 12.6                |
| 8             | 2012-06-06              | 46.5        | 14.42      | 11.6      | 695.4                | 19            | 2012-09-02              | 32.0        | 48.3       | 2.8       | 190.7                |
| 9             | 2012-06-11              | 18.0        | 2.40       | 1.8       | 111.9                | 20            | 2012-09-03              | 22.0        | 6.00       | 3.4       | 293.9                |
| 10            | 2012-06-17              | 17.0        | 6.00       | 2.8       | 156.6                | 21            | 2012-09-04              | 41.5        | 15.33      | 11.7      | 982.7                |
| 11            | 2012-06-18              | 20.5        | 11.17      | 4.2       | 270.2                | 22            | 2012-09-20              | 42.0        | 15.67      | 7.0       | 520.1                |

Single rainfall runoff and sediment are liable to be affected by rainfall process and antecedent rainfall, but there may be no more consistent laws. However, the runoff and sediment runoff from multiple rainfall can reflect their internal relationship. Figure 1 reflects the regression relationship between rainfall, runoff and sediment yield, and the results show that there is a significant linear relationship between the three. From the decision factor, more than 80% of the variation of runoff and sediment by rainfall, while the remaining 20% are lack of underlying surface factors; but the decision coefficient of runoff sediment and sediment yield was significantly higher than that of the fitting equation of rainfall, more than 95% of the variance can be explained by the runoff, erosion and sediment that is mainly
caused by runoff erosion.

Fig. 1 Relationship between rainfall, runoff and sediment yield

6. Erosion simulation results
The convolution formula is used to calculate the sediment yield of each rainfall. The simulation results show that the characteristics of large rainfall and large sediment yield are as a whole. Through regression of runoff and sediment yield showed that the yield coefficient of correlation between sediment and rainfall is 0.90, the correlation coefficient between sediment and runoff was 0.94, visible erosion simulation results with rainfall and runoff has a significant linear relationship. But the simulation results and the measured differences, such as the fifth field measured sediment field is higher than second, the simulation result is just the opposite, and far less than the fifth sediment; 1.9 times difference between the twenty-first field and twenty-second field sediment are measured for 1.2 times. Therefore, the simulation results may change the law of erosion and sediment yield in some cases.

7. Conclusion
This paper collected economic forest area under natural rainfall conditions of runoff and sediment data, analyzes the relationship between runoff and sediment, and the convolution model simulation of slope erosion and sediment yield in southeast coastal area, draw the following conclusions:

1) under natural rainfall, rainfall runoff and sediment by rainfall and other factors, may appear a large amount of rain sediment; statistical results show that there is a significant linear relationship between runoff and sediment.

2) convolution model simulation value and measured the average relative error is 40%, the simulation value had a significant linear relationship with rainfall and runoff model, the effective coefficient is 0.614, but in some conditions may change the laws of sediment yield.

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