Raindrop characteristics analysis (Oct 25, 2015) of natural rainfall in Zhengzhou city of Yellow River basin

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Abstract: Raindrop characteristics, including speed and size of raindrops, in Zhengzhou city of Yellow River basin were analyzed through a natural rainfall on the loess slope. Results showed that the process of natural rainfall belonged to a parabola and counts, size and terminal velocity would increase with the rainfall intensity rising. Besides, the size and terminal velocity of natural raindrops were relatively scattered; In the process of individual rainfall, the terminal velocity and its peak value were mainly focused between 1~5m/s and 3.4m/s, respectively. Size of raindrops were mainly consisted of 0.125~1.25mm, among which the terminal velocity of raindrops with a size of 0.125mm, 0.25mm, 0.375mm, 0.5mm, 0.75mm and 1mm were primarily 0.8~2.6m/s, 1~3.4m/s, 1.4~3.4m/s, 1.8~3.4m/s, 3~4.2m/s and 3.4~5m/s, respectively.

1. Introduction
Loess Plateau, the region with extremely serious problem of loss of water and soil among the world, has been the main source of sediments in Yellow River and its management is the critical factor to curb sediments [1-2]. However, due to the complexity of soil and water loss and the limitations of observational methods and content [3], some research fields, for example, law of watershed soil and water loss and the mechanism of erosion and sediment yield haven’t had a breakthrough, especially the lack of practical soil and water loss model in Loess Plateau [9], even though there being some advances around the world [4-8]. All the limitations restrict the development of soil and water loss management in depth and breadth directly [9]. To have a further study of natural rainfall distribution [11] by combining the field observation and laboratory test were the research focus to explore the mechanism of soil and water loss law, develop optimized model and establish mathematical model of soil and water loss on the Loess Plateau.

In order to establish such models, it’s imperative to analyze the scale transformation and rainfall similarity and finally the raindrops characteristics in the soil erosion experiments must be solved [12-15]. This study aims to analyze the terminal velocity and grading of raindrops, combined with the sediment results in different rainfall conditions and offer a technology support for dynamic rainfall simulation.
2. Experiment design and data acquisition

2.1 Experiment design of runoff plots
The experiment was carried out at the Zhengzhou test base of model Yellow River of Yellow River Institute of Hydraulic Research. The length, width, depth and slope of runoff plots are 5m, 1m, 60cm and 20°, respectively. Structure of plots is brick-concrete and there is a water channel at the outlet in each plots. Soil landfilled in each plots is surface loessal soil from the Mangshan Mountain in Zhengzhou, with the proportion of particle size of 0.05 ~ 0.01 mm, 0.02 ~ 0.05 mm being 43.4% and 35.45% respectively. And soil bulk density is 1.2g/cm³.

2.2 Test method
The 5m long slope was divided into five fractural surface from top to bottom. The laser optical disdrometer was used here to collect the information about characteristics of raindrops, including intensity, size, terminal velocity and number under the same terminal velocity. Slope velocity radar gun and steel rule were used to record hydraulics parameters, including speed, width and depth of runoff. Sediments were collected by 1 minute after producing runoff and analyzed the parameters mentioned above. Erosion amounts and sediment concentration were calculated by the method of substitution or oven drying and calculated the parameters like infiltration of runoff according to rainfall and runoff yield.

3. Results and analysis
In this paper, five typical rainfall time points in natural rainfall on October 25, 2015 (hereinafter referred to as 20151025) were selected. The length of each time point was 1min. The particle size of raindrops in the min length, the speed of raindrops, and the number of raindrops with the same raindrops were collected by LPM laser raindrop spectrometer. The raindrops characteristics were also analyzed. The results are as follows.

![Figure 1: In the first minute during the natural rainfall on 20151025](image)

The distribution of the particle size and the final velocity of the raindrops in the first 1 minute during the natural rainfall on 20151025 is shown in Fig.1. It can be seen from the figure that the final velocity of the raindrops in the first 1min of the rainfall is mainly concentrated between 0.6-5.8m/s and the peak velocity is 3.4m/s, and the number of raindrops with the final velocity of the raindrop is about 205, accounting for about 15%; The rainfall is mainly composed of raindrops with particle size of 0.125-1.25mm. The final velocity of 0.125mm is mainly between 0.6-3.4m/s, and the final velocity
of the raindrops with 0.25mm particle size is mainly concentrated on the range of 0.8-3.4m/s, 0.375mm diameter of the raindrops mainly concentrated on the 1-3.4m/s, the 0.5mm diameter of the raindrops mainly concentrated on the 0.8-4.2m/s, the final velocity of 0.75mm particle size is mainly concentrated on the 2.6-5m/s, the 1mm particle size of the raindrops mainly concentrated on the 3.4-5m/s.

Figure 2: In the second minute during the natural rainfall on 20151025

According to the distribution of the raindrops and the final velocity of the raindrops in the second minute during the natural rainfall process (Figure 2), the final velocity of the raindrops in the second minute of the rainfall is mainly concentrated between 0.6-6.6m/s and the peak velocity is 3.4m/s, with the number of raindrops at the end of the raindrops is about 280, accounting for about 15%; We can also see the rainfall is mainly composed of 0.125-1.25mm diameter raindrops, the final velocity of 0.125mm particle size is mainly concentrated on the 0.8-2.2m/s, the final velocity of 0.25mm size is mainly concentrated in the 1.8-3.4m/s, the final velocity of 0.375mm diameter of the raindrops mainly concentrated in the 0.9-3.4m/s, the final velocity of 0.5mm particle size is mainly concentrated in the 1.8-3.4m/s, the 0.75mm particle size of the raindrops mainly concentrated in the 3.4-4.2m/s, and the 1mm particle size of the rain speed is mainly between 3.4-5.8m/s.

Fig.3 shows the distribution of the particle size and the final velocity of the raindrops in the third minute during the natural rainfall in 20151025, it can be seen from the figure that the final velocity of the rains in the third minute of the rainfall is mainly concentrated in the range of 0.6-6.6m/s, and the velocity of the raindrops in the third minute of the natural rainfall is analyzed. At the same time, the final velocity and the peak velocity was formed, the value is 1.8m/s and 3.4m/s respectively. That is, most of the raindrop speed is 1.8m/s and 3.4m/s or so, with the number of raindrops about 205 and 230 or so, accounting for about 30% or so; We can also see the rainfall is mainly composed of 0.125-1.25mm diameter raindrops, of which 0.125mm particle size of the end of the rain mainly concentrated in the 0.8-3.4m/s, 0.25mm diameter of the raindrops mainly concentrated in the 0.6-3.4m/s, the 0.375mm diameter of the raindrops mainly concentrated in the 1.3-4.2m/s, the 0.5mm diameter raindrops is mainly between 1.8-3.4m/s, the 0.75mm particle size of the raindrops mainly concentrated in the 2.6-4.2m/s, the 1mm particle size of the rain speed is mainly between 3.4-5m/s.
Figure 3: In the third minute during the natural rainfall on 20151025

Figure 4: In the fourth minute during the natural rainfall on 20151025

Fig. 4 shows the distribution of the particle size and the final velocity of the raindrops in the fourth minute during the natural rainfall in 20151025. It can be seen that final velocity of the raindrops in the fourth minute of the rainfall is mainly concentrated between 0.6-6.6 m/s, forming two final velocity peaks, namely 2.2 m/s and 3.4 m/s respectively, that is, most of the raindrops is mainly 2.2 m/s and 3.4 m/s or so, with the number of raindrops is 210 and 275 or so, accounting for about 35%; We can also see the particle size of rainfall is mainly 0.125-1.25 mm raindrops. Of which 0.125, 0.25, 0.375, 0.5, 0.75, 1 mm particle size of the rain speed is mainly concentrated in 0.6-2.6, 0.8-4.2, 1-3.4, 1.8-4.2, 2.6-4.2, 3.4-5 m/s.
Figure 5: In the fifth minute during the natural rainfall on 20151025

Fig. 5 shows the distribution of the particle size and the final velocity of the raindrops in the 5th minute during the natural rainfall. We can see that the final velocity of the raindrops in the first 5 min of the rainfall is mainly concentrated between 0.8-6.6 m/s, and the velocity of the raindrops in the 5th minute during the natural rainfall is analyzed. Forming a final velocity peak is 4.2 m/s, that is, most of the raindrop speed is 2.2 m/s, with the raindrop speed of the number of raindrops for about 180, accounting for about 15%; We can also see the rainfall is mainly composed of 0.125-0.5 mm diameter raindrops, of which 0.125, 0.25, 0.375, 0.5, 0.75, 1 mm diameter of the raindrops mainly concentrated in 0.8-3.4, 1-3.4, 1.4-3.4, 1.8-3.4, 3-4.2, 3.4-5 m/s.

4. Conclusions

Through the analysis of natural raindrops, the following aspects have been obtained:

(1) The natural rainfall process is a process of rainfall intensity parabolic changes, and with the increase of rain intensity, the number of raindrops per unit time, particle size, the final velocity will be a corresponding increase. Natural rainfall raindrops and raindrops are relatively scattered, from small to large are distributed.

(2) During the process of this rainfall, the final velocity of the rain is mainly concentrated between 1-5 m/s, the peak of the final velocity is generally 3.4 m/s; rainfall is mainly composed of the particle size of 0.125-1.25 mm raindrops. The velocity of the raindrops of 0.125 mm diameter is mainly between 0.8-2.6 m/s, the final velocity of the raindrops of 0.25 mm particle size is mainly concentrated between 1-3.4 m/s, 0.375 mm concentrated in the 1.4-3.4 m/s, the 0.5 mm particle size of the raindrops mainly concentrated in the 1.8-3.4 m/s, the 1 mm particle size of the raindrops mainly concentrated in the 3.4-5 m/s.

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References

[1] Tang Keli, Soil and water conservation in China [M]. Beijing: Science Press, 2004.
[2] Chen Lei, Soil and water conservation in China [J], 2002 (7): 4-6.
[3] Li Zhanbin, Storm erosion test and small watershed sediment yield model of sloping land system in Loess Region [D], Doctoral Dissertation of Shaanxi Institute of Mechanical Engineering, 1991.

[4] Moldenhauer, W C. Procedure for studying soil characteristics using disturbed samples and simulated rainfall [J]. Transactions, American Society of Agricultural Engineer, 1965, 8(1):30-35.

[5] Renard K G, Foster G R, Weeies G A, et al. Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE)[J]. Agriculture Handbook, 1997.

[6] Foster G R, Lane L J. User requirements, USDA-Water Erosion Prediction Project (WEPP) [R]. NSERLReportNo1, West Lafayette: USDA-ARS National Soil Erosion Research Laboratory, 1987.

[7] Nearing M A, Foster G R, Lane L J, et al. A process-based soil erosion model for USDA-Water Erosion Prediction Project technology [J]. Trans. ASAE, 1989, 32(5): 1587-1593.

[8] Laflen J M, Lwonard J L, Foster G R. WEPP a new generation of erosion prediction technology[J]. J of Soil and Water Cons., 1991, 46(1): 34-38.

[9] Yai Wenyi, Several design theories and applications of the Yellow River river channel physical simulation [D], Doctoral Dissertation of Hohai University, 2005.

[10] Yai Wenyi, Review and Prospect of mathematical models for erosion and sediment yield in China [J]. Sediment Research, 2011, (2): 65-74.

[11] Shen Zhenzhou, Liu Puling, Xie Yongsheng et al. Transformation of erosion types on loess slope by REE tracking [J], Journal of Rare Earths, 2007, 25 (4): 67-73.

[12] Shen Zhenzhou, Yao Wenyi, Li Zhanbin, Li Mian, Xiao Peiqing, WU Yan. Transformation of Rainfall Characters on Soil Erosion Similar [J], Journal of Rare Earths, 2014, 32 (S): 130-133.

[13] SHEN Zhenzhou,YAO Wenyi, L I Mian, et al. Study on Correlativity Between Erosion and Seeping Under Different Underlying Horizon[J], Journal of Soil and Water Conservation, 2008, 22 (5): 43-46.

[14] SHEN Zhenzhou, YAO Wenyi, LI Mian, et al. Runoff Sediment-Carrying Capacity and Critical Shear Force on Slope [J]. Journal of Tianjin University, 2008, 41(4):149-153.

[15] Shen Zhenzhou, Yao Wenyi, Li Mian et al, Influence factors of runoff energy consumption and denudation amount on loess slope [J]. Science of Soil and Water Conservation, 2009, 7 (6): 9-13.