Experimental study on influence of vegetation coverage on runoff in wind-water erosion crisscross region

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Abstract. Using artificial rainfall simulation method, 23 simulation experiments were carried out in water-wind erosion crisscross region in order to analyze the influence of vegetation coverage on runoff and sediment yield. The experimental plots are standard plots with a length of 20m, width of 5m and slope of 15 degrees. The simulation experiments were conducted in different vegetation coverage experimental plots based on three different rainfall intensities. According to the experimental observation data, the influence of vegetation coverage on runoff and infiltration was analyzed. Vegetation coverage has a significant impact on runoff, and the higher the vegetation coverage is, the smaller the runoff is. Under the condition of 0.6mm/min rainfall intensity, the runoff volume from the experimental plot with 18% vegetation coverage was 1.2 times of the runoff from the experimental with 30% vegetation coverage. What's more, the difference of runoff is more obvious in higher rainfall intensity. If the rainfall intensity reaches 1.32mm/min, the runoff from the experimental plot with 11% vegetation coverage is about 2 times as large as the runoff from the experimental plot with 53% vegetation coverage. Under the condition of small rainfall intensity, the starting time of runoff in the experimental plot with higher vegetation coverage is later than that in the experimental plot with low vegetation coverage. However, under the condition of heavy rainfall intensity, there is no obvious difference in the beginning time of runoff. In addition, the higher the vegetation coverage is, the deeper the rainfall infiltration depth is. The results can provide reference for ecological construction carried out in wind erosion crisscross region with serious soil erosion.

1. Introduction

According to the terrain features and dominant external forces, three major different types of soil erosion zones are divided. They are hydraulic erosion zone, wind erosion zone and freeze-thaw erosion zone. The wind-water erosion crisscross region is a special region between the hydraulic erosion region and the wind erosion region, located in the region from north latitude 35 degrees 25 minutes to north latitude 40 degrees 40 minutes, east longitude 103 degrees to east longitude 113 degrees 53 minutes. Soil erosion in this region is more serious than in other parts of the Loess Plateau[1]. With the further development of social economy and Western Development, ecological environment management has been paid more and more attention to. Vegetation construction is the key measure of soil erosion control in the crisscross area of water erosion and wind erosion, and many vegetation construction projects such as soil and water conservation, World Bank...
projects, national debt projects and key projects of soil and water conservation control were implemented. Remarkable achievements have been made in vegetation construction, and the ecological environment in this area has been developing well. At the same time, the related research results show that the precipitation in this area has little change, but the runoff and sediment discharge have obvious decrease trend. The above-mentioned phenomena show that the influence of underlying surface change on runoff sediment transport has become a factor that can't be ignored. Many scholars have studied the relationship between vegetation and soil erosion in the hilly and gully region of Loess Plateau, and their research results also show that the relationship between vegetation and soil erosion is also significant. Vegetation cover[5~7], vegetation types[8~10], vegetation roots[11~12] and spatial allocation of vegetation[13~14], have important effects on runoff and sediment yield. Most studies have been carried out in water erosion area, but there is relatively little research on the influence of vegetation on progress of rainfall and runoff in wind-water erosion crisscross region with fragile ecological environment.

The artificial rainfall simulation experiment method was used in the research work, and the rainfall runoff variation process under different vegetation coverage conditions is analyzed in the water-wind erosion crisscross region. On the basis of experimental observation, the role of vegetation coverage in rainfall runoff production is preliminarily revealed. All research results can provide some guidance and reference for regional vegetation ecological construction and watershed hydrological process research.

2. General situation and design of test area

2.1. General situation of test area

Hantaichuan river basin, a typical watershed of wind-water erosion crisscross basin, is the experimental area. Hantaichuan river basin, one of ten small tributaries, is directly entering the Yellow River in Inner Mongolia. The underlying topography of the basin is complicated, with hills, deserts and plains. Vegetation coverage is low in the Watershed, about 12%. The water system is shaped like a feather, and the runoff producing mode is over Permeability runoff[15]. Soil erosion is dominated by water erosion, and hydraulic erosion and wind erosion crisscross in this watershed.

The field simulated rainfall experiment area is located in Dalate banner, Erdos City, Inner Mongolia. The specific latitude and longitude position is east longitude 110 degrees 02 minute 12 second, north latitude 40 degrees 03 minute 06 second. There are six runoff plots. The runoff plot is a standard plot of 20 meters long and 5 meters wide, with a slope of 15 degrees. The dry density of soil in the plot is 1.4~1.72g/cm³, the porosity of soil is about 33%~48%, and soil particle size is mainly concentrated between 0.02mm and 2mm.

2.2. Test plot layout and experimental design

2.2.1. Test plot layout and test equipment In order to ensure the basic conditions of the experimental plot are basically consistent, it is necessary to turn over the plot, and use the slope instrument to smooth the area until it reaches the slope of the experimental requirements. Then, the seed of Alfalfa was sowed in the sorted area according to the different vegetation coverage requirements. The vegetation coverage was measured by Tetra-cam ADC third generation multi spectral digital camera. Due to the poor precipitation condition in the experimental area, artificial watering and maintenance of Alfalfa should be conducted. In this way, the coverage of alfalfa can better meet the requirements of the experiment. The layout of the plots is just as figure 1 showing.

The main equipments used in the experiment are artificial rainfall simulator, TRIME soil moisture meter, Tetra-cam ADC third generation multi spectral digital camera, rain cylinder, flow bucket, ring knife and so on.
2.2.2. Experimental design The simulated rainfall experiment is carried out according to the following procedures:

Firstly, the rainfall intensity is determined in the runoff plot which is to be tested, and the rain intensity adjustment should be repeated until the scheduled rain intensity is met. At the beginning of the artificial rainfall simulation experiments, we also need to measure the vegetation coverage, initial soil water content, underground 10cm, 20cm, 30cm, 40cm, 50cm, 60cm, 70cm, 80cm, 90cm, 100cm depth, soil moisture content and conventional weather indicators such as wind speed, temperature and so on.

Then, during the artificial rainfall simulation, it is necessary to record the beginning time of runoff production, to measure the surface soil moisture content and the soil water content, yield and sediment yield at different depths during the runoff process. The soil moisture content at different depths was measured every 5 minutes. In order to ensure the accuracy of the data, each set of data was measured three times. The amount of runoff and sediment produced by rain was taken every 1min at the bucket and sampled with 100ml gravity bottle during the period.

After the rainfall test, the end time of rainfall and the end time of runoff production should be recorded, and the surface soil water content and soil volumetric water content at different depths are measured at the end of runoff yield.

Artificial simulated rainfall experiments were conducted in accordance with the order of rainfall intensity 0.5mm/min, 1.0mm/min, and 1.5mm/min. A total of 23 simulated rainfall experiments were conducted in 6 plots. and the simulation test were stopped when the runoff per minute from test plot remained unchanged. In order to ensure the effect of rainfall runoff test, all the tests were carried out under no wind.

3. Result analysis

3.1. Influence of vegetation coverage on runoff yield

As is known to all, in the process of rainfall runoff generation, the magnitude of runoff depends not only on the amount of rainfall input, but also on the amount of intermediate process consumption, such as infiltration and evaporation. That is to say, if the external input conditions are consistent, the magnitude of the flow depends on the intermediate process-infiltration process. Therefore, the effect of vegetation coverage on rainfall infiltration and its influence on the process can be judged according to the flow rate.

According to our experimental data, the characteristics of runoff in different vegetation coverage experimental plot were analyzed. In this paper, we have only analyzed the variation characteristics of runoff under 0.6mm/min and 1.32mm/min two rain intensity conditions.

Figure 2 is the relationship map of accumulated precipitation and runoff under the condition of 0.6mm/min rainfall intensity, and the vegetation coverage is 18% and 30% respectively.

It can be seen clearly from figure 2:
(1) Under the condition of 0.6mm/min rainfall intensity, the higher the vegetation coverage is, the later the rainfall runoff begin. As you can see in figure 2, When accumulated rainfall reached 5mm, runoff was generated in the experimental plots with a vegetation coverage of 18%, but there didn't generate any runoff in the experimental plots with a vegetation coverage of 30%. This phenomenon shows that the infiltration process of rainfall is relatively longer in the experimental area with higher vegetation coverage than in the experimental area with lower vegetation coverage, and the increase of vegetation coverage is beneficial to the infiltration of rainfall.

(2) After the runoff begins, the runoff from different experimental plots with different vegetation coverage varies greatly. Under the same rainfall condition, the higher the vegetation coverage is, the less the runoff is. By calculation and analysis, the runoff output from the experimental plot with vegetation coverage of 18% was about 1.2 times as large as the runoff from the experimental plot with vegetation coverage of 30%. It shows that if the other boundary conditions are basically consistent, the vegetation coverage increases, thus the rainfall infiltration will increase correspondingly.

Under different rainfall conditions, the influence degree of vegetation coverage on runoff is different. The most obvious difference is the effect on the start time of the runoff. When the rainfall intensity reached 1.32mm/min, the runoff start time of the two experimental plots, whether the vegetation coverage was 11%, or the vegetation coverage was 53%, was basically the same. This can be seen clearly in figure 3.

As the rainfall process continues, the difference of runoff yield between two different vegetation coverage test plots is becoming more and more obvious. Moreover, the difference of runoff is more obvious than that under light rainfall intensity. When the accumulated precipitation is 15mm, the runoff from the experimental plot with vegetation coverage of 11% is about 2 times as large as the runoff from the experimental plot with vegetation coverage of 53%. There are still the characteristics of high vegetation coverage and relatively low yield.

3.2. Influence of vegetation coverage on infiltration depth

Soil moisture content in different depths was measured by soil moisture analyzer. Soil moisture content was measured every 5 minutes during the simulated rainfall experiment. In this paper, we analyzed the change of soil moisture's variation of the experimental plot with different vegetation coverage under the rainfall intensity of 1.45mm/min. Thus the soil moisture contents of different depths in the experimental plot with a vegetation coverage of 43% are shown in the figure 4, and the soil moisture contents of different depths in the experimental plot with a vegetation coverage of 61% are shown in the figure 5. The solid line and the dashed line respectively indicate the soil moisture content before
rainfall and the soil moisture content after rainfall in figure 4 and figure 5. The rainfall duration was 30 minute.

From the figure 4 and figure 5, it can be seen that the soil moisture content of the surface soil increases obviously after rainfall. The water content of soil surface increased from 18.9% to 22.3% in the experimental area with 43% vegetation coverage. However, in the experimental plot with 61% vegetation coverage, the soil moisture content increased greatly, from 21.2% to 34.7%.

The change of soil moisture content in different depths (in figure 4) shows that only the surface soil moisture content changes obviously after rainfall, and the soil moisture in the depth of 20cm is slightly increased. The curve of soil water content in Figure 5 shows that the soil moisture content increases from the surface to the ground 30cm depth after rainfall.

The results show that the vegetation coverage has a significant impact on the depth of rainfall infiltration. The rainfall infiltration is deeper in the experimental plot with high vegetation coverage than in the experimental plot with low vegetation coverage. In the more than 20 simulated rainfall experiments, the rainfall can only increase the soil moisture content within 40cm in the selected test area.

4. Conclusion and discussion

Artificial rainfall simulation method was adopted in this research. The characteristics of runoff yield, surface soil moisture content and vertical variation of soil moisture in the experimental plots with different vegetation coverage were analyzed, and the role of vegetation in rainfall runoff process was discussed. The main points of understanding are as follows:

1) Under different vegetation coverage conditions, the yield of experimental plot is different. The results of artificial rainfall simulation showed that the higher the vegetation coverage is, the smaller runoff of the plot is under the same rainfall condition.

2) According with the vertical variation characteristics of soil moisture, the influence of vegetation on rainfall infiltration depth is obvious, and the higher the vegetation coverage is, the greater the rainfall infiltration depth is. When the vegetation coverage is greater than 30%, the depth of rainfall influence can reach 30cm~40cm, while the vegetation coverage is less than 30%, the rainfall will only change the surface soil moisture content.

The influence of different vegetation coverage on rainfall-runoff process was analyzed by artificial rainfall simulation experiment. As we all known, the effects of plant root system and vegetation height on runoff yield can't be ignored, thus further studies are needed.
Acknowledgment

Innovation Scientists and Technicians Troop Construction Projects of Henan Province projects and Project of science and technology development fund of Yellow River Institute of Hydraulic Research (201707) projects provide financial support for the experiments. Let us take this opportunity to express, once again, our sincere thanks.

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