Analysis on the Effects of Grass Coverage on the Runoff-Sediment Relationship

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Abstract. The studies on erosion process of naturally restored grassland were not only very important for understanding of the effect of naturally restored measures on runoff and sediment reduction, but also necessary for analyzing the reasons of water and sediment dropped in Yellow River. This paper adopted simulating runoff scouring experiment in field runoff plot, studied the erosion process and relationship between runoff and sediment under different conditions. The results showed that: (1)Compared with the bare slope which shelved for 2 months, the runoff and sediment reduction benefits in naturally restored grassland was up to 88.0% and 99.9% separately, and the runoff and sediment reduction benefits in 1-year planted grassland were 47% and 97.6% separately; (2)For naturally restored grassland, there were an obvious effect on the runoff-sediment relationship. Compared to the bare slope and 1-year planted grassland, there were less runoff and sediment in naturally restored grassland, and the runoff-sediment relationship was significantly different; (3) For naturally restored grassland, that the infiltration rate significantly increased was an important reason why the runoff and sediment reduced.

Introduction

The analysis on the causes of water and sediment reduction of Yellow River is a research hotpot in recent years, and it’s also one of the Yellow River science and technology demand in the near future[1–3]. On aspect of the effect of the change of the underlying surface on the water and sediment, scholars have analyzed the impact of soil and water conservation ecological construction measures on water and sediment reduction in the basin scale, and pointed out that the water and soil conservation and ecological environment construction measures had a certain effect on reducing runoff and sediment[4–5]. Moreover, the improvement of vegetation coverage not only increases the ability of ecological water storage, but also has a certain effect on the relationship between runoff and sediment in the area[6–9]. Through the analysis of observation data from the experimental station, other scholars pointed out that for the slope scale, vegetation reduces sediment not only by reducing the water, but also by changing the water and sediment relations. At the same time, it was considered that the reduction of vegetation on the slope scale was greater than the sand reduction rate[10], which was different from other scholars on the function of the reduction of runoff[9, 11]. Therefore, the effect of vegetation on the relationship of water and sediment in the water and sediment of the slope is still to be further studied.

In this study, the role of water and sediment reduction by grass cover was further explored by the method of simulating runoff scouring experiment in field runoff plot. Which were good for enhancing awareness of the runoff and sediment reduction and the water storage capacity, providing reference for the analysis of the causes of Yellow River water and sand dropped.

Materials and Methods

Experimental Area. experiments were conducted in the field runoff plot of soil and water conservation monitoring station in Dalad Banner, Ordos Bureau for soil and water conservation, where is the transition zone from hilly and gully region on the northwest Loess Plateau to Kubuqi Desert, undulating terrain, serious wind erosion and desertification, the average annual precipitation 316mm, and rainfall concentrated in July, August and September; dry and windy spring, harsh climatic conditions. And the vegetation types are semi-arid grassland vegetation such as bunchgrass, rhizomatous grasses, weeds. The soil of text area is sandy soil, and local sandstone outcrop. The soil particle size distribution in the experimental area was shown in Table 1.

Table 1 The soil particle size distribution in the experimental area

Item	Gravel grain		Sand grains			Powder	Clay
Particle size (mm)	20～5	5～2	2～0.5	0.5～0.25	0.25～0.075	0.075～0.005	≤0.005
Percentage (%)	0.40	1.40	9.55	15.15	30.37	42.10	1.03

Model and Site Conditions**.** experiments were conducted in the standard runoff plot with the slope of 10 degrees, and the cell length is 20m and the width is 5m. In order to meet the needs of runoff scouring, the steady flow tank which were built with the brick upper the equipment to simulate the runoff scouring, and the width is the same as runoff plot. Under the overflow edges, spread the preservative film close to surface to ensure that the overland flow uniform and reduce initial runoff velocity. The simulation test system shown in Figure 1. In order to meet the need of comparative analysis, artificial grass and bare slope were used as the contrast cells. The land of two contrast cells were moldboard plowing and removed the weeds and their roots, and then carry on the compaction to make the soil bulk density close to the state of nature. Artificial grassland is simulated by sowing of alfalfa grass. 2 months after the two contrast cells were suspended, the average height of alfalfa was 10.5cm and the coverage was approximately 50%, tests was undertaken. The site types and grass cover of the experimental plot are shown in Table 2.

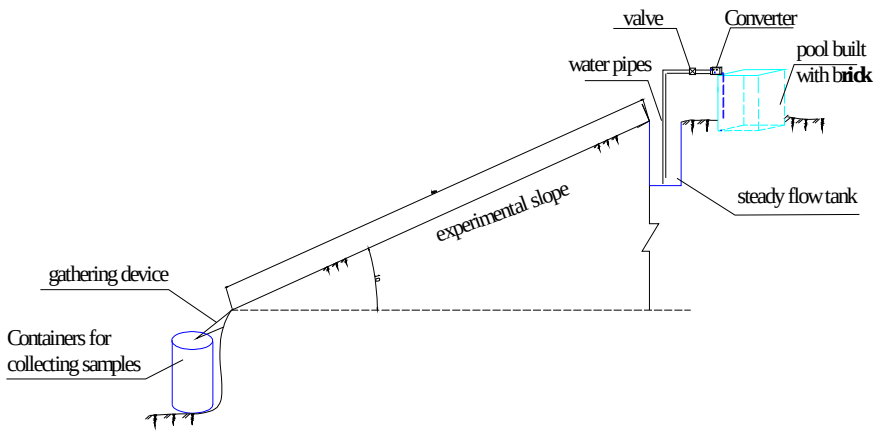

Figure 1 Experimental simulation system

According to rainfall data from 1992 to 2004 in Ordos City, the frequency of the regional daily rainfall less than 10mm in the test area was highest, the frequency of the regional daily rainfall between 10mm and 24.9mm was lower, and the frequency of the regional daily rainfall between 25mm and 49.9mm was lowest. According to the characteristics of local rainfall duration and the need of rainfall runoff generation, the local rainfall duration and soil characteristics are considered. The water inflow rates was 5.7m^3/h, the corresponding rainfall was 42.7mm, and the test duration was 40min after runoff producing, which is determined by the simulation test of heavy rainfall and runoff formation in excess of storage. Runoff and sediment samples were taken every 2min by the large buckets.

Table 2 The basic site conditions of experimental

The Site Types	Description of the grass cover of standard plot
Bare Slope	moldboard plowing and removed the weeds and their roots, and then carry on the compaction. The weed coverage rate of the test land was about 5%.
Artificial Grassland	Artificial cultivation of alfalfa. The growth period of alfalfa was about 2 months, the alfalfa height was about 10.5cm, the root length was about 11.8cm. And the highest was 19cm, and the longest was 24cm.
Ecological Restoration Grassland	Eight years after land abandonment, the grass species of slope was Gramineae weeds mainly. Its covering structure included stems and leaves, surface dry branches and leaves, topsoil flaky crust. And the species and the coverage of the surface of the earth was patchy

Results and discussion

Reduction of the process of runoff and sediment by grass cover. Under the same experimental conditions, the cumulative runoff and sediment yield process reflected the effect of runoff and sediment reduction by the slope measures. From the statistical data of a single screening, under the condition of 5.7m^3/h runoff scouring, the cumulative runoff of bare slope, artificial grassland and ecological restoration grassland were 3.82m^3, 2.05m^3, 0.46m^3, and the cumulative sediment yield was 336898g, 7975g, 60g respectively. The cumulative runoff and cumulative sediment yield of ecological restoration grassland was 12.0% and 0.02% of bare slope respectively, the cumulative runoff and cumulative sediment yield of artificial grassland was 53.6% and 2.4% of bare slope respectively. The reduction rates of the runoff and sediment yield by natural restoration grassland were 88% and 99.9%, and the reduction rates of the runoff and sediment yield by artificial grass were 46.4% and 97.6%. Therefore, the reduction rates of the runoff and sediment yield by natural restoration grassland were significantly higher than that of artificial grass slope.

After further fitting analysis, it is found that the cumulative runoff yield and sediment yield were correlated well with the duration of runoff generation. The cumulative runoff and sediment yield increased with the increasing runoff generation. The cumulative runoff (y) and duration (x) showed linear correlation (y=ax+b，a and b are coefficients). And the cumulative sediment yield (y) and duration (x) showed power function correlation (y=ax+b，a and b are coefficients).

In the fitting formula, the coefficients “a” reflected the increasing trend of cumulative process with the duration. The three kinds of slope site types were, from small to large, natural restoration grassland, artificial grassland and bare slope respectively. The analysis illustrated that the trend of cumulative runoff and sediment yield process of bare slope was the most obvious, followed by the artificial grassland and the natural restoration grassland. The results also showed that under the condition of same runoff erosion, the storage capacity of naturally restored grassland was the strongest, and the effect on runoff and sediment reduction was the most obvious.

Table 3 The relationship between Cumulative Runoff or Cumulative Sediment and time（5.7 m^3 / h）

Fitting Relationship	Site type of the slope	Fitting Formula	R^2	Sample Number
Relationship Between Cumulative Runoff and Runoff Duration	Bare Slope	y=99.052x-100.74	0.9996	20
	Artificial Grassland	y=52.241x+4.318 1	0.9984	20
	Ecological Restoration Grassland	y=12.555x-45.623	0.9965	20
Relationship Between Cumulative Sediment and Runoff Duration	Bare Slope	$y=28158x^{0.7152}$	0.9441	20
	Artificial Grassland	$y=2736.1x^{0.3127}$	0.8787	20
	Ecological Restoration Grassland	$y=4.567x^{0.678}$	0.9671	20

Effects of grass cover on the collocation relationship of runoff and sediment. The collocation relationship between runoff and sediment means that the proportional relationship between runoff and sediment yield in the samples. The collocation relationship between runoff and sediment in the area of bare slope, artificial grassland and naturally restored grassland was showed in Fig 2. As seen in Fig 2,

the runoff and sediment yield of the naturally restored grassland was least, and the distance of the data points from the origin of vertical and horizontal coordinates was the closest; the runoff and sediment yield of the bare slope was biggest, and the distance of the data points from the origin of vertical and horizontal coordinates was the furthest; other sata points in between belonged to the artificial grassland. And the data points of 3 site types were not disturbed.

By further fitting the curve of water and sediment relationship, we can see that, the correlation between the relationship of runoff and sediment of naturally restored grassland was lowest because the sediment concentration in the runoff was stable changed slightly. The relations of runoff and sediment yield of bare slope can be described by obvious exponential functions ($y=0.908e^{0.0482x}$, y is the sediment yield, x is the runoff), the correlation was higher ($R^2=0.657$) , illustrated that the sediment yield increases with the increasing runoff. The relations of runoff and sediment yield of artificial grassland also can be described by exponential functions ($y=0.0636e^{0.075x}$, y is the sediment yield, x is the runoff), but it's correlation was significantly lower than the bare slope ($R^2=0.488$). The coefficients in two fitting formulas can be seen that the runoff and sediment yield of artificial grassland was increased with the increasing flow rate of the plot, but the trend was not obvious. This phenomenon showed that the existence of grass has a significant regulatory effect on runoff and sediment yield.

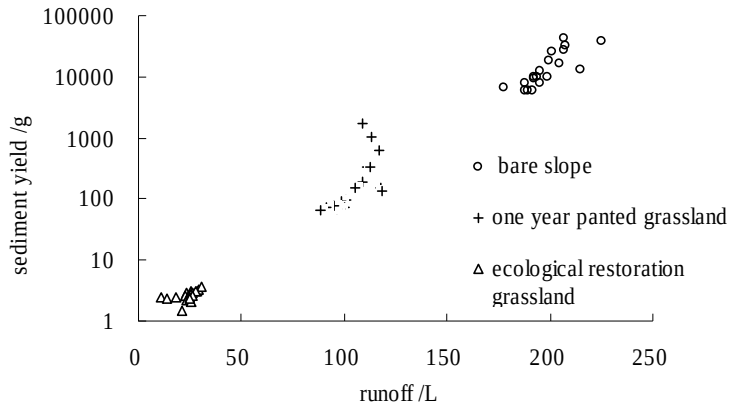

Fig.2 Relationship between runoff and sediment yield under different conditions

Effects of grass cover on soil infiltration capacity. The infiltration capacity of soil directly influenced the runoff process, and it's significantly affected by the grass. In this paper, the ratio of the infiltration quantity to the total amount of flow is defined as runoff infiltration rate.

According to statistical analysis, the infiltration rate of the naturally restored grassland, artificial grassland and bare slope was 90.1%, 49.1% and 3.4% respectively. The structures of surfaces and covers of naturally restored grassland was complex. And the effect of runoff and sediment reduction by the leaf litter near surface and the roots of perennial grasses was more obvious than the effect by the 1-year planted grass whose structure was rather single, which had significant effects of runoff and sediment reduction.

Conclusions

Naturally restored grass have a significant effect on the runoff and sediment yield reduction. Under the same experimental conditions, compared with bare slope, the reduction rates of the runoff and sediment yield by natural restoration grassland were 88% and 99.9%, and the reduction rates of the runoff and sediment yield by artificial grass were 46.4% and 97.6%.

The characteristics of runoff and sediment in 3 different site types were different. In particular, there was less runoff and sediment on the slope of naturally restored grassland, and the change trend of runoff and sediment on the slope was not obvious with the scouring duration.

Under the same experimental conditions, the main factors that affect the runoff process are soil infiltration rate. Soil infiltration rate was significantly increased by grass, especially by the presence

of naturally restored grass. Under the condition of same scouring experiment, the infiltration rate of the naturally restored grassland, artificial grassland and bare slope was 90.1%, 49.1% and 3.4% respectively.

The large scale implementation of ecological restoration measures avoided adverse effects of human activities on the underlying surface. In the natural restoration process, the surface coverage structure and the soil permeability are good, and the water storage capacity and soil anti-erosion capability were significantly improved. These all are important reasons for the decrease of water and sand under the certain rainfall conditions.

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