Effect of vegetation construction on runoff and sediment yield and runoff erosion ability on slope surface

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Abstract. Land consolidation measures affected the underlying surface erosion environment during the early stage of vegetation construction, and then had an impact on rainfall infiltration, erosion and sediment yield. This paper adopted the field simulated rainfall experiments to analyze the function that pockets site preparation measures affected on rainfall infiltration, runoff sediment yield and runoff erosion ability. The results showed that，the measures can delay the rainfall runoff formation time of the slope by 3'17" and 1'04" respectively，Compared with the same condition of the bare land and natural grassland，The rainfall infiltration coefficient each increased by 76.47% and 14.49%, and infiltration rate increased by 0.26 mm/min and 0.11mm/min respectively; The amount of runoff and sediment yield were reduced because of the pockets site preparation，The amount of runoff reducing rate were 33.51% and 30.49%, and sediment reduction rate were 81.35% and 65.66%, The sediment concentration was decreased by 71.99% and 50.58%; Runoff velocity of bare slope and natural grassland slope decreased by 38.12% and 34.59% respectively after pockets site preparation . The runoff erosion rate decreased by 67.92% and 79.68% respectively. The results will have a great significance for recognizing the effect of water and sediment reduction about vegetation and the existence of its plowing measures at the early period of restoration.

1 Introduction

The site vegetation cover was greatly improved by forest and grass vegetation constructions since 2000a. It was well known that various vegetation measures played an important role in promoting rainfall infiltration, delaying runoff and reducing erosion [1-6]；Furthermore, it also had a certain effect to adjust the peak and bottom of the runoff and sediment yield process curve ， which indicated that vegetation measures were one of the reasons for the phenomenon of sharply decrease in runoff and sediment production in recent years [7-10].But little attention has been taken to the effect of site preparation measures which existing in vegetation land on rainfall infiltration and runoff - sediment production. Pockets site preparation was an important and easy method for vegetation plantation and restoration，and it also played an important role in the soil erosion environment，So，It was great significance to study the influence which pockets site preparation affected on rainfall infiltration and runoff dynamics parameters. The study will have a great significance for exploring the causes of water and sediment reduction.

2 Materials and Methods

2.1 Site conditions

The research area was located at the slopes that belongs to LuoYuGou small watershed in Tianshui city. And some plots were built on the slope with 10 miles long and 2 miles wide，Study area distributed low liquid limit clay with hard texture. And covered with natural vegetation，The main species of vegetation were *Coronilla varia* and *Juncus effusus*, The plots site conditions were listed in Figure 1-2 and Table 1.

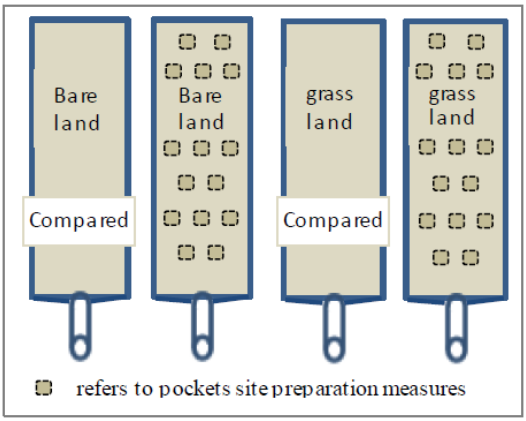

Fig. 1. Site conditions schematic diagram

The planting pockets site preparation diameter × depth was about 30cm × 30cm. And distribution of staggered on the slope. Each plot had 70 planting holes, all pockets site preparation area is about 4.95m2, accounting for 24.75% of the total area of the plot. The

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original soil was dense, soil covered the planting pocket was soft. Amorpha fruticosa seedlings were planted about 5mm roots diameter, and cutted seedlings above ground surface, When experimenting, Amorpha fruticosa seedlings began to germinate and with the length of about 10-15cm only, In this article the role of Amorpha fruticosa plants was negligible.

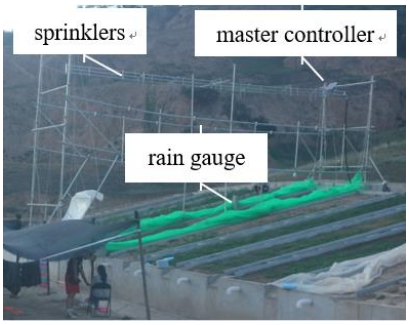

Fig. 2. Experimental plots photograph

Table 1. Experimental plots basic site conditions

site conditions	Preparation methods	water content (%)	Rainfall intensity（mm/h）	pockets site preparation
Bare land	the surface grass were cutted off，no grass cover.	11.0	93.5	Compared
	the surface grass were cutted off，planted *Amorpha fruticosa L.* and distributed with triangle shape	15.8	100.9	Yes
Natural grassland	Cover with Coronilla varia and Juncus effusus , no treatment.	17	104.4	Compared
	Cover with Coronilla varia and Juncus effusus , planted *Amorpha fruticosa L.* and distributed with triangle shape	17.5	104.6	Yes

2.2 Simulated rainfall

QYJY-501 artificial rainfall system equipment was used to simulate rainfall, The portable device consists of master controller, water pump, rain shower, rain gauge and data download analysis software. There are five groups of rainfall sprinklers, each with three different aperture sprinklers, sprinklers can be used alone or in combination, to choice the different aperture sprinklers and pressure to achieve different rainfall intensity. And real-time online adjust the rainfall intensity through rainfall gauge data, and ensured the simulated rainfall was more than 80% similar to natural rainfall in rainfall intensity, drop velocity, and droplet size.

When start simulate rainfall and record the start time，and simulate rainfall lasted for one hour after the runoff occurred. During the experiment, observed runoff velocity and collected muddy sand samples.

3 Results and analysis

3.1. Pockets site preparation impacted on infiltration and runoff - sediment production

The calculation of rainfall infiltration rate was divided into two stages. Before runoff occurred, the rainfall infiltration rate was equal to the rainfall intensity. And after runoff generated, the infiltration rate was calculated according to the difference between rainfall and runoff [11]. runoff and sediment yield both were estimated based on the collected muddy water samples, Various types of runoff and sediment parameters were shown in Table 2.

The later runoff occurred indicated that the infiltration capacity of slope is stronger. Compared with the plots without pockets site preparation, The time of runoff occurred on that of slope with pockets site preparation was more later obviously， and rainfall infiltration rate was more higher too， The Runoff volume was significantly lower than that of the comparative slope without the pockets site preparation.

For the bare land, the time of runoff occurred was delayed from 1'38" (under rainfall intensity of 93.50mm/h) to 4'55" after conducted pockets site preparation. The infiltration coefficient increased from 0.34 to 0.60, with increments of 76.47%, and the infiltration rate increased from 0.31mm/min to 0.57mm/min. After the pockets site preparation, the infiltration rate increased by 0.26mm/min, resulted the total runoff volume decreasing from 1290.11L to 857.77L， Reduced by 33.51% .For the natural grassland, pockets site preparation measures can delay the time of runoff occurred from 2'24" to 5'19"，and it can increase the infiltration coefficient from 0.69 to 0.79, with increments of 14.49%, and increase the infiltration rate 0.66 mm/min to 0.76 mm/min, which increased by0.105 mm/min. Eventually, The measures of pockets site preparation can lead the total runoff volume decreasing from 714.74 L to 496.81 L , Reduced by 30.49% under natural grassland conditions. It can be seen that pockets site preparation measures can reduction runoff and sediment production obviously. This phenomenon can be clearly seen in Figure 3 and Figure 4 too.

About reducing sediment, pockets site preparation measures can cut down sediment reduction 81.35% and 65.66% corresponding to bare land and natural grassland, and sediment content reduced by 71.99% and 50.58% respectively.

Table 2. Comparison of runoff and sediment parameters

Item		Bare land		Natural grassland	
		No	Yes	No	Yes
Runoff generate	Observation(s)	1'38"	4'55"	2'24"	5'19"
	Prolongation(s)	/	3'17"	/	1'04"
Infiltration coefficient	calculation	0.34	0.6	0.69	0.79
	increased percentage	/	76.47	/	14.49
Infiltration rate	Calculation (mm/min)	0.31	0.57	0.66	0.76
	Increased infiltration rate (mm/min)	/	0.261	/	0.105
Runoff volume	Runoff total(L)	1290.11	857.77	714.74	496.81
	reduction rate(%)	/	33.51	/	30.49
Sediment quality	Sediment yield(kg)	28.69	5.35	9.29	3.19
	Sediment reduction rate/%	/	81.35	/	65.66
Sediment content	Calculation (kg/m^3)	22.24	6.23	12.99	6.42
	Reduced percentage (%)	/	71.99	/	50.58

Notes: "Yes"refers to"pockets site preparation"
"No"refers to "compared"

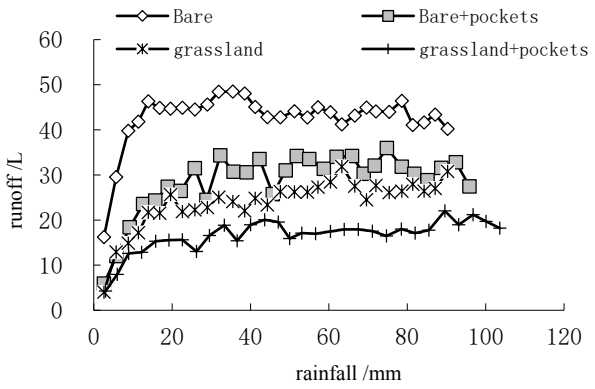

Fig. 3. Runoff process under simulate rainfall

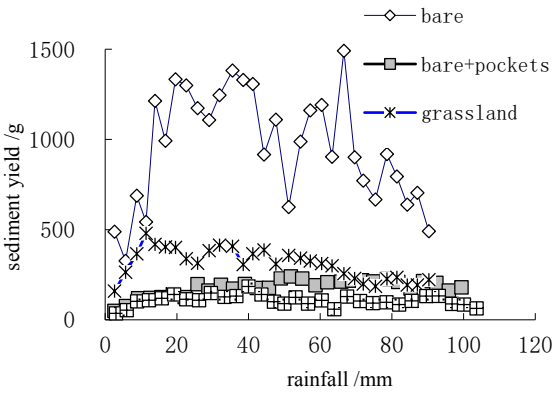

Fig.4. Sediment process under simulate rainfall

3.2 Influence of pockets site preparation affected on runoff erosion ability

Runoff velocity and soil detachment rate were used to indicate the strength of runoff erosion. Soil detachment rate [12] was that the quantity of runoff soil denuded and removed within a unit runoff area and a unit time. Runoff erosion ability parameters were calculated and shown in Table 3.

Table 3. Comparison of runoff erosion ability parameters

Item		Bare land		Natural grassland	
		No	Yes	No	Yes
Velocity	Observation (m/s)	0.27	0.17	0.24	0.16
	reduction rate (%)	/	-38.12	/	-34.59
Soil detachment rate	Observation (g/(s·m^2))	1.51	0.48	1.87	0.38
	reduction rate (%)	/	-67.92	/	-79.68

Notes: "Yes"refers to"pockets site preparation"
"No"refers to "compared"

Compared with the plots without pockets site preparation, the runoff velocity and soil detachment rate were all decreased after conducted pockets site preparation. For bare land the runoff velocity decreased from 0.27m/s to 0.17m/s, declined by 38.12%. And for natural grassland the runoff velocity decreased from 0.24m/s to 0.16m/s, declined by 34.59%. The influences of pockets site preparation measures affected on runoff velocity was evident in Figure 5. Under the similar conditions, the pockets site preparation measures reduced the runoff velocity throughout the experiment process.

For bare slope the soil detachment rate decreased from 1.51 g/(s·m²) to 0.48 g/(s·m²), declined by 67.92%. And for natural grassland the runoff velocity decreased from1.87 g/(s·m²) to 0.38 g/(s·m²), declined by 79.68%. It can be seen that the dynamic parameters of runoff erosion were obviously weakened after implementing pockets site preparation. and Figure 6 also intuitively reflected the difference of soil detachment rate under different site conditions.

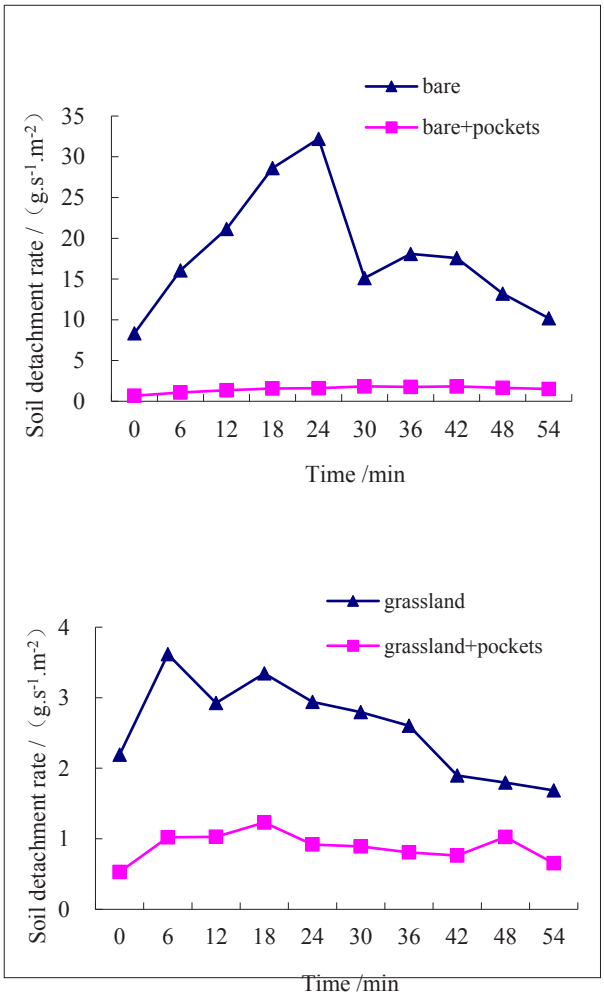

Fig.5. Runoff velocity process under different site conditions

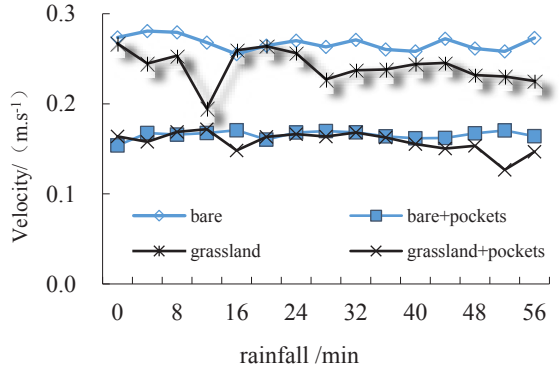

Fig.6. The difference of soil detachment rate under different site conditions

4 Conclusion and discussion

Based on the pockets site preparation plots and compared plots rainfall simulation experiment, some conclusions were made as follows:

(1) The pockets site preparation measures can delay the time of runoff generate on slope surface and increase the rainfall infiltration coefficient and infiltration rate; Reduce the runoff and sediment yield, Reduce the runoff sediment concentration.

(2) The pockets site preparation measures can significantly reduce the power of runoff erosion，and then reduces the sediment yield and runoff sediment concentration.

In the process of vegetation construction and restoration succession, the site preparation measures and the vegetation growth period all have certain impacts on the site conditions and the soil erosion environment in the initial stage of construction. As the vegetation grows， The impact of site preparation measures on the erosion environment will be weakened with the growth of vegetation and the extension of time，And then the adjustment of vegetation on runoff and sediment will be gradually highlighting with the extension of vegetation restoration period. It have great significance to study the both factors affected on soil erosion environment and the weakened or enhanced roles each other， More further researches must be taken for scientifically recognizing the impact of vegetation factors on water and sediment characteristics.

Acknowledgements

Foundation item： Under the auspices of National Science Foundation of China(No.41701326),Innovation Scientists and Technicians Troop Construction Projects of Henan Province(No.162101510004),Key Laboratory of Loess Plateau Soil Erosion and Water Loss Process and Control,MWR（201601）.

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