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RESEARCH

Effect of Rainfall Regime and Slope on Runoff in a Gullied Loess Region on the Loess Plateau in China

H. Y. Fang · Q. G. Cai · H. Chen · Q. Y. Li

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Abstract Runoff was measured from seven plots with different slopes nested in Tuanshangou catchment on the Loess Plateau to study effect of slopes on runoff in relation to rainfall regimes. Based on nine years of field observation and K-mean clusters, 84 rainfall events were grouped into three rainfall regimes. Rainfall regime A is the group of events with strong rainfall intensity, high frequency, and short duration. Rainfall regime C consists of events with low intensity, long duration, and infrequent occurrence. Rainfall regime B is the aggregation of events of medium intensity and medium duration, and less frequent occurrence. The following results were found: (1) Different from traditional studies, runoff coefficient neither decreased nor increased, but presented peak value on the slope surfaces; (2) For individual plot, runoff coefficients induced by rainfall regime A were the highest, and those induced by rainfall regime C were the lowest; Downslope, the runoff coefficients induced by three rainfall regimes presented the same changing trend, although the peak value induced by regime A occurred on a shorter slope length compared to those by regime B and C; (3) Scale effect on runoff induced by rainfall regime A was the least, and that induced by rainfall regime C was the largest. These results can be explained by the interactions of crusting, soil moisture content, slope length and gradient, and erosion units, etc., in the context of different rainfall regimes.

Keywords Gullied loess region · Loess Plateau · Scale effect · Rainfall regime · Runoff coefficient · Slope length · Slope gradient

Introduction

Runoff is one of the critical factors controlling rill erosion and gully development. Concentrated flow erosion occurs where flow erosion energy is large enough. In semi-arid and semi-humid regions, once rainfall intensity exceeds infiltration capacity, Hortonian flow occurs (van de Giesen and others 2000). However, the overland flow yield is nonuniform, and not all the water produced on the soil surface can reach the bottom of the hillslope and/or outlet of the catchment. Thus, downslope, the reduction of runoff occurs, resulting from variability in surface condition, soil surface crusting, vegetation, surface roughness, and dynamics of rainfall intensity and infiltration capacity, etc. (Wei and others 2007), among which slope, including its length and gradient, is an important issue causing this scale effect. A clear reduction was found in runoff per unit slope length as slope length was increased, and this effect became more pronounced with decreasing storm duration (Stomph and others 2002; van de Giesen and others 2000; van de Giesen and others 2005; Esteves and Lapetite 2003; Joel and others 2002). For most rainfall events, the time and volume of rainfall per unit area required before runoff

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started were larger in large plots than in small plots (Joel and others 2002). The reduction in runoff was also observed elsewhere, such as in Nigeria (Lal 1983; Lal 1997a,b), Burundi (El-Hassanin and others 1993), and Israel (Yair and Lavee 1985). As for slope gradient, an increased slope angle generally gives a higher potential for runoff. However, the results from field studies describing the effect of slope angle on runoff are contradictory (Fox and others 1997; Chaplot and Le Bissonais 2000); in some cases, the runoff increases (Sharman and others 1983); in others, it decreases (Poesen 1984) or is not significantly different (Mah and others 1992) as slope gradient increases. These discrepancies can be explained by the variability in experimental conditions (Fox and others 1997). For individual storms, runoff from similar plots is always similar. However, the measured runoff percentages and the scale effect differ enormously from one storm to the next. Therefore, the rainfall characteristic is another unneglected variable causing scale effect of runoff (van de Giesen and others 2005; Wei and others 2007). Studies found that higher rainfall intensity can reduce the spatial variability (Hawkins 1982; Dunne and others 1991; Esteves and Lapetite 2003). Van de Giesen and others (2005) pointed out that short and intensive rainstorms, coupled with high infiltration rates, give the most significant scale effect. In a laboratory experiment, Stomph and others (2002) found that scale effect decreases with rainfall duration in the context of constant rainfall intensity.

Deeply and densely dissected hilly, gullied areas with steep slopes characterize the gullied loess region on the Loess Plateau. Though progressive achievements have been conducted (given above), few works were done for the scale effect of runoff in the gullied loess region on the Loess Plateau, where soil erosion is among the severest in the world. In order to investigate the scale effect on runoff in this region, seven runoff plots on a catchment flank were selected to study scale effect of runoff on slopes.

Materials and Methods

Site Description

The study was conducted at the Tuanshangou experimental site in a gullied loess region on the Loess Plateau (Fig. 1), located 109° 47′ E and 37° 31′ N, at altitudes comprising between 950 and 1070 m a.s.l. The climate is semi-arid with mean annual rainfall of 450 mm, around 70% of which is concentrated from July to September, usually falling as hard intensity and short duration rainstorms with the maximum recorded rainfall intensity 3.5 mm min^{-1}. For deep loessial soil and strong rainfall intensity, vertical erosion units occur resulting from severer and severer erosion energy of the water flow (Wang and others 1982) (Fig. 2). The potential annual transpiration, however, can reach 1228 mm. The mean annual air temperature is 8° C varying from −27° C to 38° C during the year period 1959–1969. Local soil develops from wind-accumulated loess parent material belonging to calcic Cambisol (FAO-UNESCO 1974); the silt-sized soil texture with less organic matter leads to its easy erodibility and crusting (Liu and others 2001) (Table 1).

To collect data for study of erosion and sediment yield on different slope surfaces in Tuanshangou catchment, a total of 12 nested runoff plots, varying in size from 30 to 17,200 m^2 with different slope lengths and gradients, were built by the Yellow River Water Conservancy Commission in 1959 and closed in 1969; eleven years (1959–1969) of data were available (Fig. 1). However, for data integrity and representative of the plot, only nine years of the data (1961–1969) and seven runoff plots were selected to study runoff on slopes in the present study (Table 2). They were located on different landform units on a shady slope from hilltop to slope bottom, such as *Entire* slope (covering the whole hillslope, e.g., No. 7 runoff plot), *hilltop* (on the summit of an entire slope, e.g., No. 1 runoff plot), *Mao* slope (the upper part of an entire slope, e.g., Nos. 2–5 runoff plots), and *Gully* slope (the lower part of an entire hillslope, e.g., No. 6 runoff plot) (Fig. 1). Although there were no repetitions for the selected plots, 84 rainfall-runoff events occurred on them during the nine years of measurements; therefore, the accuracy of the study is reliable.

The runoff plots were cultivated during the study period, and the main crops included forxtail millet (*Setaria italica*), mung bean (*Phaseolus aureus*), potato (*Solanum turberosum*), Sorghum (*Andropogon sorghum*), and purple alfalfa (*Medicago sativa*). The difference of vegetation cover was not large, so their influence on runoff was neglected (Xu 2004).

Data Collection

Rainfalls during the rainy seasons were measured by self-recording hyetograph and/or common hyetograph with 20 cm in diameter beside the study plots (Fig. 1). The depth, duration, and intensity of each rainfall event were monitored, and a total of 84 rainfall-runoff events were recorded during the year period of 1961–1969.

The 20-cm-high boundary of the plots was built using bricks with cement to prevent surface water from running onto the plots. A weir, leveling with the natural surface, was installed at the bottom of each plot and connected to a collecting tank with a dividing ruler graduated in mm on its inner wall; runoff from the plot flowed out of the weir, and filled the tank. The total runoff from each plot was obtained after each rainfall-runoff event by reading the dividing ruler. Runoff depth was obtained through dividing the

Fig. 1 Location of the study runoff plots

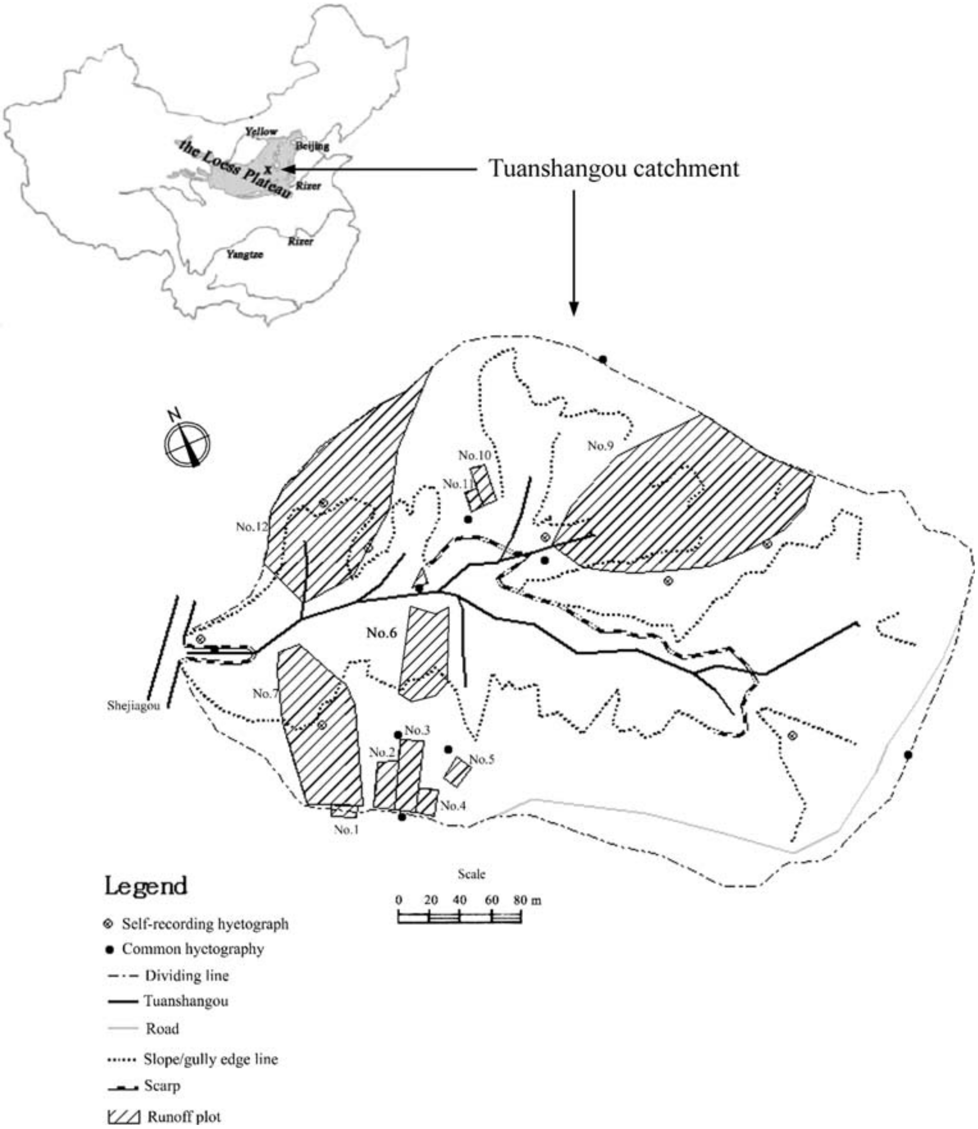

Fig. 2 Vertical erosion geomorphic units resulting from severer and severer soil erosion fashions from hilltop to slope bottom

Table 1 Soil properties of the soils in the study area

Location	Sand (%)	Silt (%)	Clay (%)	ESP (%)	Organic matter
Tuanshangou	46.1	48.7	5.2	–	0.47

From Liu and others (2001)

event volume of runoff by the plot area, and the rainfall-runoff ratio, i.e., runoff coefficient, was calculated by runoff depth divided by rainfall depth. All data have been printed and issued by the Yellow River Water Conservancy Commission for internal use.

Samples for moisture measurements were taken from drilled soil cores on the No. 1 and 2 runoff plots in 1963, 60 cm deep from slope surface at an interval of 20 cm thickness in profiles. From May 16 to November 1 in 1963, samples were conducted 45 times; the sampling interval

Table 2 Characteristics of the study runoff plots

Plot	Location	Slope shape	Gradient ‰	Dimension			Main erosion form
				Length m	Width m	Area m^2	
No. 1	Hilltop	Straight	158	20	7.5	150	Splash
No. 2	*Mao* slope (U)	Straight	404	40	15	600	Sheet/interrill
No. 3	*Mao* slope (M)	Straight	404	60	15	900	Sheet/interrill + rill
No. 4	*Mao* slope (U)	Straight	404	20	15	300	Sheet/interrill
No. 5	*Mao* slope (U)	Straight	601	20	15	300	Sheet/interrill
No. 6	*Gully* slope	Straight	827			1160	Rill
No. 7	Mao + Gully	Natural	445, 1730, 344			4080	Sheet/interrill + rill

"U" represents upper part; "M" represents the middle part; the dimensions of the plots are projected

depended on the rainfall frequency. The topsoil layers were three replicates (total of 45 × 3 samples), and each of the other soil layers were two replicates (for the 20–40 cm and 40–60 cm soil layers, each 45 × 2 samples). Then the samples were transported to the laboratory, and the soil moisture content was obtained by subtracted weight of water at 105° C for 24 h from that of fresh soil.

Statistical Analysis

In order to study the effect of rainfall regime on runoff, K-means clustering method was used to group rainfall events based on their similarities. To determine the number of clusters in the data set, numerous criteria were proposed (Perruchet 1983). In our study, attempts were made until the most suitable clusters appeared (Wei and others 2007). Normally, the classification must meet the ANOVA criterion of significant level ($p < 0.05$).

Pearson correlation was performed to assess the relationship between the rainfall eigenvalues and runoff coefficient, and the statistical analysis of the data was carried out assuming a probability level approximately equal to 0.01.

Results

Rainfall Regimes

Using K-means clustering, the 84 rainfall events during the period of measurement were divided into three rainfall regimes of A, B, and C based upon rainfall eigenvalues rainfall depth, duration and maximum 30-minute rainfall intensity (I_{30}) (Table 3). Rainfall regime A occurred 52 times, and had the largest occurring frequency, occupying 61.9% of the totaled events with a total of 820 mm rainfall; rainfall regime B occurred 20 times, and the occurring frequency occupied 23.8% of the total, with a total of 467 mm rainfall; rainfall regime C, however, occurred only 12 times. In accordance with the occurring frequency, rainfall regime A had the largest I_{30} of 0.54 mm min^{-1}, and the I_{30} for rainfall regime C the lowest 0.16 mm min^{-1}. Inversely, rainfall regime C had the largest mean rainfall depth and duration, followed by rainfall regime B and rainfall regime A. Mean rainfall eigenvalues represent the general characteristics of rainfall events. Thus, rainfall regime A is the group of events with strong rainfall intensity, high frequency, and short duration. Rainfall

Table 3 Statistical features of the rainfall regimes in the study area

Rainfall regime	Eigenvalue	Mean	Standard deviation	Variation of coefficient	Sum	Frequency (times)
A	P (mm)	15.77	11.91	0.76	820.00	52
	D (min)	138.12	95.48	0.69	7182.00	
	I_{30} (mm min^{-1})	0.54	0.52	1.70	27.91	
B	P (mm)	23.35	15.89	0.68	467.00	20
	D (min)	596.80	135.40	0.23	11,936.00	
	I_{30} (mm min^{-1})	0.26	0.15	0.58	5.26	
C	P (mm)	23.42	15.56	3.47	281.00	12
	D (min)	1169.25	162.23	3.46	14,031.00	
	I_{30} (mm min^{-1})	0.16	0.06	0.3	1.87	

P, D, and I_{30} represent rainfall depth, duration, and maximum 30-min intensity, respectively regime C consists of events with low rainfall intensity, long duration, and infrequent occurrence. Rainfall regime B, however, is composed of rainfall events that have moderate rainfall eigenvalues, i.e., higher rainfall intensity and shorter duration than rainfall regime C, but lower rainfall intensity and longer duration than rainfall regime A.

Runoff Coefficient on the Slopes

Event runoff-rainfall ratio, i.e., runoff coefficient, comprehensively reflects the influences of rainfall characteristics, antecedent rainfall, and land surface conditions, and is a good indicator of the capacity of runoff generation (Xu 2004). All the plots were adjacent, and the rainfall characteristics were regarded as the same with each other. However, due to the differences of the slopes and their locations, the runoff coefficients experienced a high degree of variability (Fig. 3). With increasing slope length for Nos. 2–4 and No. 7 runoff plots, runoff coefficients presented a peak value on the No. 2 runoff plot. Runoff coefficients at different locations differed. The coefficient for No. 1 runoff plot, located on hilltop, was lower than those of the Nos. 2–5 runoff plots located on *Mao* slope, and higher than that of No. 6 runoff plot on *gully* slope, which was the lowest one for the runoff plots. While the difference of runoff coefficients for the No. 4 and No. 5 plots, both located on *Mao* slope zones, was not large.

Runoff Coefficient with Rainfall Regime

Rainfall characteristics are the driving force for runoff generation, and different rainfall regimes could result in different runoff generation capacities for individual plot. Figure 4 shows that runoff coefficient induced by rainfall regime A was the highest, and that by regime C was the lowest. The runoff coefficients by regime A were 2 to 9 times of those by regime B, and 3 to 19 times that of those by regime C. Noticeably, in despite of rainfall regimes, downslope, the runoff coefficients presented the same changing trend for the plots, indicating the controlling role of the erosion units. In addition, the peak values of runoff coefficients by regimes A, B, and C appeared on different slope lengths: the highest runoff coefficient induced by rainfall regime A occurred on the 40-m-long slope surface (i.e., No. 2 runoff plot), while the highest runoff coefficients by rainfall regimes B and C on the 60-m-long slope surface (i.e., No. 3 runoff plots).

To investigate scale effect of runoff induced by different rainfall regimes, runoff coefficient on No. 1 runoff plot was

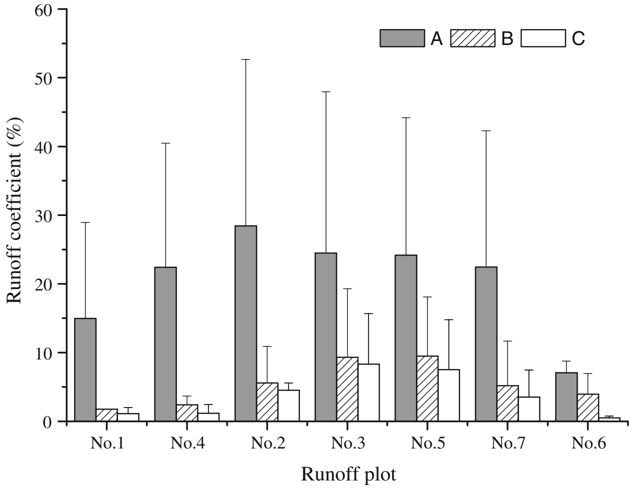

Fig. 4 Changes of the rainfall coefficients with different slopes induced by three types of rainfall regimes: A, B, and C

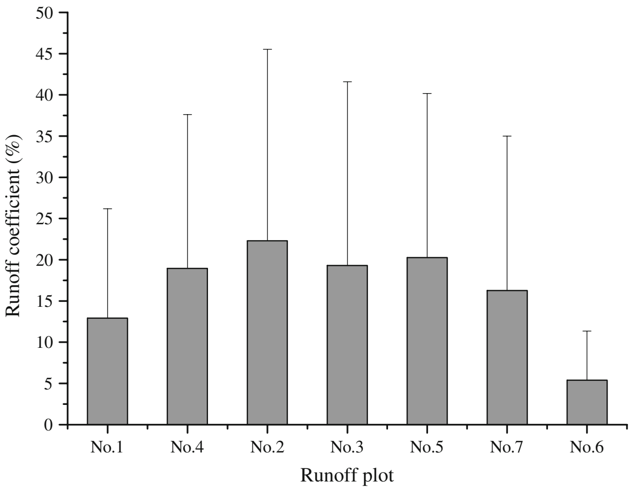

Fig. 3 Changes of the runoff coefficients with different slopes for the study plots

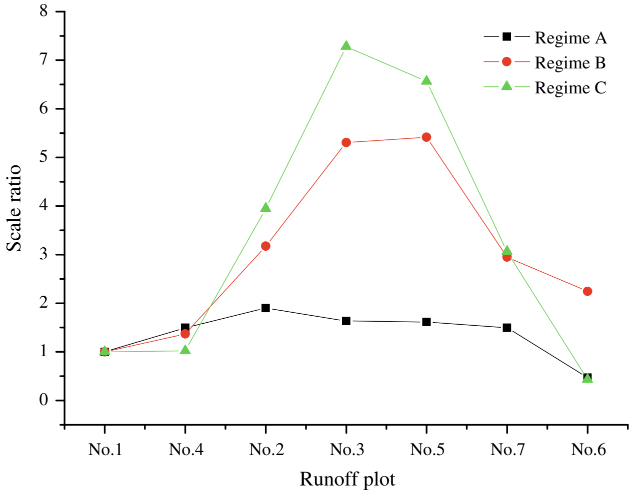

Fig. 5 Scale effects of runoff induced by different rainfall regimes on different slopes

regarded as unit, and scale ratio on the other plots was calculated as the runoff coefficient divided by that of No. 1 runoff plot. Figure 5 demonstrates that scale effect of runoff coefficient induced by rainfall regime C was the highest with the largest scale ratio 7.3, and rainfall regime A the lowest, the largest scale ratio of which was only 3.95. In accordance with the changing trends of runoff coefficients depicted in Figs. 2 and 3, the scale effects induced by the rainfall regimes also presented peak values on the slope surfaces.

Discussion

Effect of Crusting

Crusting is a common phenomenon on the Loess Plateau (Luk and others 1989; Luk and Cai 1990; Cai and others 1998; Wu and Fan 2002). Studies found the silt-sized loess soils with low organic matter content (Table 1) in the study area are highly susceptible to crusting (Cai and others 1986; Luk and others 1989; Bouza and others 1993). After a rainfall, especially for the high-intensity one, soil surface crusts form (Fig. 6a), which could reduce infiltration rate (De Roo and Riezebos 1992; Peugeot and others 1997; Vandervaere and others 1997; Esteves and Lapetite 2003). The presence of only 0.1 mm of a thick crust may reduce the infiltration rate from 800 cm day^{-1} to 70 cm day^{-1} (McIntyre 1958). Qinna and Awwad (1998) found the permeability of the deep soils was 2000-fold higher than that of the soil surface crust. The compacted soil layer on the slopes could increase runoff generation capacity (Fig. 6b).

Effect of Soil Moisture Content

Soil moisture content is one of the most important factors in influencing generation of runoff, and varies at different slope locations. Figure 7a shows that, for the same depth soil layers of 0–20 cm and 20–40 cm, No. 2 plot had higher soil moisture contents than those of No. 1 plot. In other regions on the Loess Plateau, downslope, the increasing soil moisture contents have been verified by many studies (Fig. 7b, c, d). Therefore, the increasing soil moisture contents downslope could be inferred in the study area, although no data existed for the other plots. During a storm, classic studies have verified a link between soil moisture content of the upper soil layer and storm runoff (Kirkby and Chorley 1967; Dunne and Black 1970; Chorley 1978), implying the soil moisture content of 0–40 cm soil layer, especially the 0–20 cm layer, could attribute to the peak values of runoff coefficients. However, the decreasing runoff coefficients downslope in Figs. 3 and 4 could be related to other factors (to be discussed).

Effect of Rainfall Regime

Table 4 shows that all the rainfall eigenvalues were significantly correlated with runoff coefficient at the 0.01 level, among which I_{30} was the most positively correlated one ($r = 0.684$), implying its determinant role in influencing runoff generation. Higher rainfall intensity made crusting form easier, and more runoff was generated (Vandervaere and others 1997; Esteves and Lapetite 2003). However, when the flow energy was large enough, the encrusted soil layer was destroyed and rills and/or even ephemeral gully developed, which decreased runoff coefficient. The higher the rainfall intensity, the shorter slope length required to destroy soil crust accompanied by the formation of rills and/or even ephemeral gullies to arrive at the peak value of runoff coefficient (Fig. 4), which prompted the peak value of runoff coefficient, induced by regime A, to occur on a shorter slope length than those by rainfall regimes B and C.

Runoff at the bottom of a slope is often much less than runoff calculated as rainfall excess, or point runoff, multiplied by slope length (Yair and Lavee 1985; Williams and Bonell 1988; Joel and others 2002). The difference between runoff at point level and runoff at slope level is the type of scale effect, which is a function of rainfall

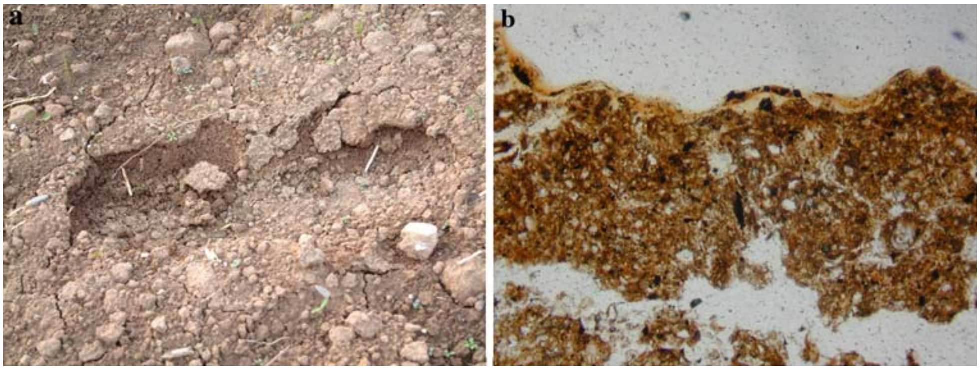

Fig. 6 Developed soil crust on the loess soil: (**a**) a general view in the field, and (**b**) the crust microstructure by scanning electron micrographs (×40)

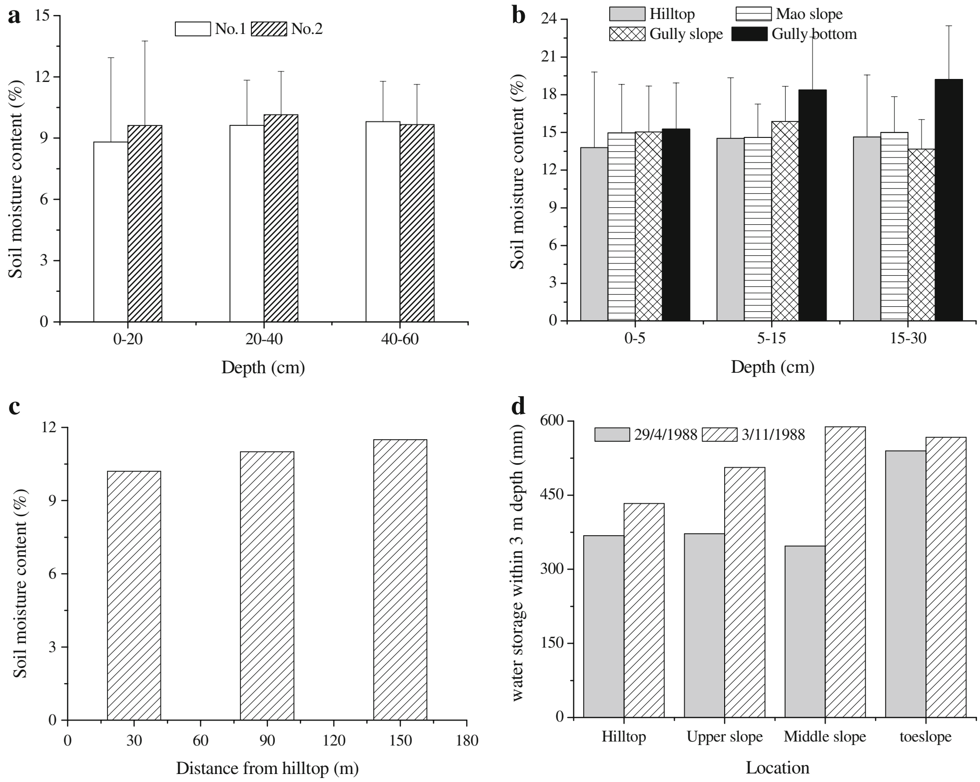

Fig. 7 Soil moisture content/soil water storage at different locations of some slopes in different regions on the Loess Plateau: (**a**) soil moisture contents (%) at different soil depths on the No. 1 and No. 2 runoff plots; (**b**) soil moisture contents (%) at different locations of a slope during 1989–1994 in Xiannangou gully (modified from Jiang 1996); (**c**) soil moisture contents (%) of 0–70-mm-depth soil layers for different distances from hilltop of a cultivated slope during the year 1988 rainy season in Danangou gully (from Fu and others 2002); and (**d**) soil water storage within 3-m-deep underneath slope surface at different locations of a cultivated slope in Zhifanggou gully (modified from Tang 2004)

Table 4 Pearsonian correlation coefficients between rainfall eigenvalues and runoff coefficient

	R_c	R_h	I_m	I_{10}	I_{30}
R_c	1				
R_h	0.261^a	1			
I_m	0.529^a	0.173^a	1		
I_{10}	0.529^a	0.428^a	0.422^a	1	
I_{30}	0.684^a	0.600^a	0.562^a	0.716^a	1

[a] Correlation is significant at the 0.01 level (2-tailed); R_c and R_h are runoff coefficient and rainfall amount, and I_m, I_{10} and I_{30} are mean rainfall intensity, maximum 10-minute rainfall intensity, and maximum 30-minute rainfall intensity, respectively

duration and intensity, slope surface characteristics, and infiltration capacity, among which rainfall characteristics is one of the most important one causing this scale effect. The short duration and strong intensity of the events of rainfall regime A made crusting formation easier, and the generated water flow could reach the slope bottom quickly, resulting in the smallest scale effect on runoff (Stomph and others 2002; van de Giesen and others 2005). Inversely, for rainfall regime C, as well as rainfall regime B, its lower runoff intensity with long duration made more runoff infiltrate into the soil, and less runoff occurring on the upper slope could reach the bottom of the slope, leading to higher scale effect than that by rainfall regime A (Fig. 5).

Effect of Slope Length

Slope length is another factor influencing runoff generation, and studies found that a runoff reduction with increasing slope length, resulting from more time of runoff, infiltrated into the soil (Poesen and Bryan 1989; Ben-Hur 1991; Lal 1983, 1997a,b; Yair and Lavee 1985; Agassi and others 1985; El-Hassanin and others 1993; van de Giesen and others 2000; Masiyandima and others 2003). However, with increasing slope lengths, peak values of runoff coefficients occurred in the present study (Figs. 3 and 4). This study is contradictory to the traditional studies mentioned above. The increasing runoff coefficients could result from the encrusted soil surface (Peugeot and others 1997; Vandervaere and others 1997; Esteves and Lapetite 2003) as well as the increasing soil moisture contents downslope, however, the decreasing ones could relate to other factors to be discussed in the next sections.

Effect of Slope Gradient

Effect of slope gradient on runoff is a controversial issue, and different viewpoints have been reported. As slope gradient increases, some studies observed a decrease resulting from a thinning and/or disruption of the crust (Poesen 1984), rills' formation (Bryan and Poesen 1989; Slattery and Bryan 1992), differential soil cracking (Govers 1990), and greater ponding depth (Fox and others 1997), etc. However, De Ploey and others (1976), Sharma and others (1983), and Djorovic (1980) observed an increase in runoff which was attributed to a decrease in depressional storage and ponding depth. Lal (1976) and Mah and others (1992) did not find any significant effect of slope angle on runoff. These discrepancies may be caused by the variability in experimental conditions.

No. 4 and No. 5 plots had the same dimension, and both located on the *Mao* slope zones where no rills occurred (Table 1), the higher runoff coefficients on No. 5 runoff plot (Figs. 3 and 4) could be attributed to the decrease in depressional storage and ponding depth due to its steeper slope gradient. In addition, for No. 5 plot, its larger slope gradient and lower position on the slope surface could lead to larger flow velocity and higher soil moisture content downslope and leave less time to infiltrate into the soil that increased runoff generation capacity (Chaplot and Le Bissonnais 2000).

Effect of Erosion Unit

On the Loess Plateau, vertical erosion units exist resulting from severer and severer erosion fashions which change from splash, sheet, or interrill, and rill to ephemeral gully and gully erosion from hilltop to slope bottom (Zheng and Huang 2002; Zheng and others 2005) (Fig. 2). In the zones where splash erosion and sheet/interrill erosion are the major erosion fashions, the reduction of infiltration rate was determined by crust formation (Morin and Benyamini 1977). However, downslope to the rill and even ephemeral gully-developed zones, the smooth surface (i.e., crusting) was destroyed, and in the undersurface, drier soil appeared. Furthermore, the fragmented surface by rills and/or gullies increased roughness of soil surface and the depressional storage that decreased runoff coefficient (Poesen 1984; Bryan and Poesen 1989; Slattery and Bryan 1992; Fox and others 1997). In addition, the thick loess colluviums could occur at the rill and/or gully bottoms as well as that at the outlet of slope, which could block the runoff flowing out of the slopes and lead to more time for the runoff to infiltrate into the soils. The colluvium debris at the Sede Boqer Experimental Watershed sometimes could even cause runoff discontinuity (Yair and Yassif 2004).

Explanation

Runoff generation is a complicated process influenced by many factors that could present different significances on the plots at different slope locations. On the hilltop and upper *Mao* slope zones, where interrill/sheet flow prevailed, the encrusted soil surface, as well as increasing soil moisture contents downslope, made runoff coefficient increase despite increasing slope lengths and slope gradients. However, the decreasing runoff coefficients downslope could be attributed to two reasons: Firstly, in the slope zones where rill and/or (ephemeral) gully occurred, the encrusted soil was destroyed and the drier soil underneath appeared, which increased runoff infiltration rate. Secondly, loess colluviums could occur at the rill and/or gully bottoms and/or that at the outlet of slope trapping and/or blocking more runoff to infiltrate into the soils. Noticeably, No. 7 plot, which enveloped both the nonrill and rill or even (ephemeral) gully occurring zones, presented a medium runoff coefficient.

Rainfall characteristics, especially rainfall intensity, greatly influence runoff generation (Tables 3 and 4). The peak values of runoff coefficients occurred at different slope lengths could be attributed to the interaction of soil crust as well as soil moisture content and erosion fashions. In the zones where interrill/sheet flow prevailed, the encrusted soil surface, as well as increasing soil moisture contents downslope, enhanced runoff generation capacity. However, when flow energy was large enough, crust was destroyed and rills and/or gullies formed, which in return decreased runoff coefficients. The transition location on the slope surface from interrill/sheet to rill erosion zones depends on rainfall regimes. The strong rainfall intensity of regime A quickened the transition process and made the peak value of runoff coefficient occur on the 40-m-long slope surface (i.e., No. 2 plot); however, the peak values of rainfall coefficients induced by low rainfall intensity of regime B, especially of regime C, occurred on the 60-m-long slope surface (i.e., No. 3 plot). As for scale effect on runoff induced by the rainfall regime A, the generated flow could arrive at the slope bottom quickly and less water was lost on the slope surface leading to its smallest scale effect. While regime C rainfalls made the least runoff reach the slope bottom and presented the largest scale effect of runoff. For regime B, which has a moderate rainfall intensity and duration, the scale effect of runoff was the medium.

Conclusion

This article discusses runoff generation capacity on slopes under different rainfall regimes in a gullied loess region, Tuanshangou catchment, on the Loess Plateau where vertical erosion units occur from hilltop to slope bottom. In our present study, seven plots located on different erosion units were selected to study runoff generation capacity, and results demonstrated that, different from traditional studies, runoff coefficients neither increased nor decreased on the slopes, but presented peak values for all the three rainfall regimes A, B, and C. Interacted by soil crusting and sealing, soil moisture content, slope dimension, erosion fashion of water flow, and others, peak value of runoff coefficient by rainfall regime A was largest occurring on the No. 2 plot; however, the lower rainfall intensity of regime B, as well as regime C, required longer slope surface to form the peak value occurring on the No. 3 runoff plot. However, scale effect of runoff caused by regime A was least due to its shortest duration and highest rainfall intensity, and that caused by rainfall regime C was the highest, resulting from its lowest rainfall intensity and longest duration, and scale effect caused by rainfall regime B, the medium.

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