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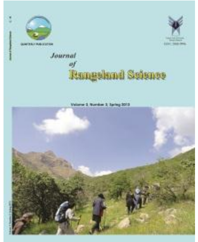

Full Length Article:

Rainfall Characteristics of the Liudaogou Catchment on the Northern Loess Plateau of China

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Abstract. The objectives of this study were to understand the rainfall characteristics of the wind-water erosion crisscross region on the northern Loess Plateau, China, to provide basis for the studies on mitigation of soil erosion, estimation on surface water resources and local hydrological circle, etc. The Liudaogou Catchment with representative climatic and hydrologic conditions of wind-water erosion crisscross region at the northern Loess Plateau was chosen as the study area. Analysis of the rain intensity, duration and amount was performed for the period from May to October for five years (2006-2010). The maximum and average rain intensity of time intervals of 3 min, 5 min, 10 min, 30 min and 1 h were quantized. Rain intensity distribution of different time intervals (3 min, 5 min, 10 min, 30 min, 1h and 6 h) has been clarified to a certain degree. Rainfall events whose rainfall duration equal or less than 30 min accounted for approximately 50% of the total number of rainfall events. Rainfall event whose rainfall amount $\leq$ 1 mm accounted approximately 50% of annual mean rainfall events whereas their total rainfall only accounted for less than 7% of mean annual precipitation during 2006-2010. This study veritably described the main rainfall characteristics of wind-water erosion crisscross region on the northern Loess Plateau to a certain extent.

Key words: Loess plateau, Wind-water erosion crisscross region, Liudaogou catchment, Rainfall analysis, Rain intensity

1. Introduction

Chinese Loess Plateau (area: 6.268×10^5 km^2; 110°-115° E longitude and 34°-40° N latitude) as a vast semiarid region and high risk region of desertification has widely been of concern not only in China but also in the world. In the process of desertification, serious soil erosion has occurred in the Loess Plateau since 17th century (Wang and Takahashi, 1999; Bo and Long, 2002). Over 60% of the total area has been subjected to the soil and water loss, consequently, Loess Plateau has been regarded as one of the most serious soil erosion areas in the world, (Shi and Shao, 2000). Natural processes of soil and water loss fluctuates in different seasons and years, which is significant in fragile arid environments with sparse vegetation covers (Merz *et al.*, 2006). Due to poor vegetative cover and fragile ecosystem in the semiarid regions, surface hydrological responses are even sensitive to small fluctuations of rainfall (Yair and Raz-Yassif, 2004; Nearing *et al.*, 2005; Leblance *et al.*, 2008). Knowledge about the role of temporal variations of rainfall variations on water erosion is thus significant for erosion control and larger-scale hydrological predictions (Wei *et al.*, 2010). In China's Loess Plateau, soil erosion and nutrient losses with surface runoff have caused severe soil quality degradation and water pollution, which is driven by both rainfall impact and runoff flow that usually occurs simultaneously during the rainfall event (Guo *et al.*, 2010). Re-vegetation is recognized as an effective means to control soil erosion and protect land from desertification (Wu and Yang, 1998; Huang *et al.*, 2003), and great effort has been made to plant trees and grass on slope land since the end of 1950s. Indeed, about 24% of erosion area has been controlled, and vegetation coverage has increased from 6.5% in 1970s to 11% in 1995 in the Loess Plateau (He *et al.*, 2003; Chen *et al.*, 2008). However, large-scale vegetation restoration has also aggravated water scarcity (Li, 2001; Shangguan and Zheng, 2006). Water is the key to vegetation restoration (Huo *et al.*, 2008).

In most regions of the Loess Plateau, the average annual rainfall ranges from 300 mm in the northwest to 650 mm in the southeast, however, the relevant mean annual evaporation varies from 623.8 to 1254.0 mm. Scarce and uneven distribution of rainfall in addition to intense evapotranspiration causes the deficiency of annual water resources (Zheng *et al.*, 2005; Kimura *et al.*, 2005). Deficiency of water resources mainly hampers vegetation restoration in the Loess Plateau (Yang, 1996; Hinokidani *et al.*, 2010). The most serious erosion area is the wind-water erosion crisscross region at the northern Loess Plateau.

Tendency of desertification in this region has become more severe than that in the southern region of the Loess Plateau due to the long-term water and wind crisscross erosion in addition to low precipitation. Average annual precipitation of this region is only 400 mm with apparent seasonal fluctuation, which leads to intra seasonal water deficiencies (Cheng *et al.*, 2007; Huo *et al.*, 2008). The spatiotemporal heterogeneity and uneven characteristics of rainfall play a key role in soil erosion (Li *et al.*, 2000; Apaydin *et al.*, 2006), as complex interactions exist between the spatiotemporal distributions of rainfall systems and watershed hydrological responses (Morin *et al.*, 2006; Baigorria *et al.*, 2007). Local storm patterns are important in determining the shape of the runoff hydrograph (De Lima and Singh, 2002). In the Loess Plateau, the erosion force is mainly rainfall and the factors affecting rainfall erosion include intensity, variation, and duration (Shi and Shao, 2000). Rainfall can cause runoff that is a basic force producing soil and water loss (Kinnell, 2005; Wei *et al.*, 2010). Ephemeral runoff is significantly affected by rainfall factors, meanwhile, runoff is an important water resource in the wind-water erosion crisscross region of the Loess Plateau (Hinokidani *et al.*, 2010). Therefore, clarification of the main rainfall characteristics such as rain intensity for different time intervals, rainfall duration and rainfall amount can provide important insights for the studies on soil erosion and relationships between rainfall and runoff. Moreover, this information becomes valuable for assessment, development and utilization of available water resources in the northern Loess Plateau. Many studies on rainfall analysis of “Intensity-Duration-Frequency (IDF)” which has drawn much attention from researchers have been conducted over the past few years (Chen, 1983; Pao *et al.*, 2004) and need accurate continuous rainfall data for a considerable period. However, only few studies have been carried out in China due to poor quality of available rainfall data due to measurement errors and use of the limited quality equipments. The aim of this study was to understand the rainfall characteristics of the wind-water erosion crisscross region of the northern Loess Plateau. The preliminary analysis of rain intensity, rainfall duration and rainfall amount was conducted by using the rainfall data observed in the rainfall concentrated period (May to October) in five years (2006-2010). Results of this study are expected to provide accurate information for studies to establish relationship between rainfall and soil erosion, relationship between rainfall and runoff of the wind-water erosion crisscross region of the northern Loess Plateau.

2. Materials and Methods

2.1. Study area

The Liudaogou Catchment (area: 6.89 km^2, 110˚21′-110˚23′ E longitude and 38˚46′-38˚51′ N latitude) was chosen as the study area because it represents diversified landscape types in terms of geology, morphology, soil, hydrology and climatic conditions, as well as a number of land use patterns of the wind-water erosion crisscross region in the northern Loess Plateau environment (Huang *et al.*, 2008; Zhu and Shao, 2008). This catchment is situated at the elevation ranging from 1094.0 m to 1273.9 m above sea level with only 430 mm annual precipitation and uneven monthly distribution, of which more than 70% is concentrated on the period June to September. The annual potential evapotranspiration exceeds 1000 mm. Ephemeral runoff is restrictively generated only for intensive rainfall in the rainy season (Huang *et al.*, 2011). Terrain is considerably complicated (Fig. 1b), and many gullies in various scales spread around the main river channel. The rigorous wind and water crisscross erosion causes severe degradation of the ecological environment and increases the risk of desertification. The natural vegetation has been severely destroyed and there is almost no large-area distribution, and vegetation coverage is less than 25% (Han *et al.*, 2009; Wang *et al.*, 2009; Huang, 2010).

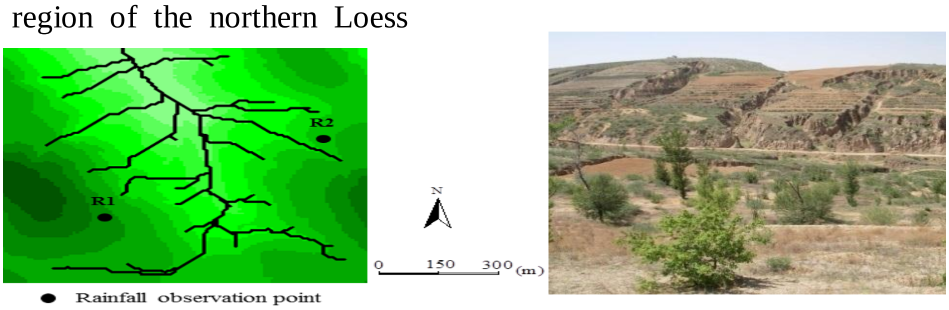


Fig. 1. Layout of rainfall observation & natural condition of the Liudaogou Catchment (a) Layout of rainfall observation (b) Natural condition (terrain and vegetation) of the Liudaogou Catchment (May, 2007)

2.2. Methodology

Rainfall observations were conducted on slope land on both sides of a large gully at upstream of the Liudaogou Catchment. Two locations for observation were identified and marked as R1 (110°21'41.52" E and 38°46'80.74" N) and R2 (110°21'46.23" E and 38°47'33.50" N), and elevation of the two points were 1256 m and 1247 m, respectively. The tipping rain-gauges (Model number: 7852M-L10, Dimensions: φ165×240H (mm)) were used and rain gauge of this type records data once for every 0.2 mm rainfall occurred. Layout of rainfall observation is shown in (Fig. 1a).

The studies on relationship between rainfall and soil erosion in China in recent years indicate that two types of data are used in rainfall analysis due to the difference between the laboratory and field conditions. Because instability of rainfall intensity at natural conditions and limitation of the observing conditions, rainfall data of the relatively large time intervals such as 30 min and 1 h are used for researches on rainfall analysis (Zhang and Zhu, 2006; Wang *et al.*, 2010). Based on control over the artificial rainfall equipment, rainfall intensity of various time intervals can be obtained under laboratory conditions and the shorter time interval are selected for rainfall analysis such as 10 min, 5 min and 1min (Yuan *et al.*, 2010; Xiao *et al.*, 2011). In this study, rainfall observations were obtained in the natural slope land and the span for rainfall analysis covered the entire rainy season of five years (2006-2010). Considering the rainfall feature of the study area where the most part of the annual precipitation received in rainy season generally in short duration and high intensity which is closely related to soil erosion and runoff, the observed rainfall data was separated into the shorter intervals such as 3 min, 5 min and 10 min, and the longer intervals such as 30 min, 1 h and 6 h by means of Box Car Pro 4.3 software (Statement: There is no conflict of interest between the authors and the Box Car Pro 4.3 software) on time axis and rainfall distribution for each of the above time intervals can be achieved. Since there were no visible differences between the observed results during the mutual observation period in the two locations R1 and R2, the results of the processed rainfall data provide the arithmetic mean of rainfall on the two locations.

3. Results and Discussion

3.1. Comparison of mean annual precipitation (1956-2010) and monthly distribution in the period 2006-2010

Monthly rainfall distribution of 2006-2010 is presented in the (Table 1). Comparison of mean monthly rainfall in the period 2006-2010 and mean annual (1956-2010) is shown on the (Fig. 2).

According to the results presented in the (Table 1), mean annual precipitation of 2006-2010 was 476.6 mm/a slightly higher than the mean annual rainfall of 430 mm of (1956-2010). Mean rainfall in the rainfall concentrated period (May-October) of 2006-2010 accounted for 92.2% of mean annual precipitation (2006-2010). (Fig. 2), showed that although monthly rainfall distribution of 2006-2010 was similar to that of 1956-2010, rainfall in July was significantly lower than that of the mean annual and rainfall in September was obviously higher than the mean annual of the period (1956-2010). Except July and September, there was no distinct difference of monthly rainfall distribution between mean of 2006-2010 and mean annual of 1956-2010.

Table 1. Statistical results of monthly rainfall distribution (mm)

Given year→ Month↓	2006	2007	2008	2009	2010	Average	Percentage of Total Annual %
Jan	9.2	0.4	3.0	0.4	0	2.6	0.6
Feb	0.4	8.4	2.4	3.6	0.4	3.0	0.6
Mar	2.6	17.6	12.0	6.6	17.4	11.2	2.3
Apr	2.8	16.8	25.0	4.2	24.0	14.6	3.1
May	59.0	47.0	24.2	42.8	58.6	46.3	9.7
Jun	51.2	45.6	106.6	40.8	50.0	58.8	12.3
Jul	84.8	55.8	44.6	111.8	36.6	66.7	14.0
Aug	108.4	120.0	129.2	157.2	177.8	138.5	29.1
Sep	35.8	65.8	133.4	127.2	96.8	91.8	19.3
Oct	22.6	98.4	16.6	22.6	26.4	37.3	7.8
Nov	7.6	0.0	5.8	10.2	0.0	4.7	1.0
Dec	0.2	5.2	0.0	0.0	0.0	1.1	0.2
Total	384.6	481.0	502.8	527.4	488.0	476.6	100

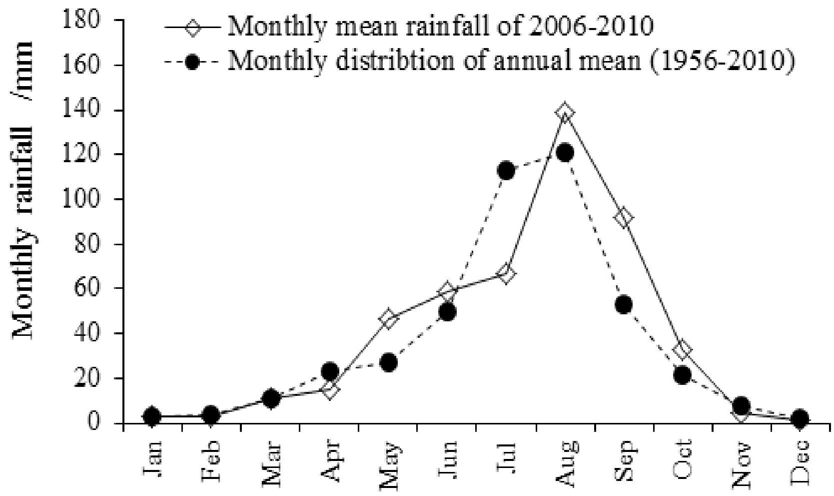


Fig. 2. Comparison of monthly mean rainfall between (2006-2010) and mean annual (1956-2010)

3.2. Analysis of rain intensity of each time interval

Rainfall data in the considered period (May-October) of 2006-2010 was separated on time axis using Box Car Pro 4.3 software by time interval of 3 min, 5 min, 10 min, 30 min, 1 h and 6 h, respectively, and the observed rain intensity distribution of each time interval are shown on the (Fig. 3a- Fig. 3f), respectively. The results of rain intensity distribution of each time interval of each month are presented in the (Table 2).

According to the results of rain intensity of different time intervals (Fig. 3, Table 2), most number of rain intensity of 3 min interval was equal or less than 0.13 (mm.min^{-1}), and rain intensity of merely 2 times was higher than 1.8 (mm.min^{-1}) within 2006-2010, the maximum was 2.2 (mm.min$^{-1)}$ which happened on 2010-08-11.

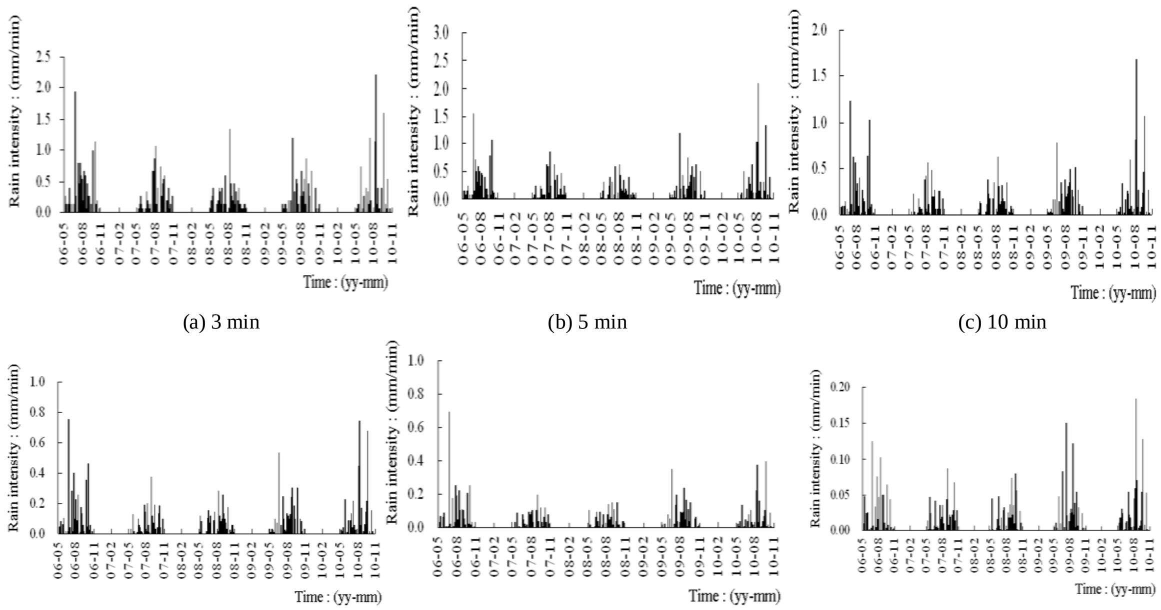
Most of 5 (min) rain intensity was equal or less than 0.2 (mm.min^{-1}) and number of rain intensity which was higher than 1 (mm.min^{-1}) was only 11, and the maximum also occurred on 2010-08-11 reaching 2.08 (mm.min^{-1}). Most of 10 min rain intensity was ≤ 0.1 (mm.min^{-1}) and there were only 6 events higher than 0.8 (mm.min^{-1}), and the maximum was 1.68 (mm.min^{-1}) (2010-08-11).

Most of rain intensity was equal or less than 0.05 (mm.min^{-1}) of 30 min interval and only 4 events was higher than 0.6 (mm.min^{-1}), and the maximum was observed on 23rd June 2006 which reached to 0.75 (mm.min^{-1}). Number of rain intensity equal or less than0.03 (mm. min^{-1}) was more than 70% of 1 h interval, and rain intensity higher than 0.4 (mm.min^{-1}) was only once observed on 23rd June 2006 (0.70 mm.min^{-1}). Number of rain intensity equal or less than 0.01 (mm.min^{-1}) was more than 65% of 6 h interval, and rain intensity higher than 0.1 mm.min^{-1} was only 6. The maximum rain intensity in 2007, 2008 and 2009 of 3 min interval was obviously lower than that of 2006 and 2010. The maximum value of time intervals of 5 min, 10 min, 30 min and 1 h in 2007 and 2008 was visibly lower than the corresponding values of 2006 and 2010, which was due to relatively low intensity of intensive rainfall events in 2007 and 2008. (Table 2), shows rain intensity distribution of different time intervals in each month in the considered period of 2006-2010. Number of rain intensity equal or less than 0.13 (mm.min^{-1}) accounted for 60.4% of 3 min interval of the total number of observations and number of rain intensity higher than 0.6 mm.min^{-1} was less than 2% of the total number. There were 21 events of rain intensity higher than 1 mm.min^{-1} which was mainly received annually during June, August and September and only accounted for 0.4% of the total number of the observations. Number of 5 min rain intensity equal or less than 0.2 (mm.min^{-1}) accounted for 94.8 % of the total number of observations.

Number of rain intensity higher than 0.4 (mm.min^{-1}) was less than 2.0% of the total number of observations among which number of rain intensity higher than 0.8～1 (mm.min^{-1}) and that higher than 1 (mm.min^{-1}) accounted for 0.3% of the total number of observations of 5 min interval. No rainfall event occurred with rain intensity higher than 0.8 (mm.min^{-1}) in July. Number of rain intensity ≤ 0.1 (mm.min^{-1}) accounted for 89.7 % of 10 min interval of the total observations. Number of rain intensity >0.4 (mm.min^{-1}) only accounted for 1.2% of the observations among which rain intensity higher than 0.8 (mm.min^{-1}) was only 6 and only accounted for 0.2% of the total number of observations. In July, there was no rainfall event whose 10 min rain intensity was higher than 0.8 (mm.min^{-1}).

Number of rain intensity equal or less than 0.05 (mm.min^{-1}) slightly exceeded 80% of the total number of observations of 30 min interval. Number of rain intensity higher than 0.05～0.4 (mm.min^{-1}) and that higher than 0.4 (mm.min^{-1}) accounted for 19.2% and 0.5% of the observations, respectively. There was no rainfall event of 30 min interval whose rain intensity was higher than 0.4 (mm.min^{-1}) in July.

Number of rain intensity equal or less than 0.03 mm.min^{-1} and rain intensity higher than 0.06～0.27 mm.min^{-1} accounted for 73.1% and 11.4% of the total number observations of 1 h interval, respectively. Only 6 events whose 1 h rain intensity was high than 0.27 (mm.min^{-1}) and 3 events occurred in August. Number of rain intensity high than 0.4 (mm.min^{-1}) was only 1, indicating that event probability of rainfall of 1 h interval with rain intensity higher than 0.4 (mm.min^{-1}) was merely 0.1% in 2006-2010. Number of rain intensity equal or less than 0.01 mm.min^{-1} accounted for 65.1% of the total number observations of 1 h interval. Only 6 events whose 6 h rain intensity were higher than 0.1 (mm.min^{-1}).



(a) 3 min (b) 5 min (c) 10 min
(d) 30 min (e) 1 h (f) 6 h

Fig. 3. Distribution of rain intensity of different time intervals

Table 2. Monthly distribution of rain intensity of different time intervals (Number)

	3 min/ mm.min-1						5 min/ mm.min-1						10 min/ mm.min-1						30 min/ mm.min-1						1 h/ mm.min-1						6 h/ mm.min-1					
Month	≤0.13	>0.13≤0.4	>0.4≤0.6	>0.6≤0.87	>0.87≤1	>1	≤0.2	>0.2≤0.4	>0.4≤0.6	>0.6≤0.8	>0.8≤1	>1	≤0.1	>0.1≤0.2	>0.2≤0.4	>0.4≤0.6	>0.6≤0.8	>0.8	≤0.05	>0.05≤0.1	>0.1≤0.2	>0.2≤0.4	>0.4≤0.6	>0.6	≤0.03	>0.03≤0.06	>0.06≤0.13	>0.13≤0.27	>0.27≤0.4	>0.4	≤0.01	>0.01≤0.03	>0.03≤0.05	>0.05≤0.08	>0.08≤0.10	>0.10
May	610	240	1	1	0	0	768	4	2	0	0	0	579	15	3	0	0	0	274	32	3	1	0	0	163	24	11	1	0	0	48	16	6	0	0	0
Jun	489	281	10	6	2	6	648	17	3	7	1	3	446	28	6	4	4	1	212	38	9	1	1	2	129	30	12	1	1	1	42	13	5	1	1	1
Jul	513	350	20	8	0	1	685	37	15	3	0	0	451	44	23	4	1	0	210	37	22	7	0	0	126	25	20	8	0	0	51	19	5	1	0	1
Aug	948	696	26	21	3	9	1256	82	20	10	4	4	804	81	44	11	4	2	348	70	42	11	4	1	193	56	36	16	3	0	57	33	10	4	1	3
Sep	743	492	22	7	4	4	1048	26	8	6	3	2	760	51	13	5	3	2	385	52	20	5	0	1	224	42	25	5	1	0	64	21	7	5	0	1
Oct	383	201	2	2	1	1	473	8	3	0	1	1	327	29	6	0	0	1	175	22	11	0	1	0	109	17	12	1	0	0	49	8	3	2	0	0
Subtotal	3686	2260	81	45	10	21	4878	174	51	26	9	10	3367	248	95	24	12	6	1604	251	107	25	6	4	944	194	116	32	5	1	311	110	36	13	2	6
Total	6103						5148						3752						1997						1292						478					
Subtotal/Total/%	60.4	37	1.3	0.7	0.2	0.4	94.8	3.4	1	0.5	0.1	0.2	89.7	6.6	2.5	0.6	0.4	0.2	80.3	12.6	5.4	1.2	0.3	0.2	73.1	15	9	2.4	0.4	0.1	65.1	23	7.5	2.7	0.4	1.3

3.3. Comparison of the maximum, minimum and average rain intensity of different time intervals

The maximum, minimum and average rain intensity in the considered time in 2006-2010 is presented in (Table 3). Average rain intensity refers to the arithmetic mean of rain intensity throughout the entire span of all rainfall events for each time interval in the considered period of 2006-2010. Since the rain gauge to record data once for every 0.2 mm rainfall occurred (approximately 1 drip rain into rain gauge) the minimum rainfall of each time interval (3 min, 5 min, 10 min, 30 min, 1 h and 6 h) was 0.2 mm. The rainy event whose rainfall amount was less than 0.2 mm could not be observed. Therefore, an insignificant difference may exist between the maximum and minimum rain intensity of the observed results (Table 3) and the actual corresponding value of each time interval theoretically. For example, the actual minimum rainfall amount of each time interval might be 0 ～0.2 mm (exclusion from 0.2 mm).

When rainfall amount of a single rainfall event is less than 0.2 mm, it will be evaporated soon at the study area and can almost not change conditions of underlying surface. Therefore, rainfall amount less than 0.2 mm for a single rainfall event can be neglected from perspective of effective rainfall and it almost does not affect the results of rainfall analysis at the study area. Results in (Table 3), indicate that the maximum, minimum and average rain intensity of time interval of 10 min were 0.80, 0.5 and 0.67 times of the corresponding value of 5 (min) interval, respectively; while the maximum, minimum and average rain intensity of 1 (h) interval were 0.32, 0.05 and 0.25 times of the corresponding value of 3 min interval, respectively. Thus, a conclusion can be drawn by comparison among the maximum, minimum and average rainfall intensity of every time interval that by increasing the time interval the rain intensity showed a decreasing tendency.

Table 3. Maximum, minimum and average rain intensity of different time intervals (2006-2010)/ (mm/min)

Time Interval/min	Maximum Intensity	Minimum Intensity	Ration of Maximum and Minimum	Average Intensity
3	2.2	0.07	31	0.12
5	2.08	0.04	52	0.09
10	1.68	0.02	84	0.06
30	0.75	0.007	107	0.04
60 (1h)	0.70	0.003	233	0.03
360 (6 h)	0.18	0.0006	300	0.013

3.4 Rainfall duration and rainfall amount

The divided methods for every single rainfall event are listed below and the separated results of rainfall data of 10 min interval used as 10 min interval can be considered as a representative time unit to divide (Table 4, number of rainfall event with rainfall duration higher than 10 min accounted for more than 60% of total number of rainfall event) rainfall event, in addition, analysis on the observed results is relatively to be carried out.

1）A continuous rainfall was determined as a single rainfall event during occurrence of which there was no interruption equal or higher than 10 min as well as no rainfall event before and after 1 h of such continuous rainfall.

2）When a non-persistent rainfall occurred within 1 h with interruption (s) equal or higher than10 min and there was no rainfall within a few hours before and after, such non-persistent rainfall was confirmed as a single rainfall event.

3）For a long period of non-persistent rainfall, if its time span exceeded 6 h without interruption higher than 1 h and such rainfall was confirmed as a single rainfall event. The main basis for such divided method was in consideration of the main hydraulic conditions of the underlying surface such as water content in the top soil (etc.) could not change significantly, although it ceased during the time span of rainfall, in other words, interruption of rainfall has insignificant impact on the process of rainfall -runoff.

Few cases of rainfall could not meet the dividing conditions of the above methods (1) - (3) to ascertain such rainfall, thus it was necessary to consider the actual rainfall process in light of the above methods.

Rainfall in the considered period from May to October in 2006-2010 was divided using the methods as mentioned above and the analyzed results of rainfall duration and rainfall amount of all rainfall events are presented in the (Table 4). The total number of rainfall events in the considered period in 2006-2010 was 449 (Table 4). Rainfall event whose rainfall duration equal or less than 30 min accounted for 52.1% of the total number, and number of rainfall events with amount equal or less than 1.0 mm was 225 which accounted for 50.1% of total number of events. Number of rainfall event of rainfall duration higher than 30 min～1 h and 1～2 h accounted for 11.8% and 13.2% of the total number, respectively. Number of rainfall duration in the ranges of higher than 2～4 h, 4～6 h, 6～12 h, and >12 h was less than 10% of total number of rainfall events, respectively. Number of rainfall duration higher than 12 h was only 10 which was merely equivalent to 2.2% of total number.

From the perspective of rainfall amount, number of rainfall event with rainfall amount equal or less than 5 mm was 349 which accounted for more than 77% of the total rainfall events, while that equal or less than 1 mm was equal to 50.1% of total number. Number of rainfall event with rainfall amount higher than 5～10 mm was 43 which was equivalent to 9.6% of the total rainfall events. Number of rainfall amount in the ranges higher than 10～20 mm and >20～40 mm was 27 and 22 events, respectively, and total number of these two ranges accounted for 10.9% of total number. There were 6 rainfall events whose rainfall amount higher than 40～80 mm and the average annual was merely 1 time/a in 2006-2010. If rainfall amount of such rainfall event is 60 mm, which is equivalent to the average range higher than 40～80 mm, the rainfall amount reaches to 12.6% of annual precipitation (mean annual precipitation was 476.6 of 2006-2010). Only 2 rainfall events whose rainfall amount exceeded 80 mm and such rainfall event only accounted for 0.4% of total number of rainfall events, and average event probability was less than 1 time/a in 2006-2010. Mean annual number of rainfall event in the considered period for a single rainfall amount equal or less than 1 mm was 45 times/a, if the maximum of 1 mm is to be chosen to calculate the rainfall amount, the total rainfall amount of this type of rainfall event is only 45 mm. In other words, the total rainfall amount of 45 rainfall events (a single rainfall amount was less than 1 mm) accounted for less than 10% of the mean annual precipitation. Number of rainfall event for a single rainfall amount higher than 20 mm was 6 times/a in 2006-2010, if the minimum value of 20 mm was to be chosen to perform calculation, the total annual rainfall amount of such rainfall event reaches to 100 mm which exceeds 25% of the mean annual precipitation.

Table 4. Distribution of rainfall duration and rainfall amount (Number)

Rainfall amount (mm)	Rainfall duration ≤10(min)	>10～30(min)	>30(min)～1(h)	>1～2(h)	>2～4(h)	>4～6(h)	>6～12(h)	>12(h)	Total	Percentage of number of each range accounted for total rainfall events / (%)
≤1	148	43	21	13	—	—	—	—	225	50.1
>1～5	20	20	26	32	18	8	—	—	124	27.6
>5～10	1	1	3	8	10	11	7	2	43	9.6
>10～20	—	1	3	2	5	6	7	3	27	6.0
>20～40	—	—	—	4	2		14	2	22	4.9
>40～80	—	—	—	—	1	1	3	1	6	1.3
>80	—	—	—	—	—	—	—	2	2	0.5
Total	169	65	53	59	36	26	31	10	449	
% of number of each range	37.6	14.5	11.8	13.2	8.0	5.8	6.9	2.2	100	100

4. Conclusions

The conclusions are as follows:

1) Rain intensity distribution of different time intervals (3 min, 5 min, 10 min, 30 min, 1h, 6 h) has been clarified to a certain degree, the maximum rain intensity of 3 (min), 5 (min), 10 (min), 30 (min), 1 (h) and 6 (h) was 2.2 (mm·min^{-1}), 2.08 (mm·min^{-1}), 1.68 (mm· min^{-1}), 0.75 (mm·min^{-1}), 0.70 (mm·min^{-1}) and 0.18 (mm·min^{-1}), respectively. Event probability of low rain intensity was higher than that of high rain intensity for each time interval and with increasing of time interval the rain intensity decreased.
2) Rainfall event with high intensity in July was less compared to that of June, August and September, and there was no rain intensity higher than 0.8 (mm· min^{-1}) of 5 (min) and 10 (min) interval, as well as higher than 0.4 (mm·min^{-1}) of 30 min interval and 0.27 (mm·min^{-1}) of 1 h interval in July.
3) From the perspective of rainfall duration, rainfall event of duration equal or less than 30 min and higher than 30 (min)～2 (h) accounted for 52.2% and 25% of total number of rainfall events, respectively. Number of rainfall duration higher than 2 (h) accounted for 22.9% among which rainfall duration higher than 12 (h) was merely equivalent to 2.2% of total rainfall events.
4) From the perspective of rainfall amount, rainfall event of rainfall amount equal or less than 1 (mm) accounted for 50.1% of mean annual number of rainfall event, whereas its rainfall amount only accounted for less than 10% of mean annual precipitation. Number of rainfall event of rainfall amount higher than 20 (mm) was 6 times/a and its rainfall exceeded 25% of mean annual precipitation of 2006-2010.

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ویژگی‌های بارش حوضه Liudaogou در شمال فلات لوئس چین

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چکیده

هدف از این مطالعه درک ویژگی‌های بارش باران در فرسایش آبی- بادی، منطقه متقاطع در شمال فلات لوئس در چین می‌باشد. جهت ارائه مبنایی برای مطالعات در کاهش فرسایش خاک، منابع آب سطحی و دایره هیدرولوژیکی محلی، برآورد شده است. حوضه آبریز Liudaogou با شرایط آب و هوایی و هیدرولوژیکی از فرسایش آبی بادی، در منطقه متقاطع در شمال فلات لوئس به عنوان منطقه مورد مطالعه انتخاب شده است. تجزیه و تحلیل شدت باران، مدت زمان و مقدار آن در طول دوره پنج ساله از ماه می تا ماه اکتبر (۲۰۱۰-۲۰۶) انجام شد. حداکثر و متوسط شدت بارش در فواصل زمان ۳ دقیقه، ۵ دقیقه، ۱۰ دقیقه، ۳۰ دقیقه و ۱ ساعت کوانتیزه می‌شد. توزیع شدت باران در فواصل زمانی مختلف ۳ دقیقه، ۵ دقیقه، ۱۰ دقیقه، ۳۰ دقیقه، ۱ ساعت و ۶ ساعت درجه خاصی را توضیح داده است. رویدادهای بارش باران با مدت زمان برابر یا کمتر از ۳۰ دقیقه برای حدود ۵۰٪ از تعداد کل رخدادهای بارندگی را به خود اختصاص داد. رویداد بارش باران که مقداری کمتر یا مساوی ۱ میلیمتر به خود اختصاص داده حدود ۵۰٪ از میانگین رویدادی بارش سالانه، در حالی که بارش کل تنها کمتر از ۷ درصد متوسط بارش سالانه در طول سالهای ۲۰۱۰- ۲۰۰۶ به خود اختصاص داده است. این مطالعه در حقیقت تا حدودی توصیف کننده ویژگی بارش باران از فرسایش آبی بادی، منطقه متقاطع در شمال فلات لوئس می‌باشد.

کلمات کلیدی: فلات لوئس، فرسایش باد، منطقه متقاطع، حوضه لیوداؤگو، تجزیه و تحلیل بارش، شدت باران