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Effect of rain characteristics on runoff threshold and soil erosion (Case Study: The research station of Jashlobar- Semnan)

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ABSTRACT

Estimating the design flood is one of the main steps in designing and measuring different structures and hydraulic facilities which could be conducted in different ways. In cases where the saving capacity of the system would be significant or period of the design flood would be long (For example in designing the overflow of dams), using mathematical models for converting the design rain into the design flood is a common option. The selected design rain which will generate the design flood should possess some characteristics among which would be the way of rain distribution during raining time which is expressed as the temporal pattern of the design rain. In this study, this method has been employed in order to extract the pattern of the design rain by means of the data related to the stability rain gauge in Jashlobar region and by being supported by pilgrim method in Australia which has had good compatibility and agreement with the climate conditions in Iran and had publicity. According to temporal changes in the intensity of the flood rains, recognizing the precise temporal patterns of the rain in a region is of great importance. In this research, in order to extract the most appropriate temporal patterns, cloudbursts were divided into continuities of 1, 3, 6, 9, 12, 18, 24 and 48 hours. Initially, all data and information related to the occurred cloudburstsin the region and the runoff and precipitates samples were taken from the research center of Semnan and the data were categorized through an exact investigation of the status of each cloudburst which led to a division into data related to runoff and the ones without runoff. Thereafter, the suspicious data were omitted and in the next step, the characteristics of the rains were extracted which required the graph of all cloudbursts to be created. At first the characteristics of the cloudbursts and the pattern of the rains distribution through pilgrim method and then the amount of rain in the area in each quarter was specified. Then, the average between the census obtained from both sites were calculated and the graphs of the rain patterns, with and without runoff, were provided and the intersection point of two graphs of erosion and precipitation threshold limit has been determined through adapting the graphs with and without runoff.

Introduction

Paying attention to the census and information of the rains shows that raining around the world does not have a homogeneous distribution and have temporal and local changes (Alizade, 2004). In studying watershed, dam building, civil and drainage engineering, temporal distribution of rains would be required the way that it would be an important factor to have the temporal distribution of the rain for designing the urban wastewater, controlling the flood and designing the potential for flood or soil erosion. Furthermore, the way of temporal distribution of rain in a specific time during the rain or during a rain generating maximum floods forms an input data of simulating the watershed models (Amin et al., 2000). Estimating the design flood is an important component of hydrological studies about water sources, especially in dam building outlines. The first step in estimating the design flood in a watershed by means of the rain census would be selecting a design rain and the design rain is usually estimated using the intensity- duration-frequency (IDF) curves for a specific return period and a definite raining time. The design rain generating and causing the design flood is defined and specified by some characteristics which are as followed: total amount, total continuity, local distribution and, finally, temporal distribution of rain. The total amount of design rain is specified based on the security degree required for the project. Total continuity is defined and specified according to the physiographical properties of the watershed and the adjustment power or the saving capacity of the system.The local distribution of the design rain is alsoproportional to the direction or the path of entering humidity and the storm causing fronts into the watershed and the topographical effects of the region. The pattern of temporal distribution which, indeed, introduces the way of intensity changes of the rain during raining time, has direct effect on the volume and the peak of the flood (Davoodi Rad et al, 2007) the way that in some cloudbursts the maximum intensity occurs at the beginning of the rain; however, it may be possible for other cloudbursts, the maximum intensity happens in the middle or at the end of the raining which depends on the mechanism of formation of the rain. According to the runoff

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formation processes in the watershed area, each of the mentioned patterns would cause a specific hydrographic figure of the flood (Davoodi Rad et al, 2007); this is the same as what is performed in many countries such as the United States of America in which the raining patterns for various rains has been provided by the Soil Conservation Service (SCS) which could be different due to different climatic conditions around the world. In Iran such actions have not been taken yet and its necessity for hydrological estimations is very sensible (BaniAsadi,2011). The oldest method of determining the temporal distribution pattern of the rain is probably associated with Kifer and Cho. They modeled an artificial hyetograph of the rain based on the descending relationship of rain intensity-continuity time and applying a weight coefficient (the ratio of the time before the peak to the time of the rain continuity) (Mollaei and Telvari, 2005). In 1967, Huff extracted the temporal rain distribution for intense cloudbursts of Illinois with area of 1032 square kilometers by means of the data from 49 rain gauge stations.He represented the temporal distribution models based on the fact that the most intense part of the rain had occurred in which quarter; the results of which had been of great importance in solving the problems related to designing water sources and controlling the floods (Huff, 1967). Pilgrim (1975) represented the temporal distribution pattern of the rain by means of a method called the graphic and computational average in Sydney, Australia. He provided and presented the average cumulative curves of the design rain for intense rains of Sydney by selecting 50 intense cloudbursts with different time bases during 51 statistical years. Furthermore, Chokoma and Shwab (1983) analyzed 454 cloudbursts in the Northern Apalashin in Ohio, America. According to occurrence of the maximum number of rains in each of the three equal temporal components during the rain, they divided the cloudbursts into three types of advanced, medial and lagged. This analysis is the same as the quarter rains in Huff method (1976). TalebBidokhti (1995)used methods presented by Huff (6) and Pilgrim (7) in a study and extracted the temporal pattern of rain distribution in 7 stations of Semnan province. Through investigating the obtained patterns he observed that in the area under study the rains of the third quarter have had the maximum frequencies and in the cloudbursts of the third quarter the most frequent rains have been those with continuity of three hours. Furthermore, Telori et al. (2003) also recommended the rain temporal distribution pattern for the western and eastern watersheds of Caspian Sea by using Huff and Pilgrim methods and reported that the average patterns of rains with continuities more than 12 hourshave to some extent had homogeneous temporal distribution and in rains shorter than 12 hours more than 50 percent of the rain occurs in the second half of raining. In addition, BaniAsadi et al (2003) extracted the pattern of temporal distribution of the rain by graphic method of Pilgrim for Kerman province. They reported that the maximum amount of rain for continuities of 1 and 2 hours longoccurs in the first 25 percent of the continuity, for continuities of 6, 9 and 12 hours long the maximum rain happens in the second 25 percent and for continuities of 18 and 24 hours long, the maximum amount is located in the third and forth 25 percent, respectively. In a study in order to determine the temporal distribution pattern of the rain in the time bases of 1, 3, 6, 9, 12, 18 and 24 hours in Khorasan province, specifying the rain depth in specific time intervals, dividing it into four quarters and applying ranking method to it, HatamiYazd et al. (2005) used the rain recording graphs of 18 stability rain gauges and came to the conclusion that in most short term rains with duration less than 4 hours, the rain intensity in the first 25 percent of the quarter reaches to the maximum amount. Furthermore, in long term rains (with durations more than 4 hours), the maximum amount occurs in the second 25 percent (second quarter) and, generally, in Great Khorasan province with an dry and semi-dry climate more than 50 percent of the rain takes place in the first half of the rain. In addition, Molaei and Telvari (2005) locally obtained the pattern of the rain temporal distribution for 4 stations of rain gauge in Kohgiloye and Boyer Ahmad province by using computational method of Pilgrim and concluded that in rains continuing for 1, 2, 3 and 9 hours, the maximum amount of rain happens in the second 25 percent and in rains lasting for 6, 12 and 18 hours, the maximum amount is in the third 25 percent and for rains lasting for 6, 12 and 18 hours, it occurs in the third 25 percent and, finally, in rains with continuity of 24 hours the maximum amount transfers from the forth 25 percent of the continuity duration to the end of the continuity time (forth 25 percent). In order to specify the temporal distribution pattern in Bam, Tehran, Shiraz and Gorgan cities with continuities of 1, 3, 6, 12, 24 and 24 hours, Golkar (2006) used Pilgrim and Huff methods in his study and concluded that in all patterns of 50 percent, the different quarters of Tehran and Gorgan were so much similar to each other and when one is missing the other could be replaced. Comparing the experimental probable diagram of 50 percent of the methods, they observed that the continuities of the studied stations did not have much similarity to each other, except for the one lasting 48 hours in Tehran . Furthermore, Khaksefidi et al. (2008) used the graphs associated with 9 rain gauge stations over the state to determine the temporal distribution pattern of the rain in Sistan and Baloochestan province. Through dividing the cloudbursts into four quarters and calculating the percentage of raining amounts in each quarter and ranking them, they came to the conclusion that in 2 hour rains in all stations the maximum rain occurs in the first 25 percent. In addition, in continuities of an hour the maximum amount of rain takes place in the first and second quarter. Generally, in Sistan and Baloochestan province, with a dry and desert climate, about 80 percent of the rain in short term continuities occurs in the first and second 25 percent of the raining time and in long term continuities it occurs in the third 25 percent. According to the investigations performed since 1957, studies on the rain temporal distribution patterns have started and goes on up to the present time. Different methods have been suggested and employed each of which displaying different results for a specific region. In the present study, it is attempted to provide the pattern of temporal distribution of rain for the cloudbursts happening in Jashlobar region by applying experiences obtained in other parts of the world.

Geographical and Natural Conditions of the Region

The studied area is located on the Alborz Mountain and branches of MazandaranTalar watershed and is considered as a bungalow in Semnan province being used for grazing of Sangsar nomad livestock. This area, with area of 1800 hectares, is under possession of the research center of natural resources and livestock issues of Semnan province and is known as a research station titled as “Livestock and Grassland Management” of Jashlobar. The geographical location of the lands related to the mentioned station is between 53 degrees and 7 minutes to 53 degrees and 12 minutes in eastern longitude and between 35 degrees and 45 minutes to 35 degrees and 48 minutes in northern latitude and in the northwestern side of Semnan and Shahmirzad cities. The area of the land is 2489 hectares, the average height of the region is about 2700 meters and the average raining is 300 milimeters. The total situation of the studied area is displayed in figure 1.

Figure 1 Geographical situation of the region in Iran and Semnan Province

Materials and Methods

Jashlobar watershed in Semnan province has two sites with standard erosional plans 4 kilometers distant from each other. In this study, these two sites have been used in order to compare different methods of estimating the erosion factor and investigating their abilities in estimation of cloudburst sediments. Six standard plots of 40 square meters (With dimensions of 22.1 in 1.82 meters) have been built in each of these sites. The packs of six plots have been located in two different slopes of 15 and 45 percent and in two directions of south and east, respectively. In each of these sites, a stability rain gauge system has been installed and the rains would be recorded with high precision. The pattern of temporal distribution of rain was then achieved by means of the data obtained from the rain recorders of the rain gauge stations and by graphic method which is a common Pilgrim method in Australia with a great amount of climatic similarities to Iran's. Therefore, a set of intense rains recorded in sites 1 and 2 were selected separately and with time bases of 1, 3, 6, 9, 12, 24 and 48 hours and then the dimensionless cumulative diagrams of them all were implemented on a coordinate's plane and, eventually, the average cumulative curve of the design rain were extracted based on the mentioned continuities.

Pilgrim Method

In this method, a set of intense rains recorded in the studied stations has been selected for different time bases and then the dimensionless cumulative diagram of them all has been implemented on a coordinate's plane and, finally, the average cumulative curve of the design rain has been extracted based on the mentioned continuities. Pilgrim method is based on decomposing the cloudbursts into four quarters and calculating the amount of rain in each of them and, eventually, giving specific ranks to the quarters. Thereafter, through averaging the ranks in each quarter, the index rank is defined and then the final pattern of each rain would be obtained in the form of final pattern row.

Results

In the area under investigation which is located in the watershed of Jashlobar- Semnan, the rains occurred in the region have been analyzed by the stability rain gauges located in the area and the pattern of temporal distribution of the rain has been conducted based on Pilgrim method.

The results obtained from the data exploration of the cloudbursts in the whole area are as followed:

Total amount of the occurred cloudbursts in sites 1 and 2 during the statistical period are 78among which 28 led to runoff and sediments and 50 did not lead to runoff and sediments.

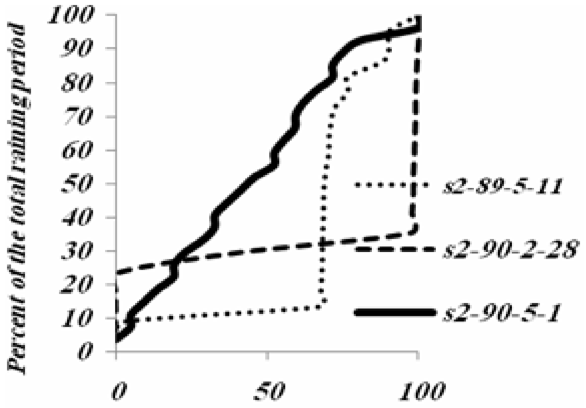

Figure 2- The typical pattern of a 6 hour rainfall without runoff in site 2

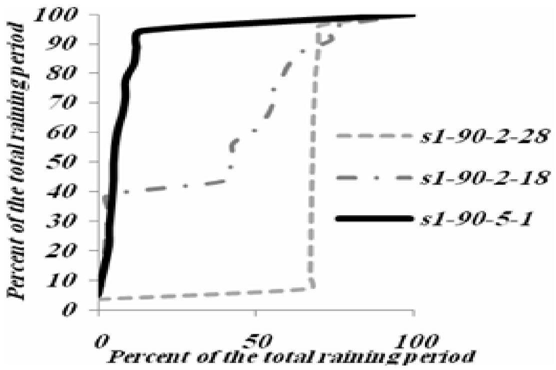

Figure 3- The typical pattern of a 6 hour rainfall without runoff in site 1

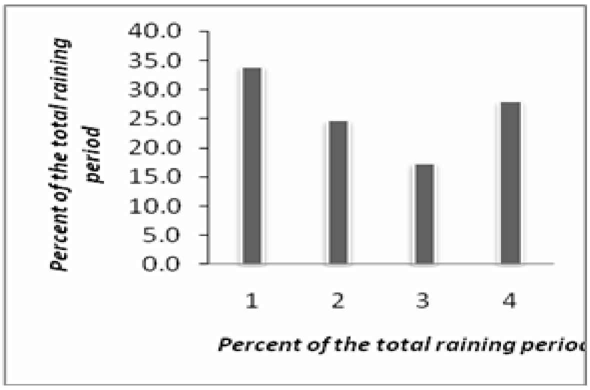

Figure 4- Pilgrim diagram for cloudbursts without runoff and sediment (Site 1)

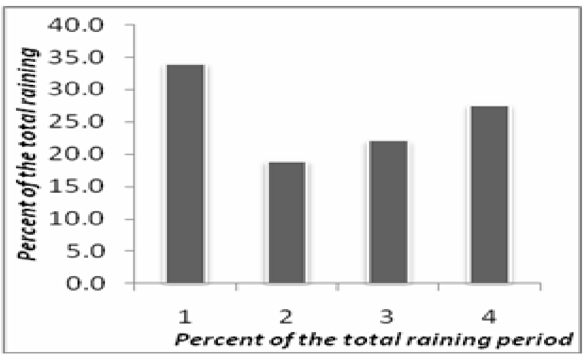

Figure 5- Pilgrim diagram for cloudbursts without runoff and sediment (Site 2)

Table 1- Results obtained from investigating the data related to cloudbursts

Cloudbursts without runoff and sediments	Cloudbursts with runoff and sediments	Number of cloudbursts happened	
19 (63%)	11 (37%)	30	Results obtained from investigating the data related to cloudbursts in site 1
31 (65%)	17 (35%)	48	Results obtained from investigating the data related to cloudbursts in site 2
50 (64%)	28 (36%)	78	Results obtained from investigating the data related to cloudbursts in the whole region

Table 2- History and time base of the occurred cloudbursts

Cloudbursts Occurred	Month of Occurrence	Time Base
Site 1	Farvardin and Ordibehesht	24 and 48 Hours
Site 2	Aban	48 Hours
Maximum amount of runoff and sediment in sites 1 and 2	21.3.1390	48 Hours

Table 3- Pilgrim table for cloudbursts causing runoff and sediments (Site 2)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			rain in each period-points				rank of each periods rainfall				% of rain in period of each rank			
			period				period				rank			
DATA	TOTAL RAIN	rank	1	2	3	4	1	2	3	4	1	2	3	4
90/3/21	11	1	0.1	4.5	5.3	1.2	4	2	1	3	1	41	48	11
89/6/2	8.9	2	1.4	0.2	5.5	1.8	3	4	1	2	16	2	62	20
89/02/13	8.4	3	0.8	1.2	2.1	4.3	4	3	2	1	10	14	25	51
89/01/29	7.2	4	1.2	0.1	5.5	0.4	2	4	1	3	17	1	76	6
89/6/3	5.6	5	1.4	0.1	0.1	4	2	3.5	3.5	1	25	2	2	71
89/8/5	5.3	6	2.3	0.3	1.4	1.3	1	4	2	3	43	6	26	25
(2) 89/8/6	5	7	0.5	0.8	2.5	1.2	4	3	1	2	10	16	50	24
90/4/3	4.9	8	4.2	0.1	0.1	0.5	1	3.5	3.5	2	86	2	2	10
89/1/20	4.8	9	0.5	0.2	0.6	3.5	3	4	2	1	10	4	13	73
89/7/5	4.3	10	0.1	0.4	0.7	3.1	4	3	2	1	2	9	16	72
89/8/16	4.3	11	0.2	1.4	1.4	1.3	4	1	1	4	5	33	33	30
89/8/12	4	12	0.6	1	1.6	0.8	4	2	1	3	15	25	40	20
(1) 89/8/6	3.4	13	0.1	0.1	1.3	1.9	3.5	3.5	2	1	3	3	38	56
89/2/4-5	3.4	14	0.9	1.1	0.8	0.6	2	1	3	4	26	32	24	18
90/2/19	3	15	1.7	0.4	0.8	0.1	1	3	2	4	57	13	27	3
89/8/17	2.7	16	1.6	0.5	0.5	0.1	1	2.5	2.5	4	59	19	19	4
89/8/15	2	17	0.6	0.2	0.2	1	2	3.5	3.5	1	30	10	10	50
				average			2.68	2.97	2.00	2.35	24.4	13.7	30.0	32.0
				standard deviation			1.24	0.98	0.94	1.22	23.9	12.4	20.5	24.9
				assigned rank			3	4	1	2				
				period			1	2	3	4				24.3
				final pattern(%) of total rainfall			24.4	13.7	32.0	30.0				13.6

Table 4- Exact Comparison between graphs with and without runoff

	Raining Percentage in Each Quarter					
	site 1		site2		Average in Two Sites	
	With Runoff	Without Runoff	With Runoff	Without Runoff	With Runoff	Without Runoff
چارک 1	37.13	34	24.39	33.9	30.76	33.95
چارک 2	12.4	24.72	13.68	18.9	13.04	21.81
چارک 3	22.7	17.4	31.99	22.1	27.345	19.75
چارک 4	27.8	28	29.99	27.5	28.895	27.75

Table 5- Analyzing the rains in sites 1 and 2 from the Pilgrim diagram and tables

30% of the rains have happened in this quarter	Rainfalls with and without runoff	First Quarter
Rains have reduced to 13 percent	With runoff	Second Quarter
Quarter 2 has happened more than 20%	Without runoff	
Raining has reduced relative to other quarters	Without runoff	Third Quarter
Raining has increased relative to the second quarter	With runoff	
46% has happened	Without runoff	Third and Fourth Quarters

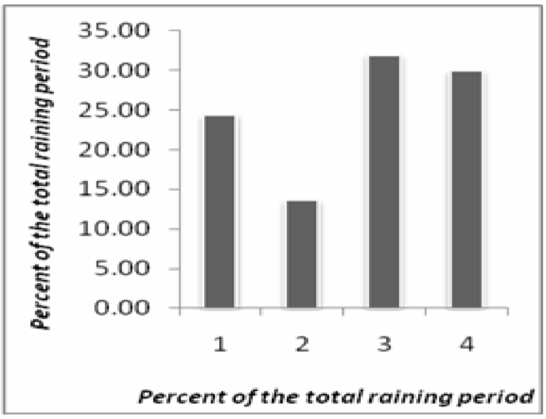

Figure 6- Pilgrim diagram for cloudbursts with runoff and sediment (Site 2)

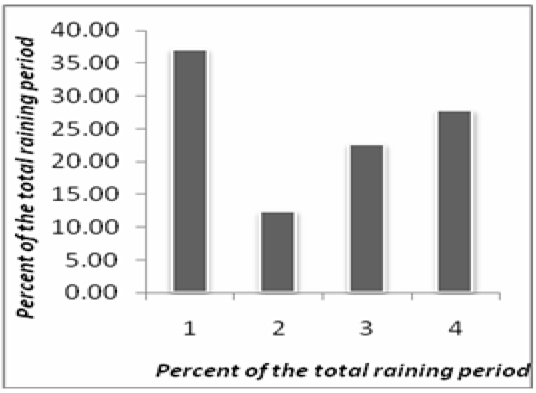

Figure 7- Pilgrim diagram for cloudbursts with runoff and sediment (Site 1)

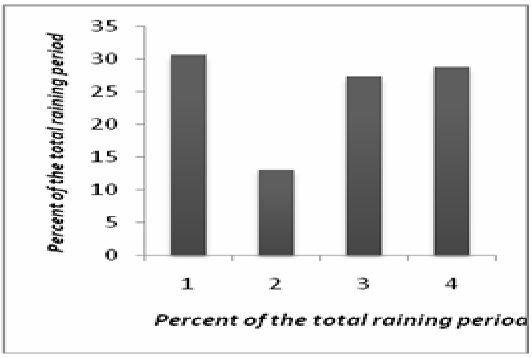

Figure 8- Exact comparison between graphs with and without runoff (Average of 1 and 2)

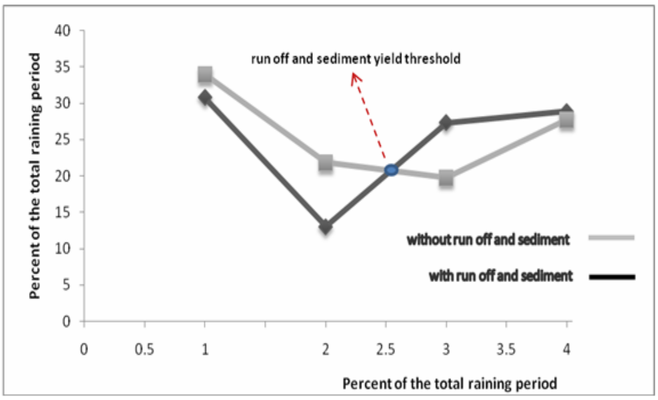

Figure 9- Threshold of forming runoff and sediment (Average of sites1 and 2)

Discussions and Conclusions

Comparing the temporal distribution of the rain in all the rain gauge stations of two sites of 1 and 2 in Jashlobar region shows that the raining pattern in rainfalls causing runoff and sediments are different from the ones without runoff or sediments. In the initial comparison, this result would be obtained that the first quarter rains in both series of the patterns are not that different and have about 3 percent difference, but the point is that in both raining patterns about 30 percent of rains among all of them have occurred in the first quarter. In quarters two and three, less rain has taken place relative to other quarters; however, their difference in two raining patterns in the region shows that in the rain patterns causing runoff and sediments, raining in the second quarter has reduced and only 13 percent of the rainfalls have occurred in this quarter. Meanwhile the rainfalls without runoff and sediments have assigned 20 percent of the rains in the second quarter to themselves. In the third quarter of the pattern of rains without runoff and sediments,amount of rainfalls has been still reducing relative to other quarters but in patterns of rainfalls with runoff and sediments, unlike other patterns, raining in this quarter has increased for more than 50 percent relative to raining in the second quarter. The milestone of the difference between raining patterns is in the third and fourth quarters such that in the patterns without runoff and sediments the total rains of quarters three and four has been 46 percent but in patterns with runoff and sediments, it has been more than 55 percent. It seems that the main reason of the difference between rainfalls with and without runoff or sediments is this difference, because in the patterns without runoff and sediments continuation of raining during the raining time is almost constant but in patterns with runoff or sediments, intense drop in raining in the secondquarter and then its increase in the third and fourth quarters caused formation of runoff and consequently generation of sediments in the area. Through analyzing the obtained quarters by means of Pilgrim method in Jashlobar region and comparing its results with the previous studies shows that the results are in good agreement with the ones obtained by Khaksefidi et al. (2000) and Hatami Yazd et al. (2005). Furthermore, in the rainfalls of site 2causing runoff, rains of the third quarter has had the most rains which had difference with the results obtained by TalebBidokhti (2005) and Raziei (2000) came to the conclusion that the maximum rains have happened in quarters 2 and 3; however, in this study 30 percent of total rains have occurred in the first quarter.

According to the researches performed and the results obtained, the following suggestions are represented:

- Doing similar studies, employing, evaluating and comparing the models obtained from this research in other watersheds of the country.
- Doing more precise investigations with more cloudbursts with vaster temporal distributions in the area under study.
- Doing more precise investigations on changeability of the effective parameters on erosion, such as the soil characteristics and the agricultural management and complementary studies on erosion and sedimentation in the considered area in the scale of cloudbursts.

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