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Understanding the Convergence of Extreme Events of Precipitation, Soil Erosion and Flow in the Representative and Paired Watersheds of Dehgin, Hormozgan

Yahya Parvizi[*a], Mahmood Arabkhedri[a]

[a]Water and soil conservation research department, Soil conservation and watershed management research institute, AREEO, Tehran, Iran

[*]Corresponding Author, E-mail address: yparvizi1360@gmail.com

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Abstract

In the analysis of the relationships between precipitation, flow and erosion events, large and important events that occur with a relatively long return period have a very high contribution to the sedimentation of the entire watershed. Today, the analysis of these events and their mutual behavior has been the focus of researchers. Dehgin representative and paired watershed is one of twelve representative and paired watersheds of the country, which are designed and equipped with the aim of obtaining basic hydrological data and other data needed for watershed management and also evaluating watershed management operations. However, comprehensive study has not been done to analyze and evaluate the quantity and quality of monitored data and data mining of climatic data, flow and soil erosion. In this research, while introducing precipitation extreme events, their impact on flow and soil erosion values in sample and control sub-watersheds of Dehgin watershed were compared. The results showed that data sufficiency in climate and flow monitoring units made it possible to provide a suitable and competent analysis of simultaneous rainfall and flow data as well as the comparison of control and sample sub-watersheds. Also, in the relevant rainfall and erosion events, clear and valuable analyzes of the difference in the behavior of the sample and control sub-watersheds can be observed against rainfall events. But the investigation of erosion and flow in the mentioned sub-watersheds was faced with few comparable scenarios. This shows that with the continuation of data collection in the long term, generalizable data can be obtained from this representative watershed for hydrological modeling in the watershed. In this watershed, extreme flow events have more consistency with higher intensity rainfall events with about 70% overlap in terms of time and quantitative ranking, but most of the extreme erosion events follow the maximum values of rainfall quantity.

Key words: Erosion Plot, Extreme Precipitation, Flood Hydrograph, Paired Watersheds.

1. Introduction

Today, for the development of watershed-scale research and modeling, experimental units are defined and used as representative watersheds. The representative watersheds are hydrological units that represent homogeneous regions in terms of ecoclimatic and physical features such as climate, lithology, land cover and geology characteristics (Parvizi et al., 2021). Paired watersheds are defined in the form of two sub-watersheds, sample and control, within representative watersheds. These two sub-watersheds, which are adjacent to each other, are similar in terms of natural conditions but different in terms of management methods. The control sub-watershed is under conventional management and the sample sub-watershed is managed with scientific methods of watershed management. The data obtained from monitoring in these watersheds is a very good capacity for developing models and modeling hydrological processes and erosion and sedimentation processes in watersheds (Shafiei and Gharari, 2014).

Kellner and Hubbart (2017) used data from experimental stations to model flow in urban watersheds. They showed that the most important parameters with coefficient of determination R^2>0.9 in predicting flow behavior in experimental sub-watersheds were the cover and utilization factors. Caloiero et al. (2017) by examining the runoff data of the Bonis experimental station (representative and paired) in southern Italy from 1986 to the research year, showed that after deforestation, total runoff increased by 50% on average annually. The research conducted by Jafari Takhti et al. (2018) in the paired watershed of Dehgin Hormozgan and Yaghobi et al. (2018) in the paired watershed of Shush Khuzestan shows the efficiency of the data obtained for use in the analysis and modeling of erosion and sedimentation processes in a watershed. Saadati et al. (2008) evaluated the SWAT model in the simulation of daily runoff in the Kasilian watershed. In Kachik representative and paired watershed of Golestan province, Kalteh et al. (2010) evaluated the physical model of LISEM in the simulation of flood water and Hossein Alizadeh et al. (2012) determined the erosion and deposition with Cs137 by portable ultrapure germanium detector.

Understanding the behavior of maximum rainfall events and resulting flow on watershed erosion, especially in areas with the potential of heavy rainstorms, is one of the key needs of research in order to manage environmental crises such as resource erosion and integrated watershed management (Arabkhedri et al. 2021). Parvizi et al. (2021) showed that the investigation and behavior of flow and erosion in the watershed affected by the occurrence of heavy rains can help the hydrological modeling of the watershed and understanding the behavior of maximum flood events in the watershed. These researchers observed and analyzed such a trend in the data obtained from the representative and paired watershed of Zidasht Taleghan. Dehgin representative and paired watershed in Hormozgan province is one of the representative and paired watersheds of the country in which continuous monitoring of hydrological variables such as precipitation, flood and erosion has been carried out on a regular basis, and this watershed includes two paired of sample and control sub-watersheds. After about two decades have passed since the beginning of data collection from this watershed, there is no clear picture and specific analysis of the production data in this station. Although some case studies have been done in the framework of student theses, with the help of data obtained in this area. However, until now, a comprehensive study has not been done on the analysis of the data obtained from the Dehgin representative and paired watershed, especially the hydrometric and erosion data with precipitation events and the compatibility and exploration of the convergence between these data. Therefore, this study was designed and implemented in 2021 to discover data and evaluate this trend.

2. Material and Methods

2.1. Case Study

Dehgin representative and paired watershed is one of the districts of Ziarat Ali in Roudan city and one of its sub-watersheds is the watershed of Esteghlal Dam of Minab. The studies of location, establishment and equipment of this watershed began in 1995 and in 2006 it was completed and launched in the watershed area of 350 ha. The mentioned watershed overlooks the village of Gale-Dej village and Sarzeh River from the north, Abtaykan from the south, the Dej River from the east, and the Rozaieh River from the west (Figure 1). In the representative watershed of 350 ha, the control sub-watershed with an area of 177 ha and the sample sub-watershed with an area of 125 ha are located. The general slope of the area is less than 2%, but the side slopes in some places reach up to 20%. Table 1 shows some physical and geometrical characteristics of representative, sample and control sub-watersheds of Dehgin. It can be seen that, contrary to expectations, the watersheds of the sample and control have differences with each other. According to de Martonne's method, the climate of the watershed is dry due to the average annual rainfall (153 to 188 mm), the average annual temperature of 13.6 °C. Land cover is of the type of tropical range with dominant species from Poaceae, Papilionaceae, Asteraceae and

Cruciferae families in order of importance. Native tropical tree species such as mesquite, Ziziphus, *Acacia oerfota* and shrubs such as Almond and the invasive species of *Prosopis juliflora* can be seen in the watershed.

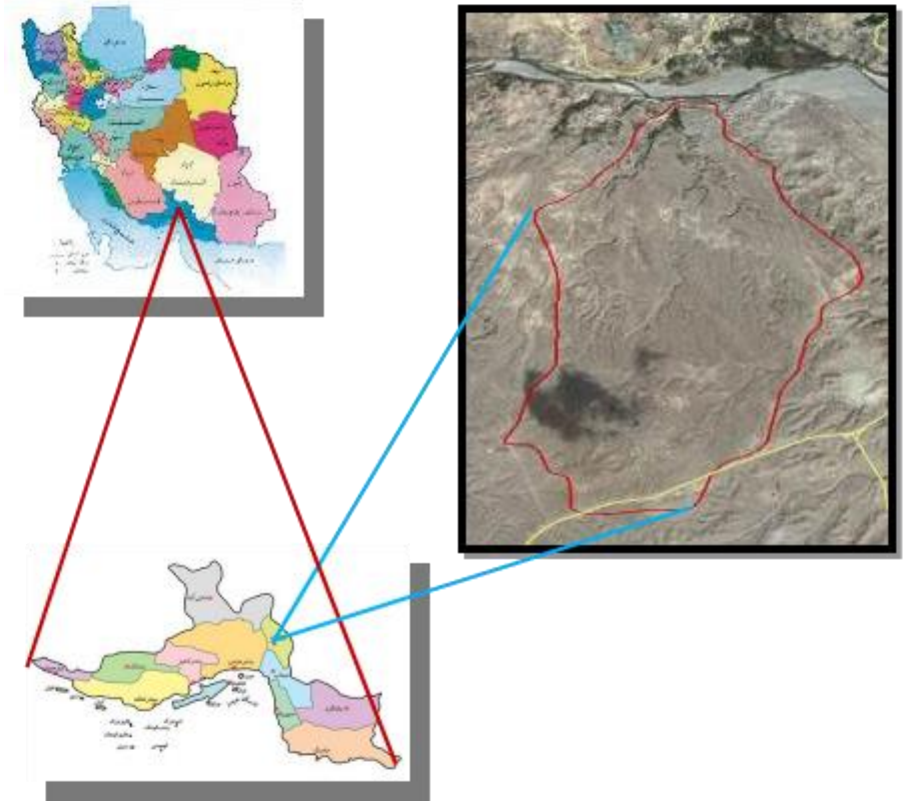

Fig. 1. The location of the watershed of Dehgin representative and paired watershed in Hormozgan province and the country

Table 1- Some physical and geometric characteristics of the representative, sample and control watershed of Dehgin, Hormozgan

Physiographic characteristics	Sample watershed	Control watershed	Representative watershed	unit
area	122.5	177.5	350	ha
Environment	6.5	6.8	9	km
The height of the highest point of the basin	504.8	520	520	meters
Basin outlet height	476	487	460	meters
The length of the main waterway	2.2	3.5	4.5	km
The total length of the waterway	7.4	10.8	23.8	km
Waterway density	6.04	6.08	5.66	-
Gravilius compressibility factor	1.64	1.43	1.22	-
concentration time	0.64	0.99	1.2	hour
Shape factor	0.25	0.2	0.41	-

In the meteorological station of representative and paired watersheds of Dehgin, two rain gauges, Lambrecht and Plovio, are currently used, which are scale and weight gauges, respectively. Flow measuring flumes of Santa Rita type with a capacity of 10 m^3/s are installed at the outlets of control and sample sub-watersheds and are equipped with Thalimedes water level meter. The specifications and technical dimensions of the mentioned flumes are shown in Table 2. Erosion plots with an area of 43.2 m^2 have been installed in three points in both sample and control sub-watersheds, and in each point, three iterations are available and active and have been recording data since 2009 (Figure 2). The volume of the reservoirs of these plots is considered to be two cubic meters due to the heavy rainfall and the forecast of high volume of runoff, and to measure the volume of runoff, a ruler has been installed on the wall of the tank.

Table 2- Characteristics of flumes in the sample and control watershed

Characteristics	Control watershed	Sample watershed
Longitude (UTM)	519492	519302
Latitude (UTM)	3071186	3071152
Flume type	Santa rhita	Santa rhita
Flume bottom width (cm)	206	206
Flume top width (cm)	495	495
Flume height (cm)	170	170
Flume length (meters)	5	5

Fig. 2. Erosion plots of Dehgin watershed; Pay attention to the two cubic meter tank and the surface covered by the armor of these plots

2.2. Research method

At first, the latest available climatic, flow and soil erosion records of the Dehgin watershed were collected from the General Directorate of Natural Resources and Watershed Management of Hormozgan Province. Then the available data were examined in terms of the length of the statistical period, the presence of statistical gaps and other data quality indicators. By removing the outlier data, the descriptive statistics analysis of the data, including the calculation of the average, minimum and maximum values, median, variance and standard deviation, and the indices of skewness and kurtosis were performed on the available data.

2.3. Data analysis

After preparing sorted files of precipitation climatic data as well as hydrometric data of flow discharge and soil erosion from erosion measurement plots in two sample and control sub-watershed, the data were quantitatively sorted in descending order. Then exceptional and extreme events of rainfall, flow discharge and recorded erosion were identified and ranked. The precipitation events were ranked based on the amount of precipitation and the maximum 30-minute intensity of storm, and extreme events were identified. Also, the extreme flow events from the outlet flumes of the subwatersheds were also ranked in descending order. The same action was performed on the recorded erosion data in the erosion plots. In the next step, the corresponding events of flow and soil erosion were also identified and specified for extreme rainfalls. Following the cumulative rainfall graph for the maximum storms, the corresponding rainfall hyetograph was drawn along with the corresponding flood hydrographs. In the following, the effectiveness of maximum rainfall events in the occurrence of maximum flood and erosion in the sample and control sub-watersheds was investigated. By matching the extreme events of the above three variables, the convergence of flow and precipitation in the extreme events of these two variables as well as precipitation with soil erosion were analyzed. Finally, the state of convergence of the changes of these three variables in extreme events was investigated.

3. Results

3.1. Quantitative and qualitative evaluation of data

Data collection and monitoring of climate variables has started since September 2006. During this period, the average annual rainfall was calculated to be 172 mm (Table 3). The ombrothermic curve of the watershed, which is drawn based on the climate data monitored in the statistical interval (Figure 3), shows that the average temperature of the watershed is high. Also, according to Figure 3, although most of the rains occurred during the winter months and later in the fall, but on average, there was rainfall in all months, even if it was low and insignificant, which indicates the region is affected by different climatic fronts. Despite the average annual rainfall of about 172 mm, the maximum daily rainfall recorded in the watershed in one event was 109 mm. This shows that in terms of climate regime, the watershed potentially has heavy and very heavy rains. Despite the relatively low rainfall, which is mostly limited to one season of the year, it indicates the Aridic moisture regime for the soil of the region.

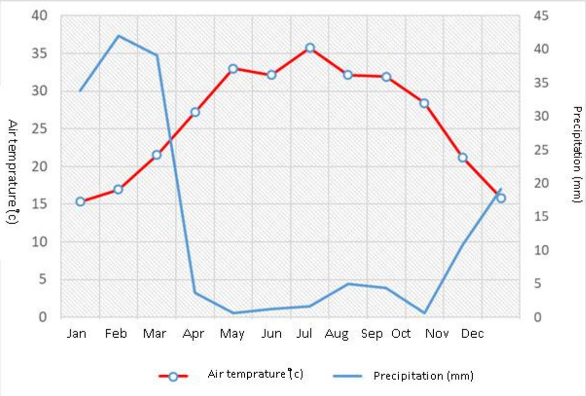

Fig. 3. Ambrothermic curve of Dehgin watershed based on watershed monitoring data in the period from 2006 to 2020

Table 3- Some quantitative indicators of climatic data of Dehgin watershed

15	The number of active years of data collection until the present research
171.9	Recorded average annual rainfall (mm)
31	The number of recorded days with more than 10 mm of precipitation in the statistical period
24	The number of recorded days with more than 20 mm of precipitation in the statistical period
8	The number of recorded days with more than 50 mm of precipitation in the statistical period
1	The number of recorded days with more than 100 mm of precipitation in the statistical period
277	The number of rainy days recorded during the years 2006 to 2020
109	The maximum daily rainfall recorded during the data collection period (mm)
Feb-Mar	The most recorded month of maximum 30-minute rainfall (October to September)

The erosion data of the erosion plots in the sample and control sub-watersheds are available since 2009. Some descriptive statistical parameters of annual erosion values in erosion plots are presented in Table 4. The maximum annual erosion in the sample and control sub-watersheds was 648 and 1145 kg/ha, respectively, and it was related to sheet or surface erosion. Most of the erosion quantities recorded in the control sub-watershed were more than twice of this quantity in the sample sub-watershed.

Changes in the amount of erosion and runoff produced in erosion plots based on the statistics available in the present study are shown in the graphs of Figure 4. As it can be seen, over time and with the passage of years since the beginning of the monitoring program, the amount of erosion and runoff measured in the erosion plots has increased in both sub-watersheds, both in the sample sub-watershed and in the control sub-watershed. The rate of increase in control sub-watershed is much higher. In such a way that in the erosion events of 2017, this quantity reached half in the sample sub-watershed, which is a sign of the effect of conservation measures and flooding on soil erosion. If we do not consider the two exceptional events of 2013, in the rest of the events, the volume of runoff in the erosion plots of the sample and control sub-watershed was almost the same. But the same amount of runoff in the control sub-watershed has caused much more erosion compared to the sample sub-watershed. Another point is that although in both sub-watersheds, erosion also increased relatively with the increase in the amount of runoff, but the rate or intensity of the increase was much higher in the plots of the control sub-watershed.

Table 4-Statistical summary of erosion recorded in the erosion plot of sample and control subwatersheds

Control watershed				Sample watershed			
Total erosion (kg/ha)	Sediment concentration (mgr/litter)	Erosion (gr/plot)	Statistics	Total erosion (kg/ha)	Sediment concentration (mgr/litter)	Erosion (gr/plot)	Statistics
20.0	0.004	0.46	Min	12.78	0.002	0.37	Min
1145.2	3355.6	3.54	Max	648.24	3455. 6	3.46	Max
452.4	1568.5	2.1	Mean	216.35	1224.4	1.47	Mean

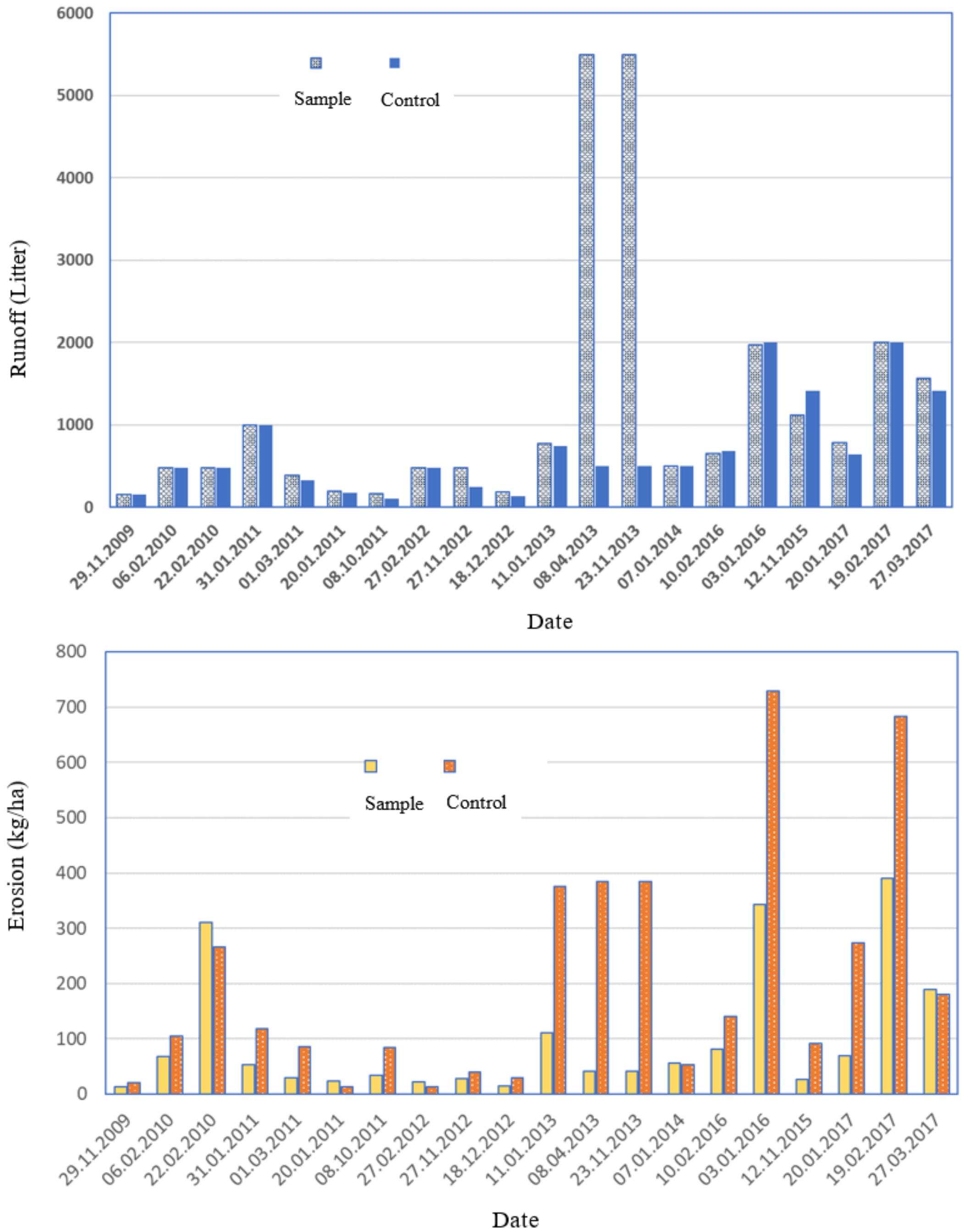

Fig. 3. Runoff and erosion events recorded in the Dehgin watershed from the beginning until now in two sub-watershed, (control and the sample).

3.2. Analysis of maximum events

After extracting the maximum data and determining the ten maximum flow and soil erosion events in the sample and control sub-watersheds, the corresponding amounts of precipitation and its characteristics were identified. At the same time, the flow hydrograph was drawn and the corresponding precipitation hyetograph was also drawn. Then, the trends of changes in precipitation and flow and the relevant indicators were compared. Table 5 shows the descriptive statistics of the maximum rainfall events recorded in the Dehgin watershed. Also, in Table 6, the ranking of the 10 extreme rainfall events based on the height of the rainfall and also based on the maximum 30-minute intensity are presented. As mentioned earlier, the highest rainfall event recorded in the watershed during the statistical collection period is 109 mm. This amount of rain fell in 29 hours in March 2014. The peak intensity of this rainfall was 85 mm per hour (Table 6). The average time of these extreme 10 rainfall events was about 9 hours and the average rainfall height in these events was 30 mm. The 30-minute peak intensity of these rains varied between 3 and 45 mm per hour (Table

5). However, as expected, the maximum precipitation events occurred mostly in the winter quarter. The interesting point is that the two events with the highest intensity of rain did not occur in the rainy season consecutively and happened in September and early October. In one of these off-season rainfall, in August 2015, 10.3 mm of rain fell in 10 minutes with a peak intensity of more than 60 mm per hour in a 10-minute period (Table 6).

Table 5- Descriptive statistics indicators of maximum precipitation events in Dehgin watershed

	30 min intensity (mm/hour)	Max 10 min precipitation (mm)	Max 1 hour precipitation (mm)	Max 6 hour precipitation (mm)	Total precipitation (mm)	Time (min)
Min	3.2	0.8	2.3	5.2	10.0	20.0
Max	45.8	14.8	36.9	97.6	109.1	1760.0
Mean	16.0	4.2	11.2	24.4	30	561.9
Std. deniation	11.44	3.32	7.62	18.21	23.12	412.3

Table 6- Ranking of maximum precipitation events recorded in Dehgin watershed

	Relative share of precipitation from the total precipitation of the year (%)	30 min intensity (mm/hour)	Max 10 minute precipitation (min)	Max 1 hour precipitation (min)	Max 6 hour precipitation (min)	Total precipitation (min)	Time of precipitation (min)	Ending time Hour	Ending time Date	starting time Hour	starting time Date
Max precipitation depth											
1	35.49	37.60	14.40	22.30	45.30	109.10	1760	07:00	15.03.2014	01:40	14.03.2014
2	36.21	34.00	7.90	27.90	97.60	97.70	370	09:30	01.02.2013	03:20	01.02.2013
3	26.46	23.80	6.30	17.80	70.10	91.00	1080	19:10	14.02.2017	01:10	14.02.2017
4	31.32	45.80	11.60	36.90	72.30	77.30	710	05:20	09.12.2009	19:30	08.12.2009
5	22.69	25.40	5.10	22.80	60.90	70.40	750	12:00	12.02.2019	23:30	11.02.2019
6	61.77	37.60	7.20	25.50	61.80	65.60	500	10:50	03.01.2016	02:30	03.01.2016
7	19.95	16.80	4.90	12.80	31.80	61.90	920	18:50	01.03.2019	03:30	01.03.2019
8	16.04	7.20	1.30	5.40	22.40	49.30	1750	13:20	07.01.2014	08:10	06.01.2014
9	31.83	29.40	5.40	22.70	42.70	48.00	970	07:30	02.02.2011	15:20	01.02.2011
10	13.75	21.60	6.80	15.10	35.70	47.30	680	04:20	18.02.2017	17:00	17.02.2017
Max 30 minute intensity											
1	31.32	45.80	11.60	36.90	72.30	77.30	710	05:20	09.12.2009	19:30	08.12.2009
2	22.98	45.80	14.80	24.00	24.40	24.40	80	22:30	10.03.2016	21:10	10.03.2016
3	10.10	40.80	10.30	20.40	20.40	20.40	30	13:10	04.08.2015	12:50	04.08.2015
4	35.49	37.60	14.40	22.30	45.30	109.10	1760	07:00	15.03.2014	01:40	14.03.2014
5	61.77	37.60	7.20	25.50	61.80	65.60	500	10:50	03.01.2016	02:30	03.01.2016
6	36.21	34.00	7.90	27.90	97.60	97.70	370	09:30	01.02.2013	03:20	01.02.2013
7	16.75	30.80	7.40	22.40	38.10	45.20	620	14:30	10.01.2013	04:10	10.01.2013
8	40.92	30.00	5.00	25.00	25.00	25.00	50	10:30	30.09.2010	09:50	30.09.2010
9	31.83	29.40	5.40	22.70	42.70	48.00	970	07:30	02.02.2011	15:20	01.02.2011
10	22.69	25.40	5.10	22.80	60.90	70.40	750	12:00	12.02.2019	23:30	11.02.2019

Examining the maximum discharges occurring in the Dehgin watershed shows that many heavy rains with high intensity have led to high outflows, especially in the control sub-watershed. In such a way that this convergence is observed in two-thirds of extreme events. One of the exceptions is the year 2020, whose maximum rainfall data was not available to the research team for review. The most extreme flow event occurred in the march of 2020, when the outflow of the both sub-watersheds was almost equal, and the peak flow of this stream in both sample and control sub-watersheds was more than 10 cubic meters per second (Table 7). It is worth mentioning that the rainfall data of this event was not available for the present research. Therefore, it was not possible to investigate and determine the rainfall-runoff trend of this event. However, due to the significant increase in the watershed area of the control sub-watershed compared to the sample, this lack of difference can be caused by the non-uniformity of the spatial distribution of rainfall in the two sub-watersheds and the high share of rainfall received by the sample sub-watershed compared to the control. There was a convergence between rainfall intensity changes with watershed outflow with a clear and relatively constant time phase difference (depending on rainfall intensity).

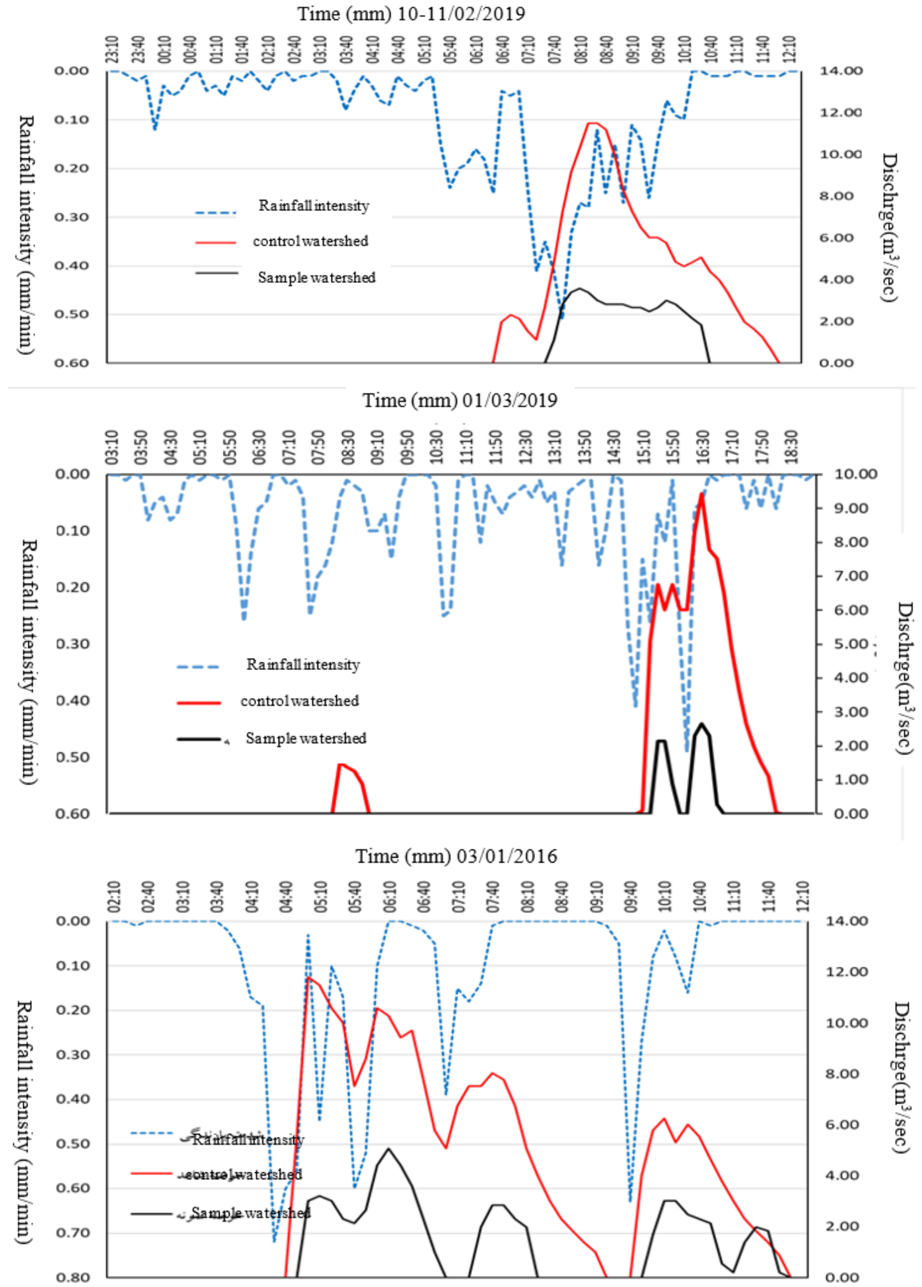

Fig. 5. Three hytographs of maximum precipitation and their corresponding flow hydrographs in the sample and control subwatershed of Dehgin

In such a way, the ups and downs of the rainfall are well matched with the ups and downs of the rising and falling limbs of the flow hydrograph in both sample and control sub-watersheds. (Figure 5) The diagrams in figure 5 clearly show the positive effectiveness of watershed management operations applied in the sample sub-watershed in controlling the flood and outflow from the watershed. In extreme events, the changes in the flood hydrograph and their differences in the two sample and control sub-watersheds are affected by watershed management operations in these two sub-watersheds. In such a way that the shape of the water hydrograph and the changes in the flow volume and even the peak intensity of the flow have been strongly affected by watershed operations in the sample sub-watershed.

Table 7- The ranking of recorded flow events at the outlet of the two control and sample watershed and their corresponding precipitation amounts

Sample Watershed											
Ranking	30 min intensity (mm/hour)	Max 10 minute precipitation (mm)	Max 1 hour precipitation (mm)	Max 6 hour precipitation (mm)	Corresponding peak discharge of the control watershed (liters/sec)	Corresponding flow volume in control watershed (m^3)	Peak discharge (liters/sec)	Flow volume (m^3)	Day	Month	Year
1	not recorded	not recorded	not recorded	--	10073	140218.8	10940	137207.9	22 و 23	3	2020
2	34.00	7.90	27.90	97.60	2961	34088.7	4189	42912.0	1	2	2013
3	45.80	11.60	36.90	72.30	6545	85170.7	3653	30373.9	9	12	2009
4	37.60	14.40	22.30	45.30	3152	32446.6	1110	28312.2	14	3	2014
5	not recorded	not recorded	not recorded	not recorded	6273	55658.5	2254	26654.0	21	2	2010
6	29.40	5.40	22.70	42.70	6006	38095.7	1638	14792.1	2	2	2011
7	23.80	6.30	17.80	70.10	2960	36171.5	1051	11781.7	14	2	2017
8	37.60	7.20	25.50	61.80	3448	36539.6	1298	9298.5	3	1	2016
9	not recorded	not recorded	not recorded	not recorded	5618	36641.6	1498	6615.6	5	2	2010
10	25.40	5.10	22.80	60.90	3249	26251.1	880	5266.7	12	2	2019
Control Watershed											
Ranking	30 min intensity (mm/hour)	Max 10 minute precipitation (mm)	Max 1 hour precipitation (mm)	Max 6 hour precipitation (mm)	Corresponding peak discharge of the control watershed (liters/sec)	Corresponding flow volume in control watershed (m^3)	Peak discharge (liters/sec)	Flow volume (m^3)	Day	Month	Year
1	not recorded	not recorded	not recorded	not recorded	10940	137207.905	10073	140218.8	22 and 23	3	2020
1	45.80	11.60	36.90	72.30	3653	30373.9	6545	85170.7	9	12	2009
3	not recorded	not recorded	not recorded	not recorded	2254	26654.025	6273	55658.5	21	2	2010
4	29.40	5.40	22.70	42.70	1638	14792.063	6006	38095.7	2	2	2011
5	not recorded	not recorded	not recorded	not recorded	1498	6615.56	5618	36641.6	5	2	2010
6	37.60	7.20	25.50	61.80	1298	9298.458	3448	36539.6	3	1	2016
7	25.40	5.10	22.80	60.90	880	5266.68	3249	26251.1	12	2	2019
8	23.80	6.30	17.80	70.10	1051	11781.75	2960	36171.5	14	2	2017

For example, in the flood event recorded on December 9, 2009, the specific discharge from the sample and control sub-watersheds was 248 and 698 cubic meters per hectare, respectively, which is an increase of about 280% in the specific discharge and showed the 80% increase in the instantaneous peak discharge in the control sub-watershed compared to the sample sub-watershed. Another point is that, despite the greater elongation of the control sub-watershed, which is expected to lead to a delay in the beginning of the rising limb of the hydrograph compared to the sample, it can be seen in all the graphs that the start time of the flow in the control watershed is earlier than that of the sample sub-watershed. This case also shows that the effect of watershed management operation on the flow characteristics is more important comparing the effect of the geometric characteristics of the watershed.

Extreme erosion values in recorded events are presented in Tables 8 and 9. The highest annual erosion in the control sub-watershed was in 2013 and in the sample sub-watershed in 2017, which were 1145 and 648 kg/ha per year, respectively. Meanwhile, in 2013, the erosion of control sub-watershed was measured at 1137 kg/ha per year in the erosion plots (Table 8). The most extreme erosion event recorded in the control sub-watershed was on January 3, 2016. In the time interval of the two stages of data recording from erosion plot, from the previous sampling date to the mentioned date, no flow event was recorded in the control sub-watershed. The same issue is also true regarding the maximum erosion event that occurred in the sample sub-watershed, which was equivalent to 390 kg per hectare (Table 9). Although extreme erosion events were recorded in the watershed, the amount of runoff recorded in the watershed was much higher than their corresponding erosion. Due to the special climatic conditions governing the Dehgin watershed climate, rains occur with high intensity and the volume of two cubic meter reservoirs of erosion plots is sometimes not enough. In such a way that the measurement of the amount of sediment resulting from high-intensity rains due to the filling and overflowing of reservoirs do not show the actual values of erosion in the area (Figure 6).

Fig. 6. The filling of one of the 2000-liter tanks of the erosion and sedimentation plots in the Dehgin Basin after rain

Table 8- Annual maximum values of erosion in Dehgin watershed and corresponding precipitation value

year	Precipitation (m^3)	Annual flow volume (m^3)	Annual precipitation (mm)	Erosion in plot (kg/ha)	Runoff coefficient
Control watershed					
2013	344882.5	41522.64	194.3	1145.2	0.12
2017	610422.5	70368.1	343.9	1137.4	0.12
2016	188505	44186.24	106.2	870.4	0.23
2010	396712.5	111539.56	223.5	371.1	0.28
2011	267670	61253.93	150.8	299.8	0.23
2015	358372.5	17346.93	201.9	91.4	0.05
2012	154070	44778.06	86.8	82.98	0.29
2014	532500	62340.65	300	52.88	0.12
2009	438070	85170.69	246.8	20	0.19
Average	0.18	365689.44	59834.09	--	452.35
Sample watershed					
2017	421277.5	16426.49	343.9	648.2	0.04
2016	130095	10660.93	106.2	424.1	0.08
2010	273787.5	33269.59	223.5	378.9	0.12
2013	330505	55909.25	269.8	194.3	0.17
2011	184730	14792.06	150.8	140.7	0.08
2012	106330	4.83	86.8	65.2	0.00
2014	367500	36525.58	300	56.2	0.10
2015	247327.5	1319.7	201.9	26.8	0.01
2009	302330	36037.69	246.8	12.8	0.12
Average	262653.6	22771.79	--	216.4	0.09

Table 9- Erosion maximum events recorded in the erosion plots of sample and control sub watersheds of Dehgin

Year	Erosion in plot (kg/ha)	Maximum intensity of 30 minutes Corresponding rainfall (mm/hour)	Corresponding discharge: Maximum discharge recorded between previous and current reading (liters per second)
Sample watershed			
19.02.2017	390.3	26.5	1110
03.01.2016	342.8	61.77	Not recorded
22.02.2010	311.1	Not recorded	2092
27.03.2017	188.7	13.7	445
11.01.2013	110.4	16.75	Not recorded
10.02.2016	81.3	Not recorded	Not recorded
20.01.2017	69.22	3.29	Not recorded
06.02.2010	67.8	5.6	1.7
07.01.2014	56.2	16.04	Not recorded
31.01.2011	53.7	5.2	532
Control watershed			
03.01.2016	729.8	61.77	Not recorded
19.02.2017	683.7	26.5	Not recorded
08.04.2013	385	7.6	488
23.11.2013	385	3.6	Recorded in 10 day
11.01.2013	375.2	16.75	2431
20.01.2017	273.0	3.29	288
22.02.2010	266.7	23.16	5618
27.03.2017	180.8	13.7	1710
10.02.2016	140.6	Not recorded	Not recorded
31.01.2011	117.8	4.8	1561

4. Conclusion

Dehgin representative and paired watershed is one of the representative watersheds in a dry region with severe erosion conditions and extreme flood events. Also, in terms of vegetation, is the only watershed represents the Persian Gulf-Omani vegetation area. Despite the relatively low rainfall, this watershed has numerous severe flood events during the evaluation years. Climatic data have less statistical gaps than erosion and hydrometric data, and logical trends can be extracted and deduced from the analysis of existing climatic data. Hydrometric data are almost complete except for two years. Nevertheless, it seems that the maximum capacity of flume in the outlet of control sub-watershed is not enough to export the entire flow discharge in some extreme events and in this context, the error will be affected by the extreme events. There is a tangible convergence between two-thirds of the extreme rainfall data with flow and extreme erosion data in the study watershed. For example, the third maximum rainfall has led to maximum flow with rank of 10 and 11 in the sample and control sub-watersheds, respectively. The same rainfall event has caused the highest recorded erosion in the sample sub-watershed and the second highest erosion rate recorded in the control sub-watershed, 390 and 684 kg per hectare, respectively. Higher intensity events appear to be more convergence with extreme flow events. This trend was also observed in the research of Parvizi et al. (2021) in the Zidasht Taleghan. Although this trend between extreme soil erosion and rain intensity is less visible. But most of the erosion events follow the high amount of precipitation or time of precipitation. These findings are in relative contrast with the findings of Nasiri et al. (2017). However, the results of Soltani-Gerdefaramarzi et al. (2014) showed an independent, but in convergence effect of time (rainfall quantity) and intensity of rainfall on the amount of surface erosion. Which is somehow consistent with the results of the present research.

It seems that due to the erosive condition of Dehgin watershed and the conditions and rainfall regime of this watershed, watershed management operations are key necessities for the sustainability of such watersheds. The management status of paired basin and the efforts made to collect data during the past years in this watershed are evaluated favorably. Continuing this process and optimizing sampling methods will help to have a comprehensive data bank in this geographical region of the country. With the help of a predicted data verification and correction structure, this detailed information bank will help the modeling process and the development of simulation models based on the data generated from the monitoring units in this representative and paired watershed.

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6. Disclosure statement

No potential conflict of interest was reported by the authors

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