Runoff and Sedimentations Changes in Various Seasons in Karoun Basin, Roud-Zard Watershed, Iran

Pedram Ansari and Ali Akbar Jamali

INTRODUCTION

Considerable increase of population, followed by the increase in food demands resulted from the changes in consumption pattern necessitates the studies on agriculture sector and food industries as well as soil and water resources regarded as fundamental bases of food production in the country. It should be stated that lack of accurate and effective management system for maintaining soil and water resources causes the considerable increase of soil and water resources destruction. On the other hand, water reservoirs, including natural water reservoirs of earth dams and huge ones in order to supply the drinking water and irrigation water for agriculture sector are of significant importance. Considering two elements of soil and water for achieving sustainable development, managing and policy making in this area have to be regarded. In order to study the effects of precipitation rate of runoff and sedimentation in various seasons, six hydrometric stations and eight rain gage ones were used in Roud-Zard watershed, Khuzestan province, Iran. Statistical analysis of runoff and precipitation concerning the mentioned hydrometric stations has been conducted during 1978 and 2011. Rain data were normal and four years selected for comparison. Also, the produced sediments were examined by the rating curves in the studied watershed. There is most rainfall in the winter, but most discharge is produced in spring. This shows a lag between rain and discharge. In spring wet soil and ground water in the area can increase the discharge. We found that in fall season there is more sediment yield instead of winter or spring. In this area of Iran farmers after gathering vegetation cover in the farm at the end of the summer season, the soil is bare and it is exposed to the rainfall erosivity. This factor can cause erosion and produce more sediment in fall season.

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the importance of dams’ water reservoirs, the avoidance of dam filling is regarded as one of the most important goals of watershed engineering. Suspended sediments in surface water flows which are created by the seasonal rains on the ground may deposit at the stream bed and finally dams and they significantly reduce the reservoir volume during a short period resulting in the dam destruction. Rainfall-runoff is introduced as one of the most complicated hydrologic processes. For many years, scientists have tried to understand the conversion process of rainfall into runoff in order to predict, simulate and control the floods, reserve water, improve water quality, develop wildlife and produce energy as well as other applications such as drainage, fish farming and recreation [3]. Hosseini and Aghabegi identified the relationships between discharge and flood using Karkheh watershed data in Paypel station and suggested a multivariate nonlinear method in order to estimate maximum momentary discharge and mean annual peak [4]. Akhondi applied the curve number method (CN) to estimate the flood by the means of GIS in the northern Karoun basin [5]. Results indicated that as the area of watershed increases, correlation coefficients of the observed and estimated discharges decrease. Yousefvand et al. studied the effects of sedimentation data classification according to the measurement time in order to estimate the suspended load of Ghare Soo River and concluded that in the model by which high and low months’ data have been classified, mean square error is less than the other models so that the model has been selected as an optimum one [6].

It was confirmed by Mosaedi and Mohammadi (2002) to determine the sedimentation rate of Gorganrood River [7]. Zarin (2005) investigated 28 hydrometric stations in Karoun and Karkheb basin and recognized the most effective elements, including mean precipitation, area, mean height, channel slope and Gravelius coefficient in minimum flow [8]. Also, Manochehri (2005) analyzed discharge data of flow and sedimentation for 12 precipitation events in Garan watershed, Kordestan province and found no meaningful relationships between discharge and sedimentation rates due to the effects of snow melting in winter and spring [9]. It has led to the intense variations in discharge value, especially for precipitation events. Bronstert and Bardossy (2003) simulated runoff based on the time variations of rainfall intensity and reflected the importance of these variations in order to produce runoff as well as moderate rainfalls [10]. Also, Achite and Ouillon (2007) studied the regression relationships of momentary and daily discharge values and sedimentation concentration with the help of 1432 samples taken from the 138 floods during a 22 year period in one of semi-dry watersheds of Algiers and concluded that the annual variations of suspended sedimentation concentration is more than the seasonal ones [11].

Sadeghi et al. investigated discharge-sediment data of 6 stations in a mountainous, forested watershed with the area of 8.4 ha in Japan [12]. Using statistical analysis and regression functions, they found that the best fitted rating curve for all the stations estimated the sediment value more than the observed one and did not improve the classified information involving time, discharge and sediment values and flow separation by the means of correction coefficient of rating curve. However, the best estimation has been done on the basis of discharge-sediment data concerning the rise and drop of the hydrologic flow curve.

Khanchoul et al. studied the suspended sedimentation in one of southern Algiers’ watersheds and used the optimum rating curve achieved by the classification of the discharge values based on the flood season in order to estimate the sedimentation rate of flood events without precipitation graphs and sampling. The results were acceptable [13]. In addition, they observed that the variability of sediment transport is dependent on seasonal rainfall distribution and geomorphic properties of the desired watershed. Herder (2013) believed that surface runoff and soil loss are more likely to be due to land use and precipitation regimes at the hillsides of Carest in west southern China [14]. Results showed that surface runoff and soil loss values at the hillsides of Carest are highly low as compared to the other regions because dual hydrologic structures such as underground drainage systems in this region can be influenced by rainfall recharge and runoff processes. Much water of rainfall events may be transferred through the pores of limestone and underground fractures, whereas little water flows as surface runoff.

In this paper, the objective is studying the effects of precipitation rate of sedimentation and runoff values. This is to be investigated during different seasons in Roud-Zard watershed. Thus, it can be concluded that the precipitation and various conditions involving vegetation and soil moisture affect the sedimentation and runoff values. The subject area and relevant to journal: Rainfall, runoff and sediment effect on soils quality and erosion. This subject affect on vegetation cover as biology life in the environment and this relate the paper to the scope of the journal.

Methodology:

After collecting the required data including rainfall, discharge and sediment, several hydrometric stations were selected and then, data were statistically separated (identifying remote data and correcting incomplete ones) based on the seasons. Finally, the effects of precipitation on sediment and discharge values have been investigated using SPSS software.

MATERIALS AND METHODS
Study Area:

Roud-Zard watershed with the area of 1346 km$^2$ is one of Karoun River branches located in the west, south of Iran at the ranges of the Zagros Mountains between eastern longitude of 49° 25’ to 50° 5’ and northern latitude of 31° 6’ to 31° 42’. Hydrometric station of Jokang is located at the exit of the watershed. In this research, 6 hydrometric stations existing in the desired area have been studied. A map of hydrometric and rain gage stations in the watershed has been prepared using ArcGIS software and demonstrated in (Fig. 1). The study stages in brief exist in a flow chart (Fig. 2).

![Fig. 1: Roud-Zard watershed and sub watersheds with hydrometric and rain gage stations in Khuzestan Province in Iran.](image)

Fig. 2: Methodology flow chart.

**Statistical investigation of hydrometric stations:**

For the hydrometric stations, data of mean monthly discharge have been gathered by the Water, Department of Khuzestan province during 1978-2011. It should be mentioned that two stations of Baghmalek and Cham-Koreh have the data of 1978-1989 and the data of 2006 are available for the Mal Agha station. Three stations of Pol-Manjenigh, Mashin and Jokang have complete data, though Pol-Manjenigh stations have incomplete data for few months and Mashin and Jokang ones are of incomplete data for one year.

To reconstruct the incomplete data, the correlation matrix of monthly discharge data was given for six hydrometric stations. Regarding the matrix, the correlations of two by two stations were meaningful. Calculating the correlation coefficient by the use of regression relationships [15], incomplete data were estimated.

**Statistical investigation of rain gage stations:**

In this paper, the existing stations have been studied in the desired region. Results showed that there are 8 Rain gage stations in the region. Monthly precipitation data were presented by the studied Rain gage stations till 2011. Since the statistical period of discharge and sedimentation is related to 1978-2011, the same period has been regarded to perform the required calculations.

**Precipitation:**

About 36 years data of rain, discharge and sediment were existed. Rain data were normal and four years (1980, 1990, 2000 and 2010) were selected for comparison (Fig. 3).

Discharge (run off) comparison in four years and four seasons (m$^3$/season/km$^2$) shows spring has had highest run off (Fig 7). Statistical comparison between season discharge and sediment yield (ton/Season/km$^2$) in SPSS software was done (Table 2) and (Fig. 7).
Fig. 3: Annual precipitation in 8 rain gage stations on the road-Zard watershed, selecting 4 years to analyze.

Results:

Precipitation comparison in four years and four seasons (mm) and % shows summer has lowest and winter has highest precipitation. (Fig 4, 5). Statistical comparison between season precipitations in SPSS software was done (Table 1) and (Fig. 6).

![Figure 4: Precipitation in years and seasons (mm).](image)

![Figure 5: Precipitation in years and seasons %](image)

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Test</th>
<th>Sig. *</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 The distribution of 1980 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.000*</td>
<td>Reject the null hypothesis</td>
</tr>
<tr>
<td>2 The distribution of 1990 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.000*</td>
<td>Reject the null hypothesis</td>
</tr>
<tr>
<td>3 The distribution of 2000 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.000*</td>
<td>Retain the null hypothesis</td>
</tr>
<tr>
<td>4 The distribution of 2010 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.000*</td>
<td>Retain the null hypothesis</td>
</tr>
</tbody>
</table>

*Asymptotic significances are displayed. (Independent samples and nonparametric test, The significance level is 0.05*)

For study relation between discharge and sediment rate, the sediment rating curve was made (Fig. 8). Using this graph can help in rebuilding imperfect data and analyzing the relation between discharge and sediment.

Mean seasonal special discharge:

Dividing the discharge amount by the area of watershed in every season, specific discharge index of each region can be computed to compare mean seasonal discharge values. Specific seasonal discharge values of the desired watersheds are presented in table 3. It should be stated that specific discharge value is in m$^3$ season$^{-1}$.
As it has been shown, the specific discharge value of all the seasons in Mal Agha station is higher than the other ones. In addition, the lowest value is attributed to Baghmalek station.

![Fig. 6: Precipitation in different years and seasons (mm) (Nonparametric test, Independent samples, Kruskal Wallis test, sig. .000) a=1980, b=1990, c=2000, d=2010.](image)

**Table 2:** Hypothesis Test Summary for comparison of seasonal special discharge (m^3/season/km^2) and seasonal special sediment yield (ton/Season/km^2).

<table>
<thead>
<tr>
<th>Null Hypothesis 1</th>
<th>Test</th>
<th>Sig. special discharge</th>
<th>Sig. special sediment yield</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The distribution of 1980 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.004*</td>
<td>0.005*</td>
</tr>
<tr>
<td>2</td>
<td>The distribution of 1990 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.021*</td>
<td>0.014*</td>
</tr>
<tr>
<td>3</td>
<td>The distribution of 2000 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.227</td>
<td>0.150</td>
</tr>
<tr>
<td>4</td>
<td>The distribution of 2010 is the same across categories of season</td>
<td>Independent Samples Kruskal Wallis test</td>
<td>0.142</td>
<td>0.052</td>
</tr>
</tbody>
</table>

Asymptotic significances are displayed. (Independent samples and nonparametric test, The significance level is 0.05*)

![Fig. 7: Comparison of seasonal a=special discharge (m^3/season/km^2) in 1980 sig. 0.004, b= special discharge (m^3/season/km^2) in 1990 sig. 0.021, c= special sediment yield (ton/Season/km^2) in 1980 sig. 0.005, d= special sediment yield (ton/Season/km^2) in 1990 sig. .014.](image)
Fig. 8: Sediment-discharge rating curve in hydrometric stations in Roud-Zard watershed.

Mean seasonal special sedimentation:
After determining the sedimentation rating relationships for various seasons by the means of mean discharge data in previous stages, sedimentation value has been calculated for different years and different seasons. Dividing the mean seasonal sedimentation value by the area, specific seasonal sedimentation index is to be achieved in order to compare the sedimentation values in the watershed. Specific sedimentation value is in ton/season/km$^2$. As it has been seen, the specific sedimentation amount of winter in Pol-Manjenigh watershed is considerably more than the other ones.

Increase of discharge and sedimentation by increasing precipitation:
After calculating specific precipitation, discharge and sedimentation values, precipitation-discharge and sedimentation ratio has been estimated in the desired watershed. Discharge-sedimentation ratio in Pol-Manjenigh watershed in humid seasons is 19 times more than dry ones which is the highest value. In Cham-Koreh watershed, the ratio is 4 times, which are regarded as the lowest one. Finally, mean ratio is computed as 10 times indicating that the precipitation rate in humid seasons leads to the increase in discharge value which is 10 times more than dry ones. Considering the sedimentation rate, the highest precipitation-sedimentation ratio as 32 times in dry seasons is related to Pol-Manjenigh station as compared to dry ones. The lowest ratio estimated as 2 times can be attributed to Baghmalek and Cham-Koreh stations. Finally, mean ratio is computed as 4 times indicating that the precipitation rate in humid seasons leads to the increase in sedimentation value which is 4 times more than dry ones.

Comparison of seasonal special discharge:
A meaningful difference has been observed between the values of seasonal special discharge (m$^3$/season/km$^2$) at 95% sig. level in the region in 1980 and 1990. The null hypothesis is rejected since meaningful difference of seasonal special discharge is evident. In 1990 and 2000, null hypothesis have not been rejected and no meaningful difference was seen between the values of seasonal special discharge. This fact can be determined in comparison with the precipitation of the desired years during the statistical period of 1980-2010. By comparing the seasons, it may be found that winter, fall and spring are of higher values of seasonal special discharge resulting from more precipitation values in the studied region during these seasons. Figures (9 and10) also (7a and 7b) show the season and year separation along with the values of seasonal special discharge that are low to high from left to right. These comparisons indicate the highest and lowest values for winter and summer, respectively. These figures demonstrate the comparability presenting the highest and the lowest percent of seasonal special discharge in winter and various seasons for 1980 and 2000, respectively. This can be caused by different precipitation rates in these years.

Comparison of seasonal special sediment yield:
According to the figure (11 and 12) also (7c and 7d), there is a meaningful difference between the yields of seasonal special sediment in various seasons at 95% sig. level in 1980, 1990 and 2010. The null hypothesis is rejected since a meaningful difference between the yields was seen. In 2000, the null hypothesis is retained and a meaningful difference between the yields has not been found. It can be specified by the comparisons of precipitation rates in 2000 during the statistical period of 1980-2010. It may be understood that winter, fall and spring are of higher yields of seasonal special sediment which may be resulted from more precipitation rates in the desired region during the above-mentioned seasons. Figure (11 and 12) shows the season and year separation along with the yields of seasonal special sediment that are low to high from left to right. These comparisons indicate the highest and lowest sediment yields for winter and summer, respectively.
Figures (11 and 12) also (7c, 7d) demonstrate the comparisons presenting the highest and the lowest percent of seasonal special sediment in winter and various seasons for 1980 and 2000, respectively. This can be caused by different precipitation rates in these years. Seasonal special discharge and seasonal special sediment are proportionally low or high, indicating the direct relationship between discharge and sediment.

Fig. 9: Season and year separation with the values of seasonal special discharge (m3/season/km2).

Fig. 10: Comparisons of the highest and lowest percent of seasonal special discharge in %.

Fig. 11: Season and year separation with the values of seasonal special sediment yield (ton/Season/km2).

Fig. 12: Comparisons of the highest and lowest percent of seasonal special sediment yield in %.

Discussion And Conclusion:
Dividing precipitation, discharge and sedimentation values by the area of watershed for each season, specific precipitation, discharge and sedimentation indices can be computed in order to compare their seasonal values of the desired watersheds. In this study, it has been found that the increase of the area will reduce specific discharge amount. This result is confirmed by Akhondi (2001) who conducted a study in the northern Karoun
It is due to the increase of water potholes and wetlands as well as more opportunity for water penetration into the ground which may reduce the discharge amount.

Sedimentation data were classified on the basis of dry and humid seasons by which better results have been achieved while modelling discharge and sedimentation relationships because of precipitation variations in various seasons which play important roles in the sedimentation amount. It is in conformity with the results reported by [6, 7, 11, 12, 13, 16, 17].

According to the results, precipitation in humid seasons (spring and winter) leads to the increase in discharge amount as well as sedimentation rate. The area is reversely related to the sedimentation and runoff values that may be in agreement with the results achieved by [4, 8, 12, 13, 18, 19]. Precipitation rate and area are regarded as important parameters affecting the runoff and sediment amounts in the watersheds. It has been confirmed by the studies conducted by [8, 17, 20]. In the end can conclude about rainfall and sediment in this watershed, there is most rainfall in the winter but most discharge is produced in spring. This shows a lag between rain and discharge. Watershed is vast and some water penetrate to soil in winter. In spring wet soil and ground water in the area can increase the discharge. Contributions of this subject to knowledge.

Finally, we expect more sediment yield in winter because of more rainfall, but we found that in fall season there is more sediment yield. In this area of Iran farms after gathering vegetation cover at the farm at the end of the summer season, the soil is bare and it is exposed to the rainfall erosivity. This factor can cause erosion and produce more sediment in fall season.

REFERENCES


