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Analysis of Relative Flows in the Catchments without Gauging Station; Case Study: West of Urmia Lake Basin

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ORIGINAL ARTICLE

ABSTRACT
An important factor for designing soil and water projects is the estimation of annual runoff volume at project location, with no precise runoff data. One common method for estimation of the runoff is through meteorological parameters and physical characteristics of the region. The present paper attempts to complete the statistics from partial stations via linear regression and the randomness of the data was tested by the RUNTEST test and its results were satisfactory. Modeling relative annual and monthly runoffs in Iran is an essential task for precise planning of water projects engineering in catchments without hydrologic statistics and data. One important factor to be considered in understanding the catchments' hydrologic behavior is investigation of output currents in different time periods of daily, monthly, and annual scales. Thus, this study attempts to use multivariate linear regression to provide a decent model for estimation of annual runoff for the catchments of the Nazloo-Cahi, Barandooz-Chai, Shahr-Chai and Roze-Chai Rivers in the west of Urmia Lake.
Keywords: Watershed, Annual Runoff, Rainfall, Physical Characteristics, Multivariate Regression, Urmia Lake

INTRODUCTION

One of the methods of tackling the problem of draught is an efficient use of water resources. It is recommended that rainfall and snowfall and other underground and surface water sources be used in an optimum way and this may not be possible unless hydrologic phenomena are fully known. Water deficiency has long been a big problem in Iran and has caused such technical, cultural, economic and social problems that even the modern scientific use is still affected [1].

Nowadays, water resources management is considered as one of the basics of sustainable development. Although more than eight decades ago hydrology emerged as a science, it has advanced enormously during this period. The primary consideration about the water resources in a region is identifying them and evaluating their potential. Hydrology studies on surface waters are essential to programming and planning water projects. The basic principles of all hydrology studies on surface waters and all other water projects are statistical data and generalizing them. Highly accurate statistics and long-term data collection may play a huge role in the preciseness lack of accurate statistics and short-term data collection necessitates selecting a suitable method for estimation of hydrological factors with the lowest possible rate of error [8].

A catchment's runoff is known by many different names including average annual discharge, average seasonal and monthly discharges, maximum flood discharge, average discharges of short-term aridity (minimums) or excess of water (maximums), volume of the flood, volume of the monthly and yearly quota each of which focus on a specific parameter of runoffs. For instance, when we talk about the maximum yearly momentary flood discharge, topography, morphology and other features identifying catchment are generally focused. On the other hand, in case of average monthly and yearly volumes, the area of the catchment and yearly or monthly rainfall is considered to be important.

The main aim this study attempts to reach is to find the equations with which the runoff of the Urmia plain could be calculated. These equations are computed through analyzing regional runoffs. In order to do so, data from hydrometer stations and information about the catchments in the Urmia plain were investigated and then logical equations were offered for the region. These equations may be of great help in any plan for the water resources of the catchments that lack accurate statistics and have similar features with the regions with statistics.

A Brief Introduction to the Region under Study

The region under study was the West Azerbaijan province in northwestern Iran. The western catchments in the west of Urmia Lake including the Barandooz-Chai, Nazloo-Chai, Roze-Chai and Shahr-Chai Rivers' catchments. The Discharge gauging stations in this region were of different areas of 185 km^2 to 2029.56 km^2. The

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region under study is located in the latitude of 37°-13' to 37°-44' and longitude of 44°-48' to 45°-14'. The highest and lowest points were 1600 and 1252 meters above sea level.

METHODOLOGY

A list of Discharge gauging stations was made for the region under study. Since the statistics from partial stations were to be completed and generalized, the data from some stations not correlating with the neighboring stations with short-term statistical period were simply omitted from the study. Then another list was made for the thermometer and Pluviometer stations under control of the Ministry of Energy of the Islamic Republic of Iran and The Regional Water Department of West Azerbaijan. Then the final list was compiled according to the possibility of completing and generalizing statistics of the partial stations and homogeneity test for the basic time period of the study to be used in subsequent investigations.

The period selected for this study was 30 years from 1975 to 2005. Using the RUNTEST program, a test of homogeneity was conducted for the discharge and rain data from all stations in the region. The regression model and SPSS program were used for recovering the partial statistics of the runoff discharge.

In order to provide the runoff model, raining, temperature, and height data of the stations were used to get the gradient equations of raining and temperature (fig. 1). Then, physical characteristics of the catchments were excerpted from topography maps and the average height of them was identified on hypsometry curves. The model was later tested to estimate the runoff through multivariate linear regression models.

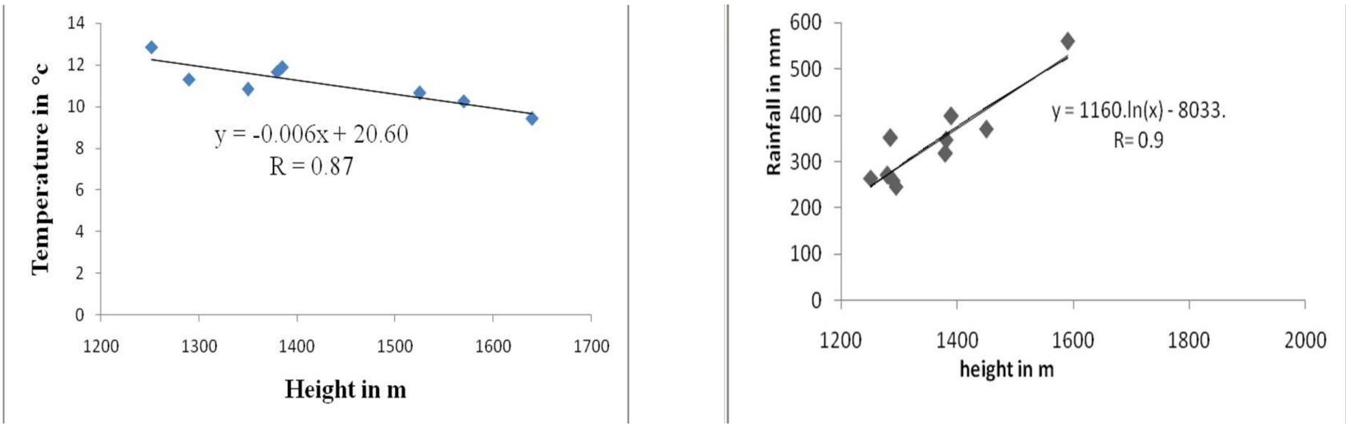

Figure 1. Gradient equations of raining and temperature

Multivariate Linear Regression Models

The relationship between the annual volume of the runoff, physical characteristics of the catchment and meteorology parameters, a multivariate linear regression model was used that had the following order:

$Y= m_0+m_1X_1+m_2X_2+m_3X_3+ \ \dots$

Where Y is the estimated annual runoff

X_i, i= 1, … is the independent variables and

m_j, j= 1, … is the constant coefficients of the regression equation.

In order to increase the accuracy of the equations, constant coefficients of the regression equation must possess the following features. There should not be a relation among independent variables and also, physically speaking, the independent variables ought to have a logical relation with the independent variable. Finally, the independent variables' coefficients should be logical after the regression for instance the higher rainfall should result in a larger volume of runoff.

The present study had several combinations of (physical and meteorological) parameters as the independent variables of the runoff prediction models and offered models with highly and significantly correlated coefficients. LINEST command of the Microsoft Excel was applied to reach the multivariate linear regression equation and the coefficients were computed through regression method. For instance, desirable results were obtained when the LINEST command was applied between the area of the catchment, slope of the catchment and average height of the catchment as independent variables and average volume of annual runoff as the dependent variable.

The Model for Finding the Annual Runoff Based on Physical Characteristics of the Catchment

In this case, physical characteristics of the catchments like area, average slope, average height, and Gravelius coefficient were considered as independent variables of the model. The results revealed that coefficients of area and slope of the catchment were positive and the coefficients of height and Gravelius were negative i.e. as the area and average slope increase in the catchment, the runoff takes a decreasing trend. This may be due to considering these two relatively related parameters of height and slope and this may result in the direct relation between runoff and slope and negative relation between runoff and the height. As the Gravelius coefficient increase, the runoff decreases. It could be said that the increase in the Gravelius coefficient stretches the catchment and higher absorption of the rainwater and as a result lower runoff from rain.

Considering the result of the equation, multivariate regression model took the following form:

$Y= 634.72+0.18A+ \ 6.9S- \ 0.11H- \ 316.06F_G$

Where A is the area of the catchment, S is the average slope of the catchment, H is the height of the catchment and F_G is the Gravelius coefficient.

Figure 2 compares the observed runoff and the predicted volume. The X is the predicted runoff and Y is

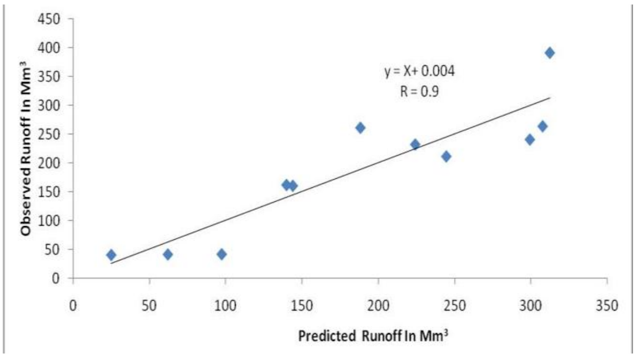

Figure 2. Comparioson of observed and predicted runoff based on physical characteristics of the catchment

The Model for Finding the Annual Runoff Based on Meteorological Parameters and Physical Characteristics of the Catchment

All physical characteristics and meteorological parameters from all hydrometer stations were taken as independent variables. Table1 shows the results of the model. Considering this table, it could be concluded that the coefficients of area, slope and average rainfall were positive, the Gravelius coefficient and height were negative and the temperature coefficient was zero. In

the observed runoff in the hydrometer stations. The correlation coefficient is 0.9.

other words, the larger area and the bigger slope increase the volume of the runoff. As the rainfall increase, the runoff increases as well however, the raise in the Gravelius coefficient decreases the runoff. Since the temperature coefficient is zero in this model, it may not have any effect on the volume of the runoff. Thus, one of the parameters of the model is omitted. The important point worth mentioning is that the height coefficient is negative. This could be justified by the point that since the average rainfall of the catchment is calculated through gradient method, the model has taken effect of height just once.

Considering Table 1, the multivariate regression model for the above-mentioned case will be:

$$Y= 743.81+ 0.17A+ 6.71S- 0.32H+ 0.39P-308.36F_G$$

Where A is the area of the catchment, S is the average slope of the catchment, H is the height of the catchment, P is the average rainfall and F_G is the Gravelius coefficient.

Figure 3 compares the observed runoff and the predicted volume. The X is the predicted runoff and Y is the observed runoff in the hydrometer stations. The correlation coefficient is 0.9.

Table 1. Meteorological parameters and Physical characteristics of the Catchment

Station	Runoff (McM)	Area (Km^2)	Average Slope	Height (m)	Rain fall (mm)	Temperature (°c)	Gravelius coefficient	prediction
	y	x1	x2	X3	x4	X5	x6	
Abajalo sofla	240.62	2029.56	21.45	2048.90	817.21	6.88	1.97	299.87
Tapeak	391.37	1799.77	23.43	2120.00	856.80	6.40	1.82	312.66
Karim abad	211.29	569.62	33.85	2288.30	945.47	5.28	1.52	244.16
Goyjali	40.09	388.57	10.05	1707.00	605.30	9.17	1.79	21.89
Kalhor	40.96	185.00	17.67	2466.00	1032.28	4.08	1.47	62.19
Mir abad	160.20	190.03	35.42	2499.00	1047.71	3.86	1.59	140.71
Band	161.78	416.52	25.42	2145.80	870.84	6.23	1.63	143.38
Gasemlo	41.31	341.22	19.25	1931.00	748.42	7.67	1.66	100.19
Hashem abad	232.17	415.18	18.33	2050.00	817.83	6.87	1.24	225.57
Dizaj	261.12	660.71	17.66	1948.10	758.65	7.55	1.51	189.42
Babarood	263.70	1155.47	16.64	1875.70	714.69	8.04	1.41	304.57
	m_6	m_5	m_4	m_3	m_2	m_1	m_0	
	308.36	0.00	0.39	-0.32	6.71	0.17	743.81	

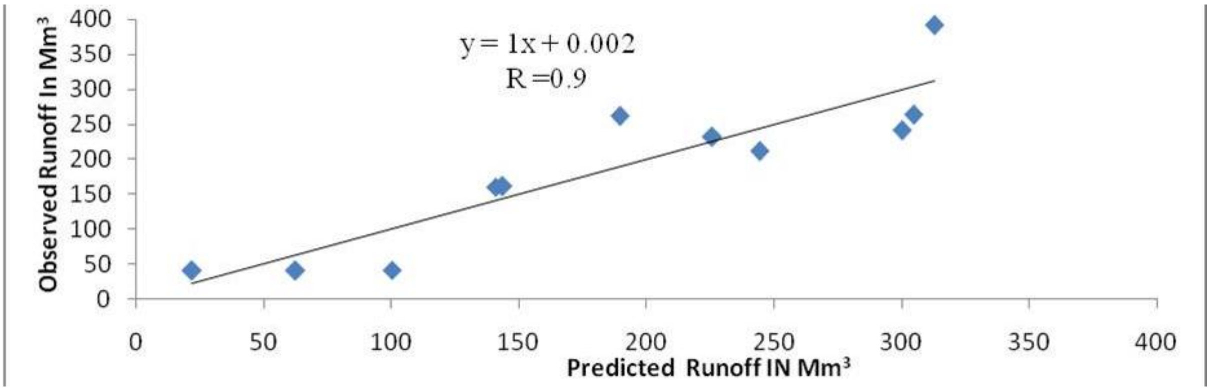

Figure 3. Comparison of observed and predicted runoff based on physical characteristics and meteorological parameters

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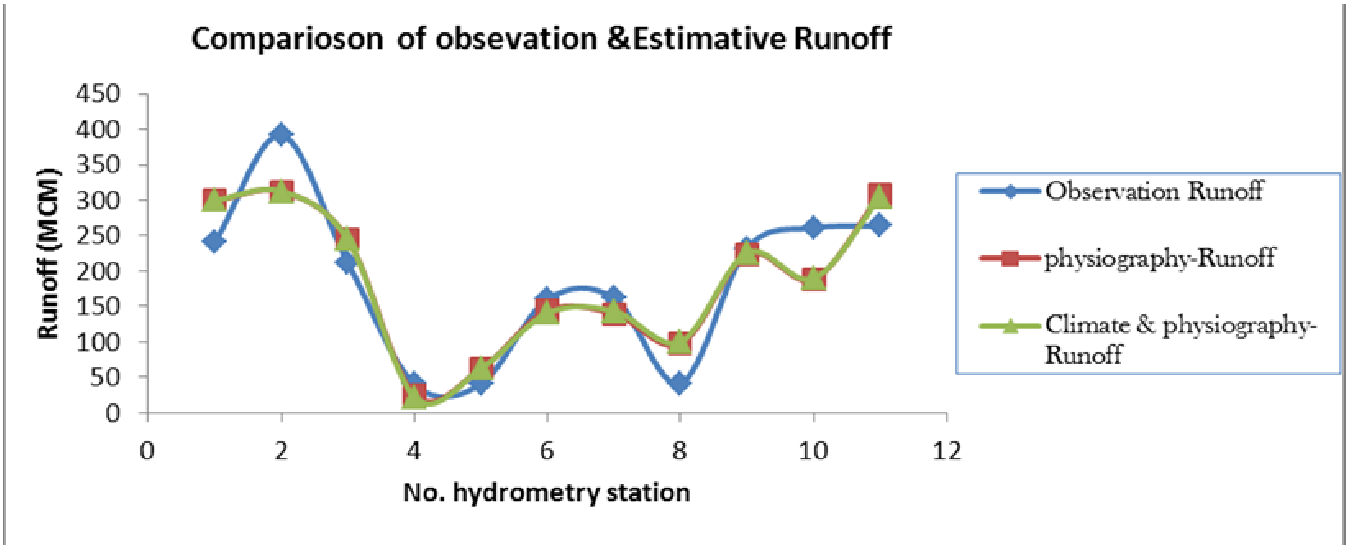

Figure 4. Comparison of observation and estimative runoff

DISCUSSIONS AND CONCLUSION

As it was mentioned before, the statistics of the impartial stations were completed and generalized through linear regression and the randomness test on the data were conducted using RUNTEST test and had satisfying results.

In the present study, gradient method was taken to find the amount of average annual rainfall and temperature. In this method, the height of stations under studies varied from 1252 to 1642 meters above sea level. Since there was no rain gauge and meteorology stations in high altitudes, extrapolation is used for stations beyond the domain of the present study and this increases the error risk. Figure 4 shows the annual runoff in three forms of observations, predication based on physical characteristics and based on meteorology and p [physical characteristics. a close look at this figure, reveals that the amount of runoff in both models concord fully therefore when the data available on meteorology is not enough, the model based on physical characteristics would be applied for it needs lower number off parameters.

Considering figure 4, it could be concluded that the observed data were close to the predicted data in Hashem-Abad, Band, Karim-Abad, Gooyjali-Aslan and Kalhor and their error rate was about 5% but in other stations, this rate was between 10 to 15%. Moreover, it could be concluded that in the Shahr-Chai and Roze-Cahi Rivers catchments, the annual runoff could be precisely estimated in the hydrometer stations.

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