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Full Length Research Paper

A comparison of methods for estimating the mean annual runoff coefficient at ungauged stream in southwestern region, Kingdom of Saudi Arabia

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Abstract

Water plays an important role in the development of human society as it subjected to be used for various purposes, among which the domestic use deserves more attention in arid and semi arid regions. There are numerous methods used to calculate the runoff coefficient in the ungauged streams. The objective of this study is to create a simplified method to calculate the runoff coefficient, by comparing several methods concluded by different earth scientist in the ungauged streams. Hence, a relationship has been developed between runoff coefficients calculated from basin area to make correction for area as function for thirty seven catchments distributing in southwestern region of K.S.A. The comparison between the resulting runoff coefficient of these methods by statistical programming to produce Dendritic, diagram found that the measured runoff coefficient and runoff coefficient calculated from the new relation is located on the same similarity level 2 and put in the same class. Where the runoff coefficient resulted from other methods located at different similarity. Then according to the statistical results which indicate that measured runoff coefficient and calculated are of have the same similarity level and the same class which is very accurate than the other methods.

Keywords: Annual runoff coefficient, Catchments area, Ungauged streams.

INTRODUCTION

Runoff estimation in ungauged catchment is a challenge for the hydrological engineers and planners. For instance any hydrological study in a watershed must determine the runoff at its outlet based on the estimation of annual runoff coefficient. The priority of estimation of mean runoff coefficient discharge volume of the stream which reflect these wadies are recommended or not recommended for dam constriction because its helps to calculate the annual harvesting.

The studied area comprise thirty seven (37) watershed distributing in southwestern region of K.S.A. The basin area of the studied watersheds ranging from 3.77 to 12816 Km^2 with the total catchments area of to33,132 Km^2 (Figure 1). Watershed characteristics such as basin area, slope, shape, and vegetation are important factors affecting various aspects of runoff (e.g., water yield, peak flow, base flow, direct storm runoff). A number of studies have been carried out worldwide to investigate these relationships (Hewlett et al., 1984; Wolock, 1995; Singh, 1997; Bruijnzeel, 2004; Andreassian, 2004; Lajoie et al., 2007, Fang et al., 2008; Tran and Melinda., 2013).

Omag (1984), suggested methods depends on basin characteristics such as drainage area ,mean annual precipitation, forest cover index and main channel slope to determined mean annual runoff at ungauged streams.

Sen and Al-Subai (2002), calculated the mean values of runoff coefficient C_R for the catchments of Baysh, Damad, Jazan and Khulb (gauged streams) ranging an area from 900 to 4652Km^2 and made relationship between the basin area and their mean measured runoff coefficient and suggested equation to calculated runoff coefficient for ungauged streams as

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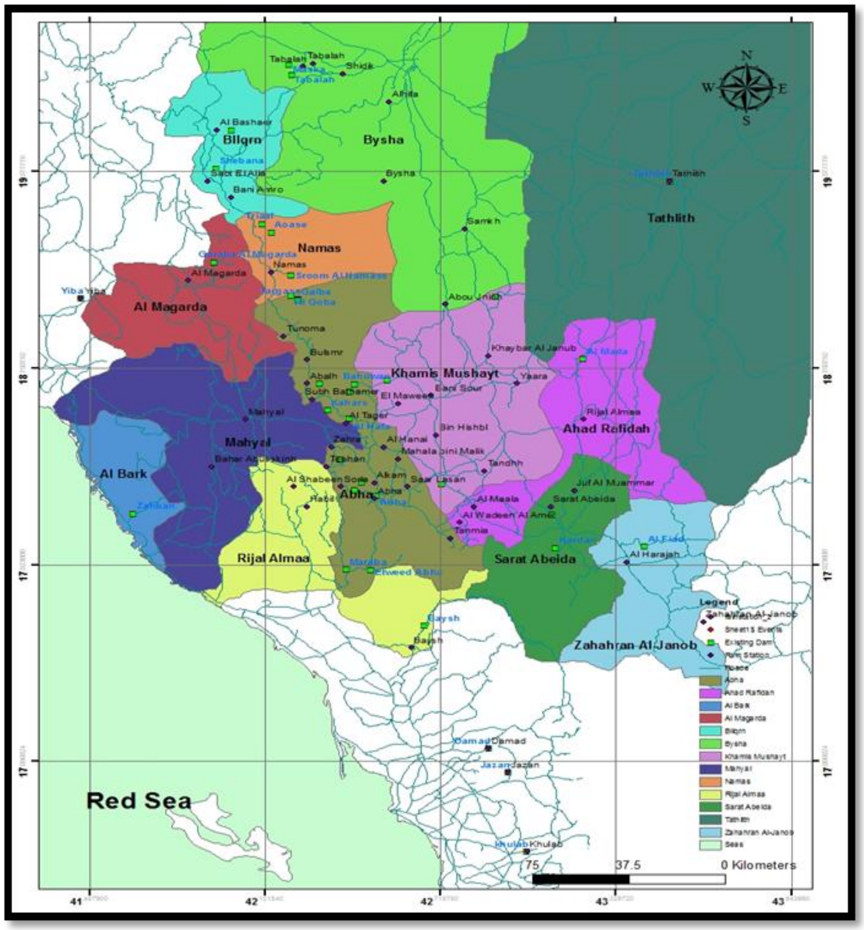


Figure 1. Location map of the study area

$C_R = A^{-0.359}$. In the current paper this equation has been applied to calculate small area less the used area by Sen and Al-Subai (2002), in the relationship in southwestern region K.S.A, and it's give high mean runoff coefficient

Al-Hasan and Mattar (2013), suggests method depends on the main slope of wadi to determine the Runoff coefficient C_R for ungauged stream. Their method depends on 16 gauged catchments representing several regions in kingdom of Saudi Arabia. The studied catchments were divided into two groups based on the main stream slope, group A less than 0.01 ($C_R = 2.841S_m$) and group B more than 0.01 ($C_{R=}\ 0.498S_b$). When the author applied the equation of Al-Hasan and Mattar (2013) has been applied in the two catchments area of the same mean annual rainfall but different in areas (Sroom Al Namass, 4.22 Km^2 and Al Gara,7.78 Km^2) and main stream slope (0.0933 and 0.0184 respectively), hence found that the small area of high slope give high volume of annual runoff. Where the outcrops of catchment of Al Gara dam consist of biotite - hornblende granodiorite to monzonite unit and characterized by large massive but the catchment of Sroom Al Namass outcrops consists of diorite and quartz diorite with fault bounded outcrops (Figure 2).

The current study presents in an attempt to established easy and accurate method to calculate the runoff coefficient, the results have been compared with two other methods to calculate the runoff coefficient in the ungauged streams.

GEOLOGY OF THE STUDY AREA

Many authors have studied the geology of the area including Brown and Jackson, (1958), Rooney and Al-Koulak (1978, a and b), Coleman (1973a), Stoeser (1984) and others. The geologic map of the studied area 0f 1:250,000, S.G.S. (Saudi Geological Survey), 1985 contains several outcrops of rock units predominantly by upper Proterozoic metamorphosed volcanic and sedimentray rocks of the Baish,Bahah,Jiddah,Ablah and Halaban groups and by upper Proterozoic plutonic rocks ranging in composition from gabbro to granite ,Tertiary and Quaternary basalt and Quaternary suficial deposits overlie of the Proterozoic rocks in several parts in studied area (Figure 2).

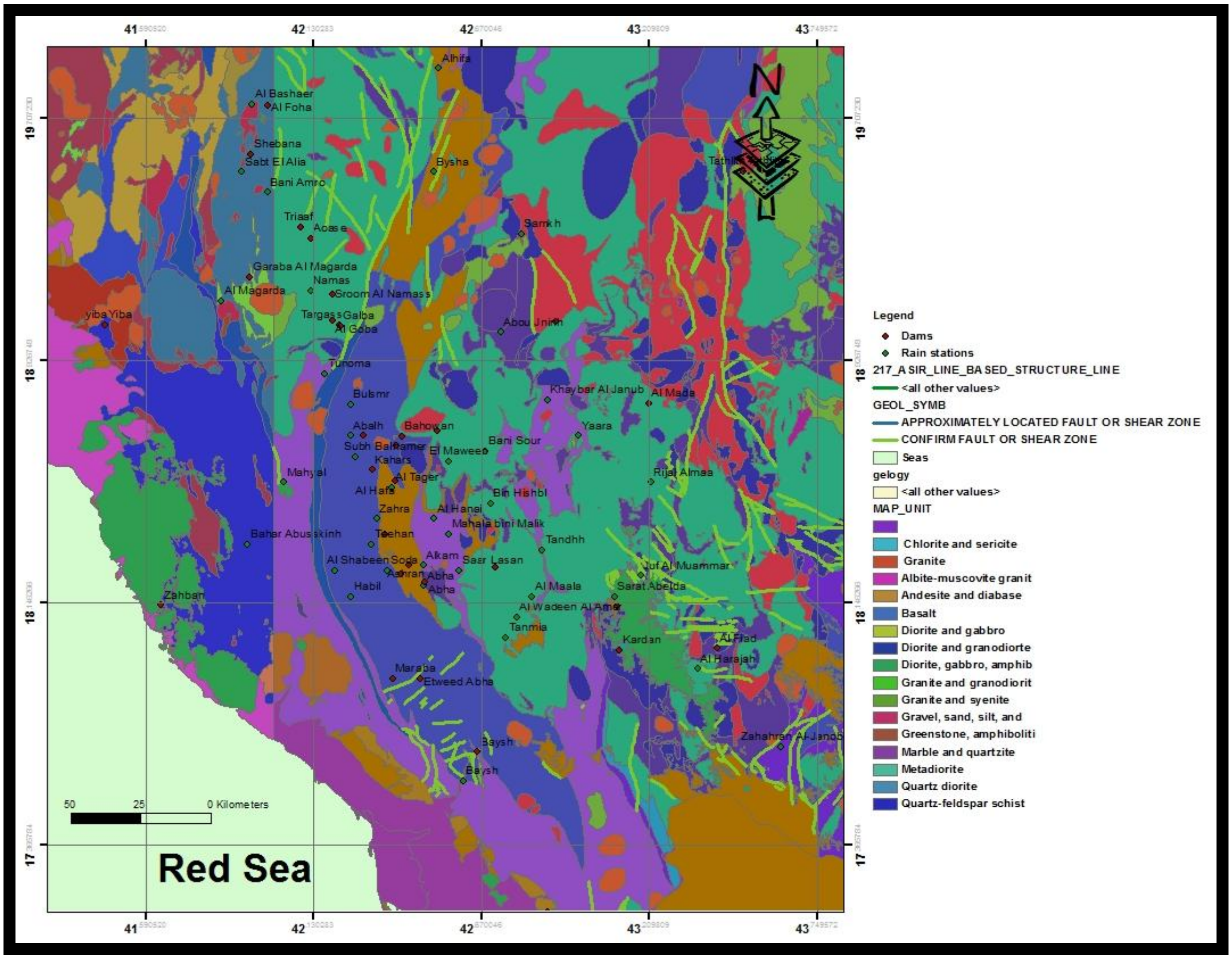


Figure 2. Geologic map of the study area.

MATERIALS AND METHODS

Data of forty nine rain station (Table 1) and thirty seven catchments areas in southwestern region of K.S.A (Table 2) are used to determine the Runoff coefficient C_R .The topographic maps (121 maps) on scale of 1:50000 were collected and then scanned and registered with tic points and rectified in Arc map Arc Gis 10.2. Further, the rectified maps were projected and merged together as single layer. The morphometric analysis of the studied basins has been obtained by using ASTER, Digital Elevation Model (DEM) with 30m resolution together with registered topographic maps. By using WMS 8.4 software program delineate and calculate the morphometric characters of every watershed. Unfortunately, the available records of six runoff stations are limited compared to rainfall stations in studied area. The correlation of all results for every methods, calculated runoff coefficient in ungauged watershed to the measured runoff coefficient by using statistical program SPSS 17 to determine the best method for calculation runoff coefficient and compare with measured runoff coefficient.

RESULTS AND DISCUSSION

The aim of study is to create a simplified method to estimate the runoff coefficient of ungauged streams to calculate annual runoff volume. The study area depends on the two main parameters like drainage area and the main channel slope, because no forest cover and its barren land.

The strength of Pearson `s correlation coefficients (r) Al-Hasan and Mattar (2013) used to compare the amounts components of measured runoff coefficients (C_{Rm}) and the watershed geomorphologic parameters as (basin slope, main stream slope, basin area and curve number) shown in tables 3 and 4. The comparison proved that there is no relationship between the basin area and curve number related to the basin slope and main stream slope (i.e. negative correlation). Where the correlation between high numbers basin area and curve number correlated to the basin slope and main stream slope with small numbers must give negative correlation. But by the increasing area of the basin, its have more chance to collected more rainfall surface water. Where, if calculated the runoff coefficients as function of basin

Table 1. Rainfall stations in the Asser region

No	Station name	Station Code no.	Coordinates		Average annual precipitation (mm)	Recording years	Number of years
			Latitude	Longitude			
1	Abalh	A206	18.6833300	42.2500000	229	1967-2009	43
2	Bin Hishbl	A128	18.4666700	42.7000000	64	1974-2000	27
3	Mahyal	SAU113	18.5333300	42.0333300	282	1970-2009	40
4	Tabalah	B114	20.0166700	42.2333300	100	1965-2001	37
5	Teehan	A130	18.3333300	42.3166700	278	1982-2009	28
6	Subh Balhamer	A117	18.6166700	42.2666700	175	1965-2009	45
7	Khaybar Al Janub	B110	18.8000000	42.8833300	78	1970-2009	40
8	Shidik	B008	19.9861100	42.3750000	49	1990-2008	19
9	Abou Jninh	B208	19.0166700	42.7333300	52	1967-1999	33
10	Bahar Abusskinh	SA108	18.3333300	41.9166700	256	1965-2005	41
11	Bulsmr	A127	18.7833300	42.2500000	269	1970-2009	40
12	Alhifa	B005	19.8666700	42.5333300	53	1966-2008	41
13	Yaara	A110	18.6833300	42.9833300	102	1965-2009	45
14	Habil	SAU144	18.1666700	42.2500000	417	1971-2009	39
15	Al Hanai	A201	18.4166700	42.5166700	111	1966-1996	31
16	Zahra	A124	18.4166700	42.3333300	184	1970-2009	40
17	Soda	A118	18.2500000	42.3666700	336	1965-2009	45
18	El Maween	A107	18.6000000	42.5666700	119	1968-2009	42
19	Bani Sour	A113	18.6333300	42.6833300	80	1970-2009	40
20	Saar Lasan	A006	18.2500000	42.6000000	196	1970-1999	30
21	Namas	3007	19.1500000	42.1220000	360	1968-2009	42
22	Al Wadeen Al Amer	A103	18.1000000	42.7833300	244	1965-2009	45
23	Sarat Abeida	A004	18.1666700	43.1000000	76	1981-2009	29
24	Abha	A005	18.2000000	42.4830000	277	1970-2009	40
25	Al Harajah	A104	17.9333300	43.3666700	146	1966-2009	44
26	Juf Al Muammar	A105	18.2333300	43.1833300	75	1968-2009	42
27	Alkam	A106	18.2666700	42.4833300	292	1970-2009	40
28	Al Maala	A213	18.1666700	42.8333300	49	1967-2009	43
29	Al Bashaer	B217	19.7500000	41.9333300	113	1981-2003	23
30	Al Tager	A108	18.5166700	42.3833300	90	1970-2009	40
31	Al Shabeen	SA116	18.2500000	42.2000000	283	1968-2009	42
32	Al Magarda	SAU122	19.1166700	41.8333300	202	1969-2009	41
33	Mahala bini Malik	A112	18.3666700	42.5666700	132	1965-2009	45
34	Bani Amro	B216	19.4666700	41.9833300	236	1970-2002	33
35	Bysha	B113	19.5333300	43.5166700	14	1965-1975	11
36	Sabt El Alia	B009	19.5333300	41.9000000	282	1990-2009	20
37	Tanmia	A121	18.0333300	42.7500000	319	1965-2009	45
38	Tandhh	A123	18.3166700	42.8666700	117	1965-2009	45
39	Tunoma	A120	18.8833300	42.1666700	241	1965-2009	45
40	Rijal Almaa	A126	18.5333300	43.2166700	46	2006-2009	4
41	Samkh	B219	19.3333300	42.8000000	57	1971-2004	34
42	Zahahran Al-Janob	N103	17.6833300	43.6333300	162	1965-2009	45
43	Yiba	SA 402	19.041667	41.458333	254	1972-1978	8
44	Tabalah	B 405	20.028333	42.269722	281	1969-1983	16
45	Tathlith	B 404	19.535278	43.515000	85	1979-1967	14
46	Khulab	SA 421	16.716389	43.017778	450	1970-1984	14
47	Jazan	SA 418	17.050000	42.950000	528	1970-1986	18
48	Damad	SA 417	17.15000	42.883333	549	1970-1986	18
49	Baysh	SA 415	17.572778	42.612222	373	1970-1986	18

Table 2. Morphometric parameters of studied basin.

No	Basin name	Catchment area(Km^2)	Stream slope (S_m)	Basin Slope (S_b)
1	Maska	36.98	0.0154	0.1301
2	Tabalah	1181.39	0.0110	0.138
3	Al Foha	296.68	0.0120	0.1157
4	Al Goba	416.99	0.0199	0.2046
5	Triaaf	20.27	0.0407	0.1842
6	Aoase	19.59	0.0357	0.1526
7	Al Gara	7.78	0.0184	0.1081
8	Garaba Al Magarda	92.24	0.0295	0.1496
9	Sroom Al Namass	4.22	0.0933	0.423
10	Targass	516.01	0.0527	0.1017
11	Al Mseereq	1202.00	0.0115	0.1438
12	Galba	92.56	0.0050	0.05898
13	Kahars	52.24	0.0256	0.1617
14	Al Mada	826.23	0.0100	0.0661
15	Shebana	20.22	0.0298	0.1067
16	Kadar Al Hema	136.31	0.0153	0.0803
17	Amaq Bl Ahmar	52.46	0.0345	0.1503
18	Bahowan	32.59	0.0236	0.1695
19	Al Mawen	40.36	0.0364	0.1753
20	Al Hafa	3.77	0.0525	0.099
21	Tabab	13.54	0.0241	0.1401
22	Ashran	34.85	0.0405	0.1864
23	Etweed (Khmes)	385.32	0.0100	0.063
24	Al Soda	6.76	0.0403	0.1465
25	Abha	44.74	0.0351	0.1838
26	Zahban	470.27	0.0104	0.1091
27	Al Magazama	83.38	0.0100	0.0619
28	Al Fiad	295.97	0.0119	0.134
29	Kardan	28.20	0.0113	0.101
30	Maraba	534.21	0.0307	0.3589
31	Etweed Abha	511.71	0.0323	0.334
32	yiba	2861	0.0164	0.2211
33	khulab	783	0.0333	0.2381
34	jazan	1410	0.0281	0.2488
35	damad	994	0.0315	0.2966
36	Baysh	4808	0.0130	0.3256
37	Tathlith	12816	0.0056	0.0522

Table 3. Declare parameters and measured runoff coefficient (Al Hasan and Mattar, 2013).

Region	Basin name	Measured runoff coefficient (CR)	Basin slope (Sb)m/m	Stream slope (Sm)	Basin area Km2	Area -weighted curve numbers
Asir	Tathlith	0.0059	0.0522	0.0056	12816	86.10
Al Madinah	Al khanaq	0.0055	0.0246	0.0027	35658	69.80
	Al Hannkiyah	0.0159	0.0301	0.0053	3104	63.70
Al Qassim	Uqlat As Suqur	0.0126	0.0235	0.0017	31850	74.90
	Ar Rass	0.0023	0.0144	0.0021	78988	78.80
Riyadh	Hanifah	0.0347	0.0652	0.0033	1637	70.10
Makkah	Khulis	0.0750	0.1350	0.0088	2855	67.30
	Ranyah	0.0324	0.0632	0.0039	10215	67.50

Table 4. The strength of Pearson `s correlation Measured runoff coefficient and some geomorphologic parameters (Al Hasan and Mattar (2013).

some geomorphologic parameters	Correlation between Vectors of Values				
	Measured runoff coefficient (CR)	**Basin slope (Sb)**	**Stream slope (Sm)**	**Basin area**	**Area -weighted curve numbers**
Measured runoff coefficient	1.000				
Basin slope	0.950	1.000			
Stream slope	0.692	0.809	1.000		
Basin area	-0.574	-0.606	-0.637	1.000	
curve numbers	-0.504	-0.280	-0.205	0.441	1.000

area and then made correlation the result is different.

In this paper we calculate the Runoff coefficient C_R for 30 ungauged watershed and 7 gauged watershed by using Sen and Al-Subai (2002) and Al-Hasan and Mattar (2013). The results of these two methods are different because the first author depends on basin area, and the second author depends on the main stream slope of the stream .In this paper correction for the results of Runoff coefficient C_R as measured from Al-Hasan and Matter (2013) and draw relation between the log Runoff coefficient C_R with log area of the same catchments Figure 3.

The equation of Al-Hasan and Mattar, (2013) must be corrected for function of area. For this propose draw relation between log calculated runoff coefficient C_R (by equation of Al-Hasan and Mutter (2013) with log area of catchments (Figure 3). The results equation for determination Runoff coefficient C_R as a function of area in the southwestern K.S.A., is as follows: $Runoff\ \ coefficient\ C_R = -0.01\,ln(A) + 0.12 (Where\ A\ catchment\ area)$

The author applied there three methods Sen and Al-Subai (2002), Al-Hasan and Mattar (2013) and the strength of Pearson `s correlation coefficients(r) express the extent to which two variables are associated. A value of zero indicates that variables have no correlation at all. A value of +1 indicates that two variables are perfectly correlated while a value of -1 indicates that they are perfectly negatively correlated.

Data of thirty seven catchments basins correlated with the capacity of each dam and annual runoff volumes calculated by Sen and Al-Subai (2002), Al Hassn and Mattar (2013) methods and the author method. The results show that very strong positive correlation between the capacity and annual runoff volume for each dam with the author method than the other methods (Table 7).The Dendritic diagram(R-mode cluster) show that the measured runoff coefficient and runoff coefficient calculated from the author method is located on the same similarity level 2 and put in the same class, and the runoff coefficient resulted from method of Al Hassn and Mattar, (2013) located at similarly level 12, but the independent case of Sen and Al-Sebai (2002) method located at similarity level 25, (Figure 4).

resulted equation to calculates the Mean Runoff coefficient CR and Volume of annual runoff for every catchments for the thirty seven catchments areas (tables 5 and 6). The annual runoff volume for any catchments is estimated as the following:

$Annual\ Runoff\ \ volume = Catchments\ area\ x\ Annual\ rainfall\ x\ Annual\ runoff\ \ coefficient$

Multivariate Statistical Analysis

A statistical approach was used to investigate the association among different parameters such as mean runoff coefficient measured, mean Runoff coefficient calculated Sen and Al-Subai (2002), mean runoff coefficient calculated Al-Hasan and Mattar , (2013) and Calculated by the author(Tabel5). Also, correlate the capacity of each dam with the resulted mean annual runoff volume for every method (Table 6). This association can be demonstrated by simple correlation analysis. The correlation coefficients were calculated for all possible pairs of parameters (variables) as mean annual runoff volume for every method variables. The

CONCLUSIONS

In south western Saudi Arabia, flash floods often take place as a consequence of excessive highly intense rainfall. Urban areas and major wadies are subject to destructive floods. In this paper, thirty seven watersheds were analyzed in relation runoff coefficients with basin area, with having seven runoff gauge station .It has been demonstrated that watershed basin must be factor affect runoff coefficient .The results equation for determination runoff coefficient C_R as a function of area equals : $Runoff\ \ coefficient\ C_R = -0.01ln(A) + 0.12$.The author applied Al Hassn and Mattar, (2013), Sen and Al-Sebai (2002) methods and the resulted equation and made correlation for the measured Runoff coefficient with the resulting Runoff coefficient by three methods, which approved that same similarity between measured Runoff coefficient and Runoff coefficient calculated by author. Also, correlation between the capacity of each

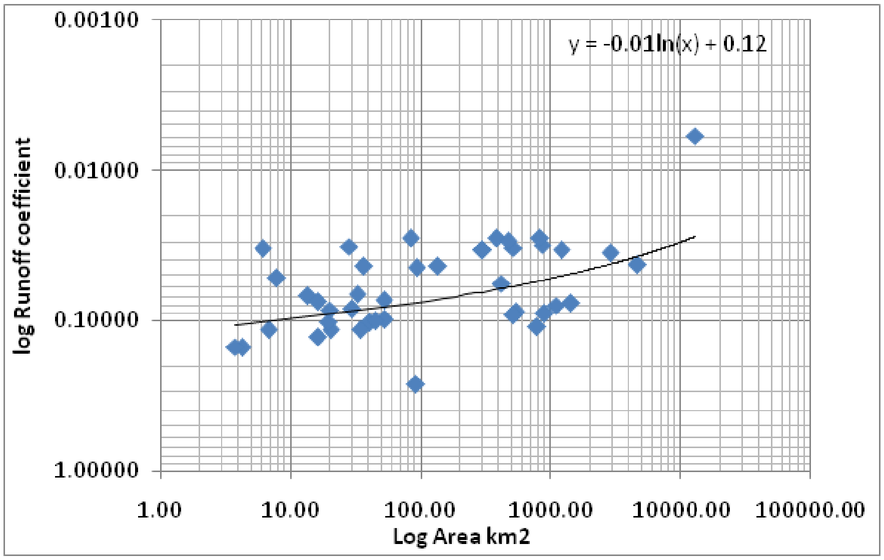


Figure 3. Runoff coefficient as a function of area for the ungauged streams in southwestern of K.S.A.

Table 5. Mean annual precipitation and Runoff coefficient calculated with different methods.

No	Wadi name	Catchment area(Km2)	Mean annual precipitation P(mm)	Mean Runoff coefficient Measured	Mean Runoff coefficient Calculated Sen and Al-Subai (2002)	Mean Runoff coefficient Calculated Al-Hasan and Mattar(2013)	Mean Runoff coefficient Calculated as a function of area
1	Maska	36.98	98.02		0.27359	0.04375	0.083896228
2	Tabalah*	1181.39	281.53	0.045	0.078897	0.03125	0.049258832
3	Al Foha	296.68	281.53		0.129553	0.03409	0.063073459
4	Al Goba	416.99	234.80		0.11465	0.05654	0.059669378
5	Triaaf	20.27	375.14		0.3395	0.11563	0.08990858
6	Aoase	19.59	375.14		0.343684	0.10142	0.090249808
7	Al Gara	7.78	375.14		0.478783	0.05227	0.099484437
8	Garaba Al Magarda	92.24	375.14		0.295209	0.26507	0.074756061
9	Sroom Al Namass	4.22	375.14		0.197058	0.14972	0.105601649
10	Targass	516.01	219.80		0.596366	0.03267	0.057538739
11	Al Mseereq	1202.00	75.43		0.106208	0.03397	0.049082579
12	Galba	92.56	300.88		0.0784	0.04460	0.074721429
13	Kahars	52.24	219.80		0.196813	0.07273	0.080441515
14	Al Mada	826.23	102.45		0.241678	0.02841	0.052831268
15	Shebana	20.22	281.53		0.089693	0.08466	0.089933278
16	Kadar Al Hema	136.31	173.10		0.339801	0.04347	0.070850683
17	Amaq Bl Ahmar	52.46	228.68		0.171279	0.09801	0.08039949
18	Bahowan	32.59	173.10		0.241314	0.06705	0.085159945
19	Al Mawen	40.36	173.10		0.286288	0.10341	0.083021608
20	Al Hafa	3.77	173.10		0.265133	0.14915	0.10672925
21	Tabab	13.54	183.71		0.621003	0.06847	0.093943517
22	Ashran	34.85	335.80		0.392418	0.11506	0.084489469
23	Etweed (Khmes)	385.32	243.60		0.279479	0.02841	0.060459258
24	Al Soda	6.76	335.80		0.117948	0.11449	0.100889771
25	Abha	44.74	335.80		0.503558	0.09972	0.08199132
26	Zahban	470.27	255.76		0.255505	0.02955	0.05846693
27	Al Magazama	83.38	90.53		0.109806	0.02841	0.075765915
28	Al Fiad	295.97	135.11		0.204333	0.03381	0.063097419
29	Kardan	28.20	90.53		0.129665	0.03210	0.08660678

Table 5. Continued

30	Maraba	534.21	335.80		0.301551	0.08722	0.05719211
31	Etweed Abha	511.71	319.42		0.104894	0.09176	0.057622419
32	yiba*	2861	254.00	0.0353	0.106527	0.046592	0.040410735
33	khulab*	900	450.00	0.07	0.082325	0.027842	0.051976052
34	jazan*	1430	528.00	0.07	0.057426	0.093753	0.047345703
35	damad*	1108	515.00	0.07	0.086982	0.079832	0.049896881
36	Baysh*	4652	373.00	0.048	0.07366	0.089492	0.035549475
37	Tathlith*	12816	86	0.0059	0.080725	0.036933	0.025415503

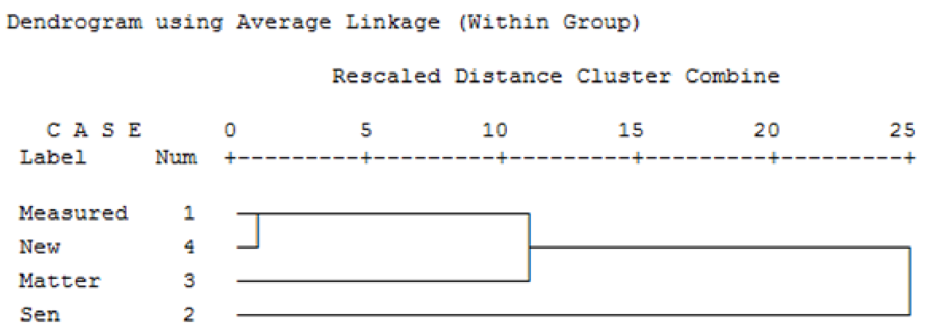
* Runoff stations

Table 6.The volume of calculated annual runoff with different methods and average annual rainfall volume.

No	Dame name	Capacity (m^3)	Average annual rainfall volume .m^3/y	Volume of calculated annual runoff by Sen and Al-Subai, (2002)m^3/y	Volume of calculated annual runoff by Al-Hasan and Mattar, (2013)m^3/y	Average annual runoff Calculated m^3/y
1	Maska	411,226	3,624,780	991,703	158,589	304,105
2	Tabalah	68,425,000	332,486,930	26,232,330	10,390,549	16,377,918
3	Al Foha	3,000,000	83,524,320	10,820,852	2,847,511	5,268,168
4	Al Goba	1,406,764	97,909,252	11,225,317	5,535,388	5,842,184
5	Triaaf	455,269	7,604,088	2,581,586	879,251	683,673
6	Aoase	629,665	7,348,993	2,525,733	745,362	663,245
7	Al Gara	134,965	2,918,589	1,397,370	152,568	290,354
8	Garaba Al Magarda	53,907	34,602,914	6,818,779	9,172,032	2,586,778
9	Sroom Al Namass	390,000	1,583,091	944,101	237,021	167,177
10	Targass	9,809,600	113,418,998	12,045,963	3,705,569	6,525,986
11	Al Mseereq	433,000	90,666,860	7,108,253	3,080,178	4,450,163
12	Galba	773,300	27,849,453	5,481,137	1,242,188.64	2,080,951
13	Kahars	446,675	11,482,352	2,775,030	835,107	923,658
14	Al Mada	4,275,000	84,647,264	7,592,306	2,404,829	4,472,022
15	Shebana	271,045	5,692,537	1,934,329	481,940	511,948
16	Kadar Al Hema	627,707	23,595,261	4,041,377	1,025,622.29	1,671,740
17	Amaq Bl Ahmar	1,000,000	119,965,523	2,894,930	1,175,836.12	964,517
18	Bahowan	213,975	5,641,329	1,615,043	378,237.57	480,415
19	Al Mawen	400,000	6,986,316	1,852,302	722,471.70	580,015
20	Al Hafa	162,000	652,587	405,258	97,334.98	69,650
21	Tabab	700,000	2,487,433	976,114	170,309.84	233,678
22	Ashran	645,011	11,702,630	3,270,639	1,346,510	988,749
23	Etweed (Khmes)	6,240,000	93,863,952	11,071,052	2,666,675	5,674,945
24	Al Soda	340,000	2,270,008	1,143,080	259,898	229,021
25	Abha	2,130,000	15,023,692	3,838,635	1,498,149	1,231,812
26	Zahban	1,360,544	120,276,255	13,207,093	3,553,730	7032183.396
27	Al Magazama	1,500,000	7,548,391	1,542,386	214,450	571,911
28	Al Fiad	2,500,000	39,988,507	5,185,102	1,351,927	2,523,172
29	Kardan	794,645	2,552,946	769,843	81,958	221,102
30	Maraba	10,000,000	179,387,718	18,816,727	15,645,964	10,259,562
31	Etweed Abha	10,000,000	163,450,408	17,411,911	14,998,912	9,418,408
32	Yiba	80,913,300	726,694,000	41,731,276	33,858,127	29,366,239
33	Khulab	-	405,000,000	35,227,511	11,276,010	21,050,301
34	Jazan	51,000,000	755,040,000	55,616,586	70,787,265.12	35,747,899
35	Damad	55,500,000	570,620,000	46,063,530	45,553,736	28,472,158
36	Baysh	193,644,000	1,735,196,000	83,688,520	155,286,160	61,685,307
37	Tathlith	-	1,102,176,000	36,946,032	40,706,666.21	28,012,358

Table 7. Correlation matrix of non–transformed data input For the capacity of dams and annual runoff volumes calculated with different methods in the studied area.

	Correlation between Vectors of Values			
Methods	**Sen and Al-Subai**	**Al Hassn and Mattar**	**Author**	**Capacity**
Sen and Al-Subai(2002)	1.000			
Al Hassn and Mattar (2013)	0.84	1.000		
Author	0.99	0.8	1.000	
Capacity	0.7	0.5	0.8	1.000



*Measured = Measured mean runoff coefficients * New= Author equation * Matter = Al-Hasan A. and Mattar Y, (2013) * Sen and Al-Subai, (2002)

Figure 4. R-mode cluster analysis of mean runoff coefficients calculated with different methods related to measured mean runoff coefficients in the studied area.

dam and annual runoff volumes calculated by Sen and Al-Subai (2002), Al Hassn and Mattar (2013) methods and the author method give very strong positive correlation than the other methods. Finally, the author calculation of runoff coefficient by the equation $C_R = -0.01ln(A) + 0.12$ is very simple and accurate accounts in studied area.

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