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Analysis of statistical parameters for rainfall series of Kaneri watershed, Maharashtra and computation of runoff for different return periods

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Abstract*—Robust hydrological information is a pre-requisite for efficient water resources assessment of a region. A hydrologist must be able to evaluate water availability, flood potential, data trends and such characteristics, so as to ensure that the results constitute the solid foundation for a decision support system for sustainable development and management of scarce water resources. In this context, the paper analyses the statistical parameters by using different distributions to compute the runoff peaks for different return periods. In water resources planning and management the statistical parameters describe the statistical distribution characteristics of a sample. By fitting a frequency distribution to the set of hydrological data, the probability of occurrences of random parameters can be calculated. In the present study, the runoff values for 50 year and 100 year return period are determined by using the annual rainfall series for the Kaneri watershed, which is near Kolhapur, Maharashtra. The results obtained by different methods are compared with Extreme Value type III distribution model.

***Keywords*—Moving average rainfall, Normal distribution, Extreme value, Return period**

I. INTRODUCTION

Robust hydrological information is a pre-requisite for efficient water resources assessment of a region. A hydrologist must be able to evaluate water availability, flood potential, data trends and such characteristics, so as to ensure that the results constitute the solid foundation for a decision support system for sustainable development and management of scarce water resources. (Patra K.C., 2008)

II. STUDY AREA

The Kaneri watershed is located near Konkan Region which is dominated by highlands. The watershed is oriented North-South and flanked on three sides by plateau ridges. It is located at 17.107 latitude and 74.548 longitude and lies 4 kms towards SE of Kolhapur on Mumbai-Banglore NH4 Highway. The catchment area of Kaneri is 965.94 Ha.

Climate :

Kaneri is situated in the agro-climatic zone with only one rainy season which lasts from the beginning of June to the middle of October. Maximum daily rainfall is 80mm. The mean annual rainfall is 513 mm with a low variability of 10%. In the watershed soil erosion is highly influenced by the erosivity of rainfall. A single intense rainfall event can cause up to 50% of the monthly soil loss. Additionally, there is high gully formation at the bottom of the

watershed. Some of these gullies have been rehabilitated by planting trees in the gullies to reduce further widening and sliding. The daily minimum air temperature ranges from 00 c to 20 0C and the daily maximum air temperature ranges from 12 0C to 40 0C. The mean daily temperature ranges from 9 0C to 30 0C.

Hydrology: The catchment drains from the North-East to South-West (Bosshart, 1995). The upper part of the watershed is dominated by highly compacted and degraded areas. The grass lands at the bottom the watershed are also compact and have a very low infiltration rate. Observations show that the degraded areas in the upper catchment and the bottom grass land areas are those which produce runoff immediately after rainfall starts. Runoff in the watershed at the beginning of the rainy season is not produced immediately after rainfall. In contrast runoff production in the middle of the rainy season occurs immediately after the rainfall starts. The runoff production after a rainfall event at the end of rainy season is faster than the production of rainfall at the beginning of rainy season but not faster than that of the mid-rainy season. The mid part of the watershed is dominated by cultivated fields. These fields have a moderate slope which is further reduced by the terraces constructed in the watershed since 1986. According to the study, the surface runoff contributes around 29% to the discharge at the outlet of the watershed. The lateral flow contributes around 49% and groundwater recharge contributes about 22% of the discharge at the outlet of the watershed.(Binium Bishuk Ashagre,2009)

Geology and Soil : The geology of the area is Basaltic lava flow which are part of Deccan Trap Basaltic Formation. It has brownish colour highly porous clayey soil with 10 to 60 cm. thickness. The watershed has -Uneven hills with 10 to 50 degree slope. The soil of Kaneri developed on the accumulated basaltic lava to form a plateau with soils varying over short distances.

III. RESEARCH REVIEW

The study (N. Bulygina et al) illustrated a simple method of conditioning hydrological model parameters on prior information in order to simulate runoff under current conditions and future land management scenarios. The prior information about current conditions, in this case, came almost entirely from the BFIHOST index from a national database of soil types. Under the case study catchment (Pontbren, a 12.5 km2 upland catchment in 10 Wales), the conditioned model was shown to simulate observed flows to an impressive level of accuracy. Under land management scenarios, new posteriors for BFIHOST and interception losses were introduced based on best available knowledge, providing probabilistic predictions of land management effects on flood runoff.(1)

The logical conclusion from the widespread observation that there is equifinality in model parameters and in model structures is to abandon the idea that a uniquely identifiable model exists. (Howard S. Wheater) Rather, there is a population of models (i.e. structures and parameter sets) that can be defined according to their consistency with the available data. The regionally estimated parameters, found using the multiple regression method, showed encouraging results with respect to both the proximity of the estimated to the calibrated parameter values, and also in the good model fits to observed streamflow data. Only limited validation was possible given the number of catchments used.(2)

L-THIA was designed to assess the long-term impacts on the hydrology of a watershed for users who want to determine the relative change in runoff from one land-use condition to another. Some users, however, are interested in results that match observed stream-flow data, which includes both direct runoff and baseflow. The calibration model has been verified using three tests in the Little Eagle Creek watershed in Indiana. Results also raise additional questions regarding the factors that control runoff production and systematic underprediction of direct runoff by L-THIA as compared to actual observed direct runoff data.(3)

IV. METHODOLOGY

In this study, the trend of rainfall and its distribution are investigated and the results of data from 1966-2011 are studied. The procedures to analyze these data are summarized as follows: The results of annual rainfall of the real data of 1966-2011 from the previous study are analysed for different parameters by different distribution models.

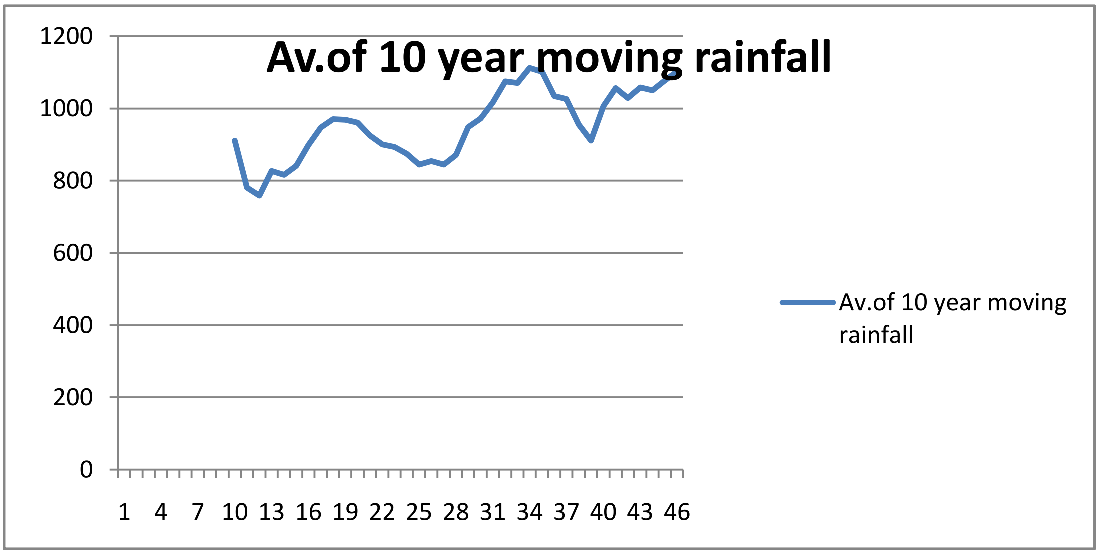
Then the annual rainfalls evaluated by moving average method at 10 years are generated from the raw rainfall data. The moving average data are tested for the tendency of data and shift in mean value .

Table1: AVERAGE OF 10 YEAR MOVING RAINFALL:

Year	Moving 10 year rainfall	Mean	Annual rainfall	Av.of 10 year moving rainfall
1966		985.03	2186	
1967		985.03	1201	
1968		985.03	425	
1969		985.03	961.2	
1970		985.03	956.6	
1971		985.03	684	
1972		985.03	422.8	
1973		985.03	771	
1974		985.03	721.8	
1975	9117.3	985.03	787.9	911.73
1976	7812.5	985.03	881.2	781.25
1977	7588.1	985.03	976.6	758.81
1978	8272	985.03	1108.9	827.2
1979	8166.8	985.03	856	816.68
1980	8413	985.03	1202.8	841.3
1981	8986	985.03	1257	898.6
1982	9479.6	985.03	916.4	947.96
1983	9708.6	985.03	1000	970.86
1984	9687.6	985.03	700.8	968.76
1985	9613.3	985.03	713.6	961.33
1986	9255.3	985.03	523.2	925.53
1987	9005.2	985.03	726.5	900.52
1988	8932.9	985.03	1036.6	893.29

1989	8746	985.03	669.1	874.6
1990	8448.8	985.03	905.6	844.88
1991	8544.1	985.03	1352.3	854.41
1992	8445.3	985.03	817.6	844.53
1993	8716.9	985.03	1271.6	871.69
1994	9482.7	985.03	1466.6	948.27
1995	9721	985.03	951.9	972.1
1996	10169.9	985.03	972.1	1016.99
1997	10752.5	985.03	1309.1	1075.25
1998	10710.7	985.03	994.8	1071.07
1999	11125.6	985.03	1084	1112.56
2000	11018.8	985.03	798.8	1101.88
2001	10342.5	985.03	676	1034.25
2002	10261.7	985.03	736.8	1026.17
2003	9553.5	985.03	563.4	955.35
2004	9110.7	985.03	1023.8	911.07
2005	10071.8	985.03	1913	1007.18
2006	10567.7	985.03	1468	1056.77
2007	10290	985.03	1031.4	1029
2008	10581.4	985.03	1286.2	1058.14
2009	10504.5	985.03	1007.1	1050.45
2010	10782.6	985.03	1076.9	1078.26
2011	11025.3	985.03	918.7	1102.53
			45311.7	

GRAPH SHOWING AVERAGE OF 10 YEAR MOVING RAINFALL



GRAPH SHOWING MEAN AND ANNUAL RAINFALL

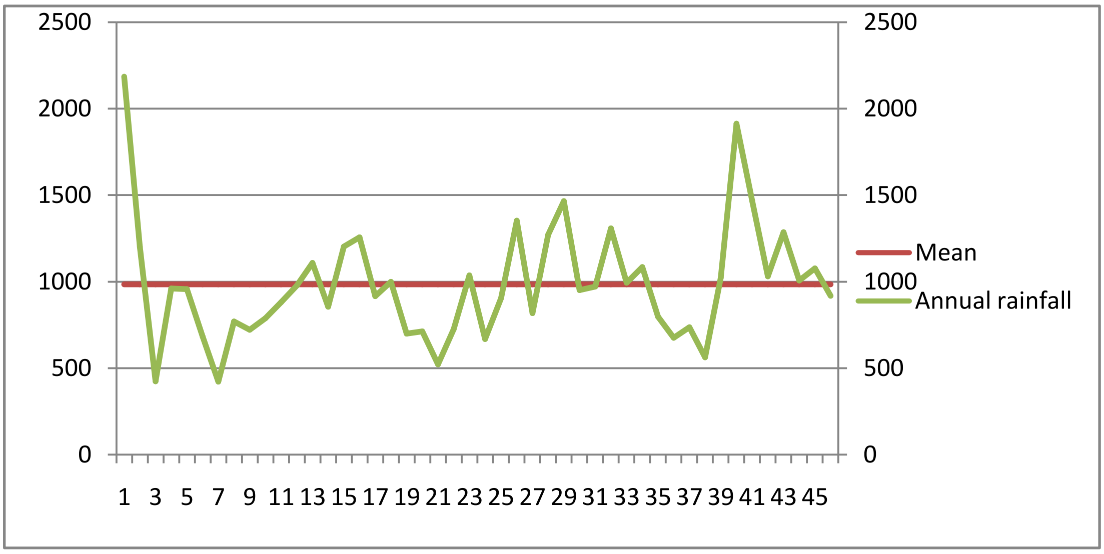


Table:

Year	P	R	(R-Rav) ^{2}	Log(R-Rav) ^{2}	col.6	col.7	Rank	Return period	Rel.Freq
1966	2186	1827.6	1042073.5	3.26	0.145	0.05525	1	47	0.02
1967	1201	990.35	33697.9	3.00	0.013	0.00151	2	23.5	0.04
1968	425	330.75	226604.6	2.52	0.131	-0.04724	3	15.67	0.06
1969	961.2	786.52	410.5	2.90	0.000	0.00000	4	11.75	0.09
1970	956.6	782.61	584.2	2.89	0.000	0.00000	5	9.4	0.11
1971	684	550.9	65474.6	2.74	0.020	-0.00274	6	7.83	0.13
1972	422.8	328.88	228388.4	2.52	0.132	-0.04821	7	6.71	0.15
1973	771	624.85	33098.5	2.80	0.007	-0.00062	8	5.88	0.17
1974	721.8	583.03	50064.1	2.77	0.013	-0.00153	9	5.22	0.19
1975	787.9	639.215	28078.0	2.81	0.006	-0.00043	10	4.7	0.21
1976	881.2	718.52	7789.8	2.86	0.001	-0.00001	11	4.27	0.23
1977	976.6	799.61	51.4	2.90	0.000	0.00001	12	3.92	0.26
1978	1108.9	912.065	11084.9	2.96	0.006	0.00049	13	3.62	0.28
1979	856	697.1	12029.7	2.84	0.001	-0.00005	14	3.36	0.30
1980	1202.8	991.88	34262.0	3.00	0.013	0.00154	15	3.13	0.32
1981	1257	1037.95	53439.6	3.02	0.018	0.00247	16	2.94	0.34
1982	916.4	748.44	3403.6	2.87	0.000	0.00000	17	2.76	0.36
1983	1000	819.5	161.8	2.91	0.001	0.00003	18	2.61	0.38
1984	700.8	565.18	58370.6	2.75	0.017	-0.00214	19	2.47	0.40
1985	713.6	576.06	53231.7	2.76	0.015	-0.00175	20	2.35	0.43
1986	523.2	414.22	154103.4	2.62	0.070	-0.01835	21	2.24	0.45
1987	726.5	587.025	48292.3	2.77	0.013	-0.00142	22	2.14	0.47
1988	1036.6	850.61	1921.1	2.93	0.002	0.00012	23	2.04	0.49
1989	669.1	538.235	72116.4	2.73	0.023	-0.00338	24	1.96	0.51
1990	905.6	739.26	4559.0	2.87	0.000	0.00000	25	1.88	0.53
1991	1352.3	1118.955	97453.2	3.05	0.028	0.00473	26	1.81	0.55

1992	817.6	664.46	20255.0	2.82	0.003	-0.00020	27	1.74	0.57
1993	1271.6	1050.36	59331.2	3.02	0.020	0.00276	28	1.68	0.60
1994	1466.6	1216.11	167551.0	3.08	0.042	0.00849	29	1.62	0.62
1995	951.9	778.615	793.3	2.89	0.000	0.00000	30	1.57	0.64
1996	972.1	795.785	120.9	2.90	0.000	0.00001	31	1.52	0.66
1997	1309.1	1082.235	75875.5	3.03	0.024	0.00360	32	1.47	0.68
1998	994.8	815.08	68.9	2.91	0.001	0.00003	33	1.42	0.70
1999	1084	890.9	7076.2	2.95	0.005	0.00033	34	1.38	0.72
2000	798.8	648.48	25058.9	2.81	0.005	-0.00033	35	1.34	0.74
2001	676	544.1	69000.8	2.74	0.021	-0.00307	36	1.31	0.77
2002	736.8	595.78	44521.0	2.78	0.011	-0.00119	37	1.27	0.79
2003	563.4	448.39	128443.4	2.65	0.053	-0.01206	38	1.24	0.81
2004	1023.8	839.73	1085.7	2.92	0.002	0.00008	39	1.21	0.83
2005	1913	1595.55	622158.1	3.20	0.104	0.03336	40	1.18	0.85
2006	1468	1217.3	168526.7	3.09	0.042	0.00854	41	1.15	0.87
2007	1031.4	846.19	1553.1	2.93	0.002	0.00010	42	1.12	0.89
2008	1286.2	1062.77	65530.9	3.03	0.021	0.00308	43	1.09	0.91
2009	1007.1	825.535	351.8	2.92	0.001	0.00005	44	1.07	0.94
2010	1076.9	884.865	6097.3	2.95	0.004	0.00029	45	1.04	0.96
2011	918.7	750.395	3179.3	2.88	0.000	0.00000	46	1.02	0.98
	Sum=	37111.95	3787323.4	132.53	1.036	-0.01787			
	Average=	806.7814		2.88					
	45312		3	5	6	7	9	10	11

V. ANALYSIS

For The Series:
Mean= Xav= 806.78 mm
Standard Deviation) σ = 290.108
Coefficient of Variation Cv = 0.3595
Coefficient of Skew ness Cs = 1.28

For The Transferred Series:
Mean= Yav= 2.881
Standard Deviation) σ = 0.1517
Coefficient of Variation Cv = 0.052
Coefficient of Skew ness Cs = -0.1188

a) Log Normal Distribution:
Following Chow's approach for Log-Normal distribution,
Cs=3Cv+Cv3 =0.156
Frequency factors for return periods of 50 and 100 years for coefficient of skewness are:
K 50= 2.913
K 100 = 3.520
Return Period Flood for Return Period of 50 years = X 50 = 1651.85
Return Period Flood for Return Period of 100 years = X 100 =1827.96

Using the Pearson Table of frequency distribution, assuming Cs=0;
K 50 = 2.055
K 100 =2.326
Return Period Flood for Return Period of 50 years = Y 50=3.192 , X 50 = 103.192 =1558.63
Return Period Flood for Return Period of 100 years = Y 100 = 3.23,X 100 = 103.23 =1713.38

b) Extreme Value Type I:
From Gumbel's K-T relation:
K 50= 2.908

K 100=3.514
Return Period Flood for Return Period of 50 years = X 50 = 1650.39
Return Period Flood for Return Period of 100 years = X 100 = 1826.19

c) Pearson Type III:
Coefficient of Skewness= 1.281
From the Table, frequency factors-
K 50= 2.658
K 100=3.198
Return Period Flood for Return Period of 50 years = X 50 =1577.86
Return Period Flood for Return Period of 100 years = X 100 = 1734.51

d) Log-Pearson Type III Distribution:
For log-transferred data:
Coefficient of Skewness=0.1185
K 50= 2.112
K 100=2.407
Return Period Flood for Return Period of 50 years = Y 50=3.20 , X 50 = 10 3.2 =1589.97
Return Period Flood for Return Period of 100 years = Y 100=3.24 , X 100 = 103.24 =1762.55

e) Normal Distribution:
For 50 year return period, T=50, p(X > x) is the area of normal curve bounded between 0 and (1-1/T) i.e. (1-1/50)=98%. From the Standard Normal Curve, for the area up to +48%(i.e.98-50) i.e. for t=0.48 $\Longrightarrow$ z=2.054
X 50= 1402.64
For 100 year return period, T=100 years, p(X > x) is the area of normal curve bounded between 0 and (1-1/T) i.e.(1-1/100)=99%. From the Standard Normal Curve, for the area up to +49% (i.e.99-50) i.e. for t=0.49 $\Longrightarrow$ z=2.328
X 100=1482.13
The same results can be obtained from frequency factor table and Stagum (1965) Equations.

VI. RESULTS

The analyses from previous study using data from 1966 to 2011 show that there are mixed result of constant and recession trend of the rainfall series. Similarly, there are also mixed results of constant and downward shift in annual rainfall. For comparison , the results of Normal Pearson Type III and Log Normal Vs.Log Pearson Type III along with the results of Extreme Value Type I Model are as below:

Distribution Type	Return Period flood of		Coefficient of skewness
	50 years	100 years	
Normal	1402.64	1482.13	0
Pearson Type III	1577.86	1734.51	1.281
Log Normal	1613.25	1703.18	1.125
Log Pearson	1589.97	1762.55	-0.1185
Extreme Value Type I	1650.39	1826.19	0

The effect of coefficient of skewness to the magnitude of event with return periods of 50 and 100 years can be seen from above table.

VII. DISCUSSIONS AND CONCLUSION

Real annual rainfall data and their moving average data of 10 years are analyzed to identify trend of annual rainfall and shift in mean value. The results from the real annual data and the moving average data indicate similar tendency with a small variation of value. However, the moving average data may be a better representative since this technique can remove the cycle effect out from the data.

Similarly, the runoff values for 50 year and 100 year return period are determined by using the annual rainfall series and the comparison of the results obtained by different methods with Extreme Value type III distribution model shows that, Extreme Value Type III Distribution gives maximum values.

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