REGIONALIZATION OF HYDROLOGIC INFORMATION IN TANZANIA (LOW FLOWS)

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ABSTRACT

Hydrologic information is required for the planning and design of water resource projects. However, Hydrologic information is always lacking at points of interest. Regionalization is aimed at estimating hydrologic information such as low flow statistics at ungauged sites. Hydrologic information from 63 catchments in Tanzania has been analysed. In this paper, pooled flow duration curves for 1, 10, 30, 60, and 90 days duration have been established. Regression equations between the low flow indices (i.e. 95 percentile and for a 10 day duration, average annual yield (AAY), average daily flow (ADF)) and catchment characteristics were developed. The pooled flow duration curves and the regression equations could be used to estimate the low flow statistics at ungauged catchments. However, it is recommended that data from all gauged catchments in the country should be used to in order to obtaion more reliable regresion equations. a more rigorous approach should be used in grouping the flow duration curves into groups of homogeneous catchments.

INTRODUCTION

The major purpose of water resource projects is to alter the temporal and spatial availability of water and its reliability to provide the necessary assurance of water, when and where needed. In water resource projects, the water storage system alters the temporal while the water distribution system alters the spatial availability of water. Both affect the water supply reliability.

The planning, design and development of water resource projects requires the aquisition of hydrologic information at the point of interest. Low flow statistics are very important variables for providing the needed information on the amount of water available at the location in the river system while the high flow statistics provide the necessary information for sizing of the protection structures. Suitable sites for location of water storage facilities are usually found at ungauged locations. There are many approaches that are used to transfer information from gauged locations to ungauged sites (Matondo et al 1989, Wisler et al 1959, Gustard et al 1989). This paper presents regionalization of low flows in Tanzania.

OBJECTIVES

The objectives in this study are given in point form as follows:

1. To develop flow duration curves for catchments in Tanzania.
2. To group the catchments into homogeneous groups.
3. Establishment of relationships between low flow indices and catchment characteristics.

METHODOLOGY

A low flow event can be described as a threshold discharge, an acumulated volume, a length of time spent below a threshold or a rate of recession (Gustard et al., 1989). The average flow is the most fundamental variable for comparing the regime of different rivers. The base flow index is also a measure of low flows. Approaches for development of flow duration curves; grouping of catchments into homogeneous groups and the establishment of regression equation are presented in the following sections.

Development of Flow Duration Curves

A flow duration curve is the cumulative frequency distribution of daily mean flows, flows for a given duration etc. A flow duration curve is contructed by counting the number of days with flow in various class intervals. The curve shows the percentage of time during which specified discharges are equalled or exceeded during the period of record. Low flow statistics are obtained from the flow duration curve.

Grouping of Catchments into Homogeneous Groups

Regionalization is an approach used to estimate or predict the low flow statistics at ungauged sites (Nathan and McMahon, 1990). The major task in regionalization studies is the grouping of catchments into homogeneous groups. Catchment characteristics have been used to group catchments with similar characteristics (Tasker, 1982b; Acreman and Sinclair, 1986; Hughes, 1987; Haines et al., 1988). However, such an approach is subjective, since catchment characteristics such as soil type, can vary very much within a basin. Thus, subjective judgement is required in grouping the catchments. In this study, catchments were grouped using the Q95 percentile as a percentage of average daily flow.

Establishment of Relationships Between Low Flow Indices and Catchment Characteristics.

The catchment characteristics that were considered in this study are: Average annual rainfall, catchment area and baseflow index. Multivariate regression analysis was applied in order to establish the relationships between low flow indices and catchment characteristics. The low flow indices that were considered are: average annual yield (AAY); the flow at 95 percentile and the average daily flow (ADF).

RESULTS AND DISCUSSION OF RESULTS

Mean daily runoff data from 63 gauged catchments in Tanzania were analysed. Flow duration curves for various durations(i.e. 1, 10, 30, 60, and 90 days duration) were developed (Onyekwuluje, 1991). The low flow statistics from the corresponding flow duration curves were also determined. Catchments were grouped together (homogeneous groups) using the Q95 percentile as a percentage of average daily flow. Tables 1 to 5 shows the flow indices/statistics for the various flow durations. It can be seen from tables 1 to 5 that there are 11 groups on Q95(1), 10 groups on Q95(10), 11 groups on Q95(30), 11 groups on Q95(60) and 12 groups on Q95(90). It can also be observed from tables 1 through 5 that a catchment which belonged to a certain homogeneous group in the one day flow duration curves belonged to another group in the 10 day flow duration curves which proves the subjectivity of the approach used in pooling the flow duration curves. Figures 1 - 5 shows the pooled flow duration curves.

It cab be seen from Figs. 1 - 5, that catchments which exhibit the flatest flow duration curves have the highest values of Q95 as a percentage of average daily flow. Conversely catchments which exhibit steep flow duration curces have the lowest values of Q95 as apercentage of average daily flow (ADF).

Regression relationships relating average annual yield, Q95(10) and Average daily flow (ADF) and catchment characteristics (average annual rainfall, area and baseflow index (BFI)) were established. Equations 1, 2, and 3 shows the established regression relationships.

$$AAY = 92.609 + 0.4349\ AAR - 0.0085\ AREA \qquad (1)$$
$R^2 = 0.699$; s.e. = 191.4 mm

$$AAY = 78.4359 + 0.437\ AAR - 244.867\ BFI - 0.0081\ AREA \qquad (2)$$
$R^2 = 0.694$; s.e. = 192.9 mm

$$Q95(10) = -1.4589 + 0.003\ AREA + 0.0868\ BFI \qquad (3)$$
$R^2 = 0.821$; s.e. = 9.581 cumecs

Table 1: Values of pooled flow duration curve indices (Duration in days: 1)

Q95 (as % of ADF)	Number of Stations	Q5	Q10	Q25	Q50	Q75	Q90	Q95
0- 5	15	382.13	223.43	95.78	31.97	11.19	4.65	1.86
5- 10	8	362.00	232.01	106.18	43.71	20.64	11.13	8.16
10- 15	12	334.40	239.71	123.41	52.34	26.53	16.05	12.26
15- 20	5	317.64	231.94	123.12	60.87	33.33	21.29	16.95
20- 25	7	277.78	219.75	129.08	69.16	39.68	26.82	22.89
25- 30	4	251.48	186.90	114.05	72.11	49.21	35.86	27.75
30- 35	1	226.62	172.30	111.02	68.15	48.45	39.74	34.20
35- 40	6	248.13	180.96	113.55	78.26	58.28	44.76	38.65
40- 45	3	216.34	168.85	115.89	82.21	61.84	49.38	42.86
45- 50	1	202.75	166.54	119.46	83.59	62.73	50.86	46.96
50- 55	1	151.46	135.35	111.98	94.26	74.92	62.84	54.78

Table 2: Values of pooled flow duration curve indices.
(Duration in days: 10)

Q95 (as % of ADF)	Number of Stations	Q5	Q10	Q25	Q50	Q75	Q90	Q95
0- 5	14	441.99	237.91	91.00	28.93	9.96	4.17	1.66
5- 10	11	371.88	238.07	108.23	39.97	18.24	10.44	6.99
10- 15	13	336.54	237.69	120.80	52.87	26.16	15.99	12.32
15- 20	6	307.97	231.97	115.95	56.23	31.17	21.62	17.14
20- 25	4	286.22	203.04	116.72	63.52	38.24	27.38	23.16
25- 30	3	260.51	196.56	118.85	69.16	44.30	31.99	27.13
30- 35	2	248.26	186.30	111.87	78.17	54.15	39.20	30.58
35- 40	4	227.94	175.11	116.73	81.25	59.16	45.37	38.31
40- 45	4	233.57	159.50	106.75	78.94	60.24	48.61	43.39
45- 50	2	249.66	170.80	113.06	80.97	63.83	51.90	46.78

Table 3: Values of pooled flow duration indices.
(Duration in days: 30)

Q95 (as % of ADF)	Number of Stations	Q5	Q10	Q25	Q50	Q75	Q90	Q95
0- 5	12	449.43	249.31	96.44	28.31	7.83	2.90	1.72
5- 10	10	354.43	244.79	115.27	43.47	20.96	12.45	7.50
10- 15	16	331.95	235.03	123.59	54.73	26.92	16.80	12.91
15- 20	4	307.34	229.06	112.44	56.49	31.06	21.79	16.99
20- 25	4	269.81	211.36	125.84	63.47	36.53	26.36	22.29
25- 30	4	267.36	211.33	127.70	69.57	42.71	31.13	26.68
30- 35	2	263.43	190.31	115.42	68.81	46.86	35.69	31.26
35- 40	2	241.80	185.12	110.56	77.40	56.57	43.65	37.23
40- 45	7	216.63	160.89	113.09	82.95	62.45	48.56	42.28
45- 50	1	196.22	162.90	122.75	86.44	65.09	53.67	48.94
50- 55	1	252.97	149.44	110.02	80.90	65.62	54.90	51.93

Table 4: Values of pooled flow duration curve indices.
(Duration in days: 60)

Q95 (as % of ADF)	Number of Stations	Q5	Q10	Q25	Q50	Q75	Q90	Q95
0– 5	12	455.28	245.41	103.72	32.68	9.31	3.56	2.14
5– 10	6	337.22	240.52	126.67	45.25	18.97	10.87	8.11
10– 15	12	327.25	227.96	126.02	55.61	27.61	16.97	12.72
15– 20	10	312.70	234.39	125.71	57.04	29.59	20.12	16.74
20– 25	5	266.37	207.86	132.54	69.75	39.48	27.97	22.26
25– 30	5	241.31	199.58	129.96	70.45	44.73	32.99	28.07
30– 35	3	227.55	179.06	114.07	77.13	53.60	40.50	33.54
35– 40	1	192.48	163.57	115.47	69.76	50.54	42.95	39.92
40– 45	4	201.92	169.07	119.36	85.43	61.75	47.40	41.48
45– 50	3	231.28	149.63	106.79	92.78	65.34	51.90	45.99
50– 55	2	201.07	148.18	117.79	87.28	67.21	56.23	52.08

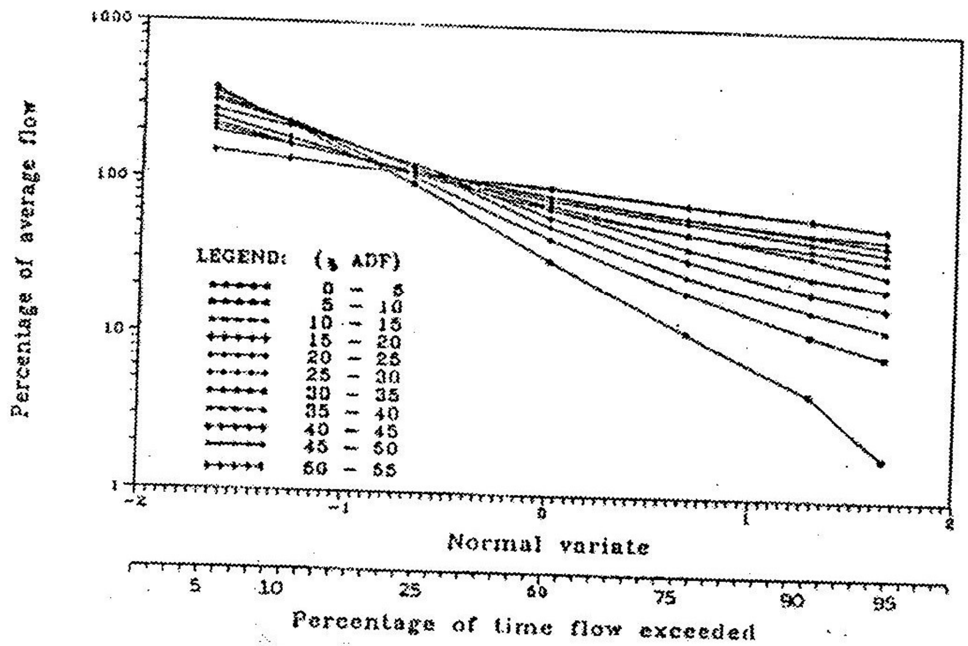

Fig. 1: Pooled one day flow duration curves

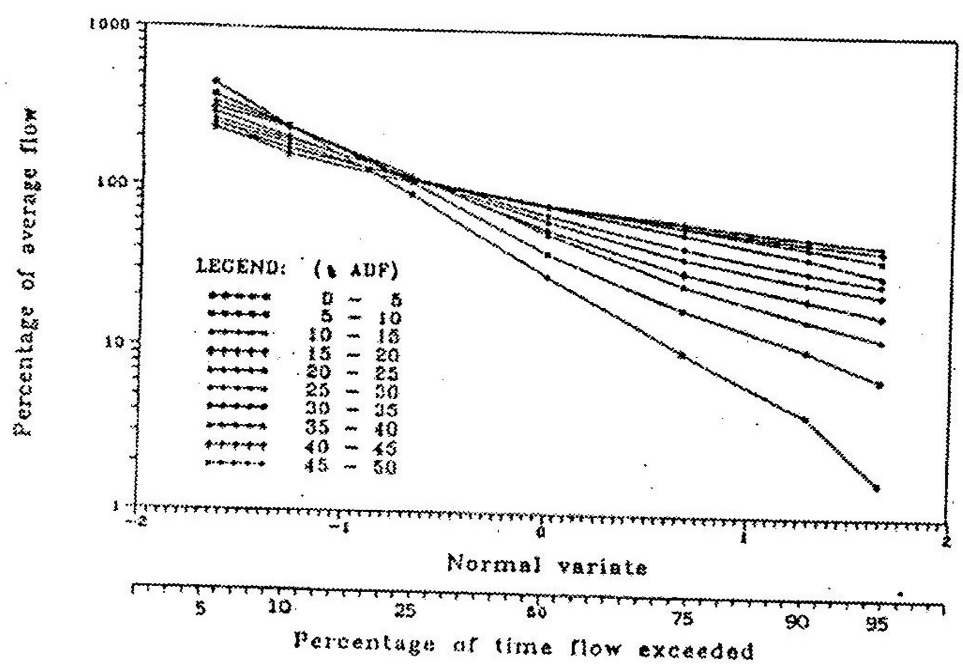

Fig. 2: Pooled 10 days flow duration curves

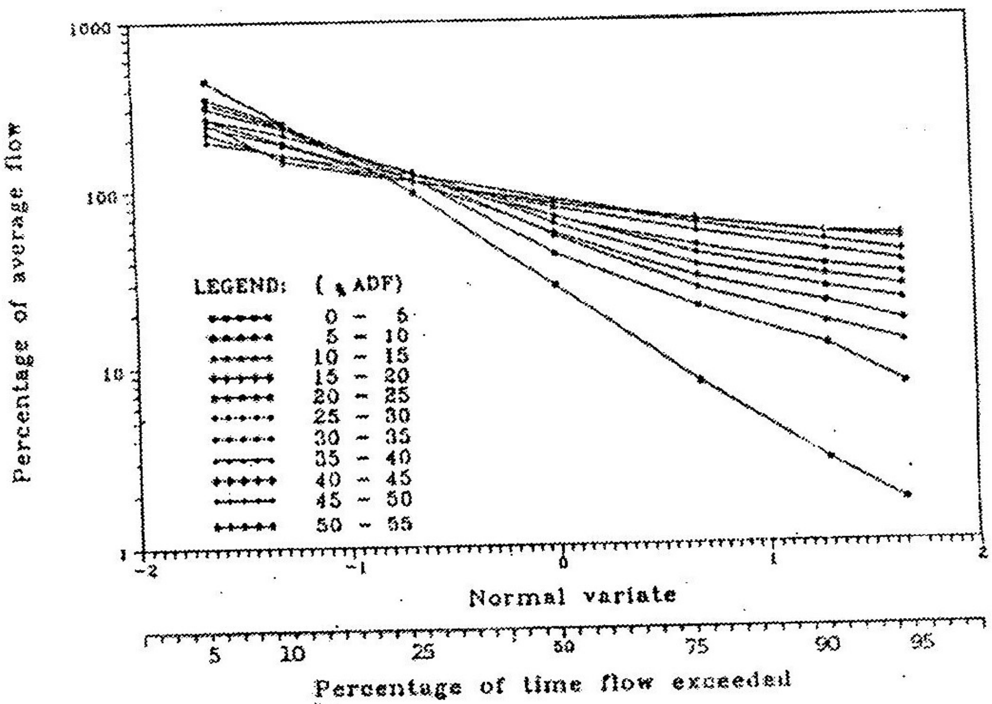

Fig. 3: Pooled 30 day flow duration curves

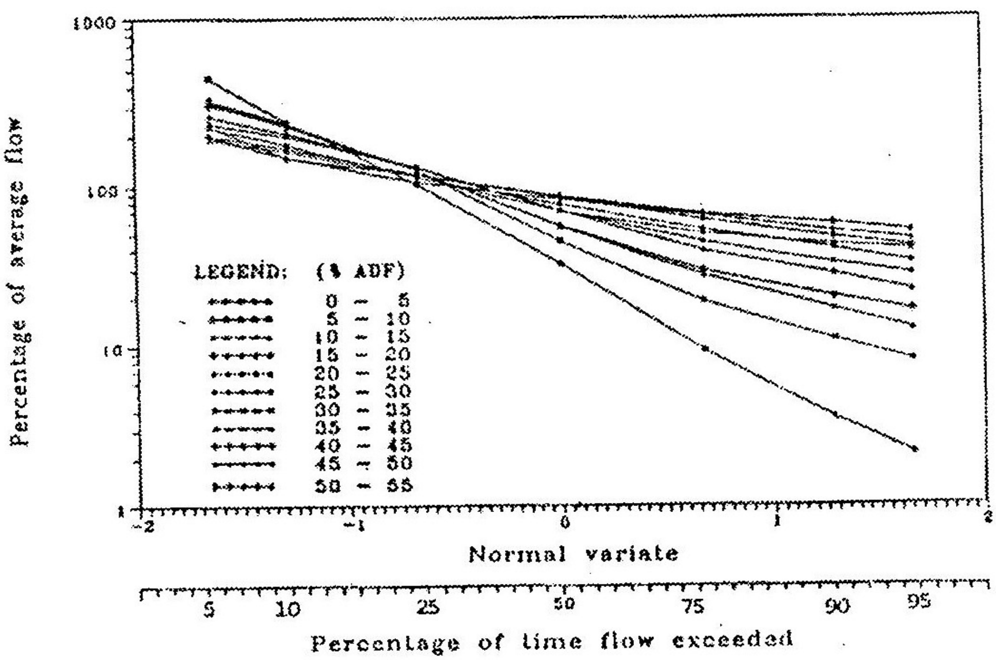

Fig. 4: Pooled 60 day flow exceeded

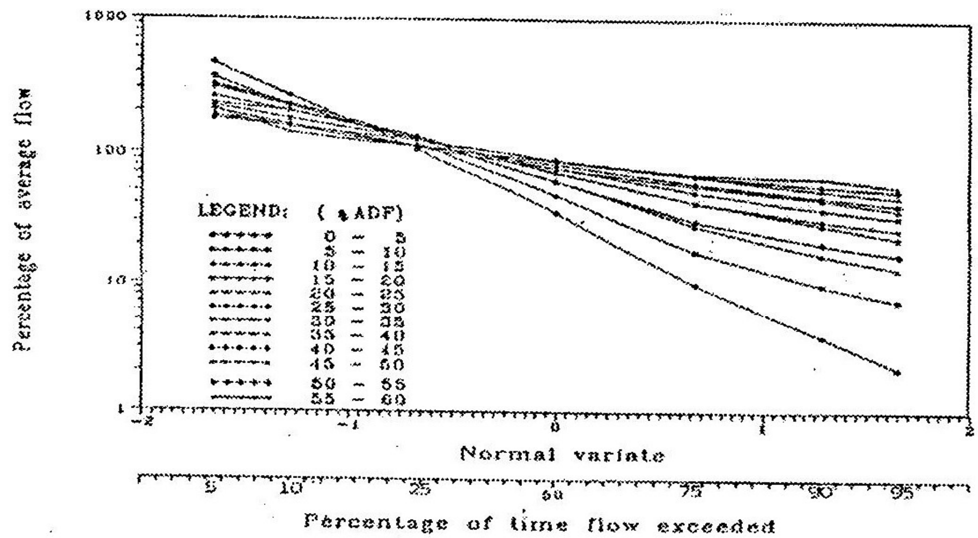

Fig. 5: Pooled 90 day flow duration curves

As stated earlier, the major aim of regionalization is to be able to estimate or predict the low flow statistics at ungauged sites. Therefore, it is necessary first to determine in which homogeneous group the catchment of interest belongs to. The only available information at ungauged sites is catchment characteristics. since the average daily flow was used in this study in the pooling of the flow duration curves into homgeneous groups, a relationship between average daily flow and catchment area was also stablished. Equation 4 shows the established relationship.

$$ADF = 0.082\ AREA^{0.68} \qquad (4)$$
$$R^2 = 0.732;\ s.e. = 0.872$$

The pooled flow duration curves and the established regression equations could be used to estimate the low flow statistics at ungauged sites. It should be noticed that equations 2 and 3 contain a baseflow index. The baseflow index could be estimated from a nearby gauged catchment. Also a relationship could be established between soil type and baseflow index. Any of the above approaches could then be used to estimate the baseflow index at ungauged site.

The average annual yield at ungauged site could be estimated using equations 1 or 2 after determining the average annual rainfall, the area and baseflow index of the basin. Equation 3 is then used to determine Q95(10), while equation 4 is used to estimate the average daily flow. The results of equations 3 and 4 are then used to determine Q95(10) as a percentage of average daily flow. This information is used to find the group of the flow duration curve which the catchment belongs (i.e. the homogeneous catchment group it belongs to). Once this is established, the flow duration curve for a 10 day duration is then determined for the ungauged catchment. Equation 3 could also be established for flow duration curves of various durations and the above proceedure is then used to establish the respective flow duration curves at ungauged site(s).

CONCLUSIONS

Hydrologic information (runoff, rainfall and catchment characteristics) from 63 catchments was analysed. Flow duration curves for different durations were established. The flow duration curves were pooled into homogeneous groups. Relationships between low flow Indices and catchment characteristics were established. The established regression equations and the pooled flow duration curves could be used to estimate the low flow statistics at ungauged sites.

RECOMMENDATIONS

Data from 63 catchments was used in this study. In order to make the analysis more reliable, and the results more practicable, data from all gauged catchments in the country should be used in establishing the flow duration curves and the regression equations. In fact regression equations could be established for each group of homogeneous catchments. Also a more rigorous approach like that proposed by Nathan et al., (1990), could be used in grouping catchments into homogeneous groups. The on going research on Analysis of river flow regimes in Tanzania should be able to fulfil the above recommendations.

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