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Assessment of Water Availability In Chindwinn Catchment

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Abstract

A study of water balance over Chindwinn Catchment has been carried out by using three decades of available Climatological and Hydrological data. (i.e, from 1967) The study was based on the monthly, annual and normal values. Actual evapotranspiration (AET) computed by as well as on the using Penman (1963) as well as Hargreaves (1985) methods. Some of the reliable data of evaporation at the stations were also used to estimate actual evaportion with the pan-coefficient value, 0.7. The values of actual evapotranspiration estimated by Hargreaves method was lower than the values estimated by Penman, but most followed the same significant trend. The soil moisture deficiency generally occur during November and April. A few cases of soil moisture deficiency do occur in August, September and October. However on the overall availability of water in the catchment is quite promising. The residual resulted from the water balance estimation may be assumed as soil moisture storage in the catchment by neglecting some losses from the catchment.

Keywords: Water balance; climatological; evapotraspiration: pan-coefficient; catchment.

1. Introduction

The region selected for this study is upper Sagaing Division, where Meteorological & Hydrological data are available at the stations along the Chindwinn River, such as Hkamti, Homalin, Mawlaik, Kalewa and Monywa. The Chindwinn River is situated on the Northern mountainous region of Myanmar. Chindwinn River is one of the largest tributary of the Ayeyarwady. The source is situated on 25°40' of Northern latitude and 97° of Eastern longitude. Its source is on the Kachin plateau. The second highest mountain in Myanmar, Saramali with the elevation of 12553 ft,

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is also located on the upper Chindwinn catchment area. Since it passes through the mountainous-region there are many streams, mostly are of streams flowing into the Chindwinn River. These streams are small tributaries of the Chindwinn River. Generally floods arise from the source of the river and the flood waves move down stream, causing damage to the crops and properties. Major floods generally occuring from July to September. The Largest tributaries of Chindwinn River are U Yu and Myitta, where U Yu, flows into Chindwinn near Homalin and Myittha near Kalewa.

The Major contribution of runoff is from rainfall over the catchment. The heavy rainfall are generally caused by monsoon through and storng monsoon. The maximum amount of rainfall over the catchment for monthly and annual are about, 686 mm and 2455 mm respectively. The Chindwinn River basin is contributed mainly by tertiary continental sediments. Among them more frequently found are sand-stones of different hardness, less frequent are clay with gypseous veins, shales and lime-stones. The width of the river ranges from 300 to 10,000 feet. Chindwinn catchment area covers 110350 sq.km. Totally the Chindwinn basin has about 120,000 acres of cultivated land. About 90% of the basin is thickly forested often by valuable species of wood. The location of Chindwinn River catchment is shown in Figure 1.

Revelant data regarding of observatory stations in the Chindwinn catchment area are as follows;

Station	Co-ordinates Latitude	Longitude	Elevation(m)
Hkamti	26°00'N	95°42'E	142.00
Homalin	24°52'N	94°54'E	131.00
Mawleik	23°38'N	94°25'E	112.59
Kalewa	23°12'N	94°18'E	110.63
Monywa	22°06'N	95°08'E	73.32

In this study, the monthly, annual and normal water balance of Chindwinn catchment were determined by a climatic appraisal of precipitation, surface and groundwater runoff and evapotranspiration throughout the basin. In this paper, a study of water balance is undertaken to evaluate the water surplus and deficit in the Chindwinn catchment, and at the same time to find out proper method for deriving actual evapotranspiration.

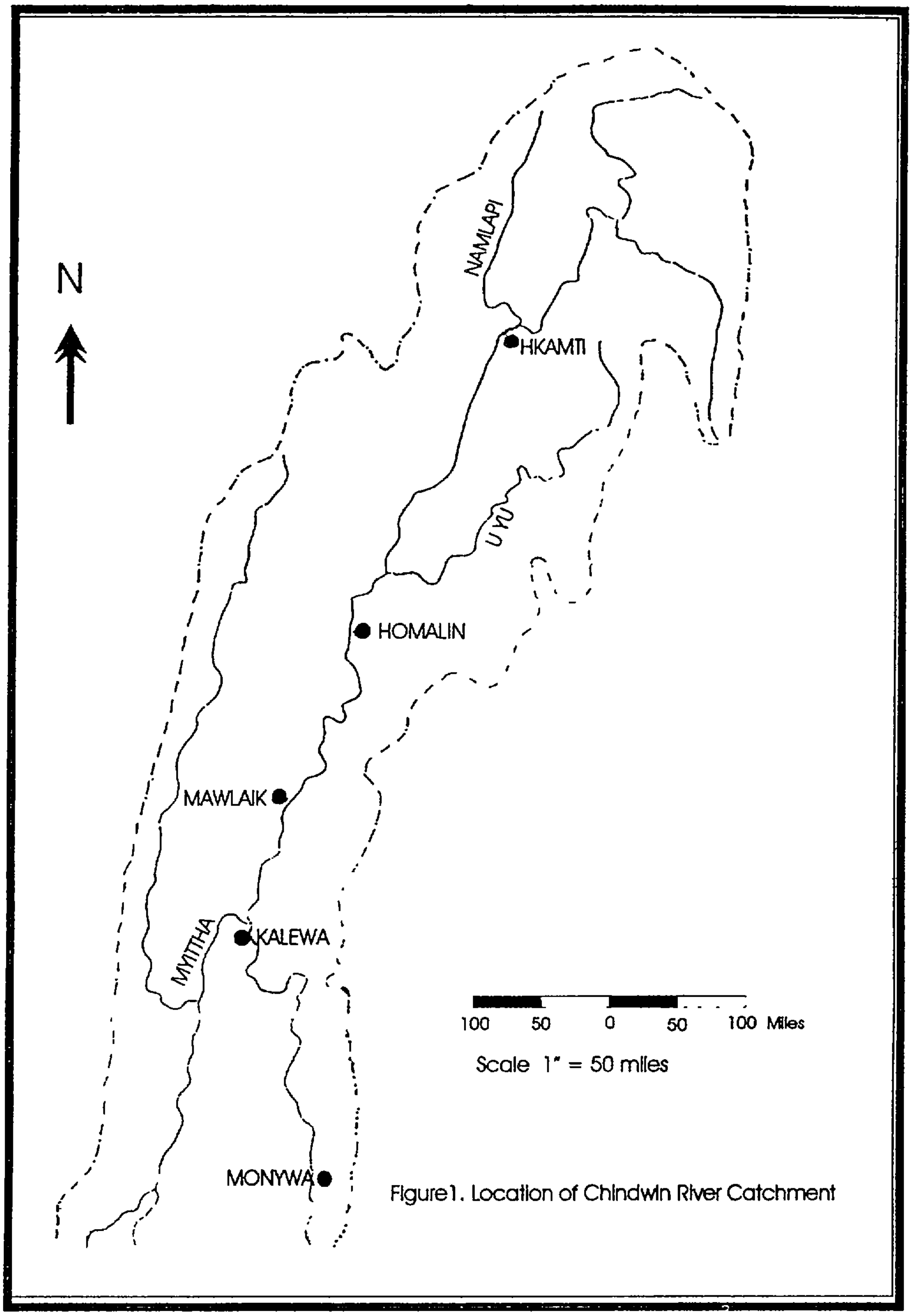

Figure1. Location of Chindwin River Catchment

2. Available Data

Rainfall and runoff data are avaliable from the year 1967 at Hkamti, Homalin, Mawlaik, Kalewa and Monywa. Evaporation data are not consistance and reliable at those stations. Some of the reliable data from these stations are selected for this study. Actual evapotranspiration data are derived by Penman (1963) and Hargreaves (1985) formulae, using climatological data such as maximum and minimum temperature, due point, wind speed, cloud and rainfall.

Surface and ground water runoff estimation

The two aspects of runoff to be studied for hydrologic purposes are the surface runoff and groundwater flow. There are several procedures for separating the hydrograph into groundwater and surface runoff. In this study, the ground water hydrograph could be easily determined by using simple hydrograph separation method and the total runoff is divided into the two constituent parts, surface runoff and ground water runoff.

The discharge hydrographs of Monywa station are drawn by using computer for each year. Then the ground water hydrograph is determined by separation method. The values of ground water runoff are obtained from these graphs. The surface runoff values are then computed by subtracting ground water runoff from total runoff. The surface runoff and groundwater runoff values for monthly and annual are listed in Table 1 and 2.

Evaporation and computation of evapotranspiration

Evaporation data along Chindwinn river are generally not consistance and reliable. A few years of reliable data are selected for this study. Actual evapotranspiration are then derived by Penman and Hargreaves methods. Penman method is a well known method and it can be regarded as standard method for estimation of evapotranspiration. Numerous researchers have highlighted the limitations in Penman's formula and some have suggested modifications of it. However, the basic concept of combining turbulent transfer and energy balance approach have made it a major and widely-accepted method for estimating potential evapotranspiration (Penman, 1963). Hargreaves method is also applied in his study, as Mohan (1992) pointed out in his study that it is suitable for humid regions. The values of actual evapotranspiration (AET) estimaed by Hargreaves method is lesser than the values estimated by Penman, but most of them are in the same trend as shown in Figure 2.

Evapotranspiration incorporates combined losses by direct evaporation and transpiration from all surfaces in a catchment. Of all hydrological processes it is the most difficult to quantify, due mainly to the complexity of the processes involved and to the variability of transpiration rates associated with heterogeneous vegetation.

In defining potential evaporation, Penman visualized a surface sufficiently extended to obviate any significant advection of energy from outside, with an abundant water supply and subject to radiation at a constant rate. Penman suggested that when the water supply is not abundant, actual

Table 1. Meteorological and Hydrological components for derivation of monthly water balance equation. (all unit in mm)

Year/ Month	R/F	SURFACE R/O	AET (by Penman)	Changes of Ground water R/O	Residual
1967					
MAY	130.6	11.21	118.2	-2.1	3.29
JUN	241.4	47.55	112.8	-0.6	81.65
JUL	383	235.58	102.2	1.82	43.4
AUG	378	228.32	94.4	2.42	52.86
SEP	318	155.26	68.2	1.64	74.9
OCT	258	247.64	94.4	0.79	-84.83
NOV	3	28.88	73.4	1.53	-100.81
DEC	21	5.1	22.2	2.11	-8.41
JAN	13	0	82.6	-1.75	-67.85
FEB	3	0	33	-6.57	-23.43
MAR	24	0	24.4	0.04	-0.44
API	43	0	43.2	-3.19	2.99
1968					
MAY	116.8	9.67	115	0.54	-8.41
JUN	510.2	141.33	109	-0.54	260.41
JUL	593.8	440.57	124	1.77	27.46
AUG	493.2	279.9	97	-0.01	116.31
SEP	359.2	279.91	97	-0.58	-17.13
OCT	120	117.74	84	0.58	-82.32
NOV	4	22.63	76	0.6	-95.23
DEC	0	1.94	23	5.47	-30.41
JAN	16.4	0	83	0.55	-67.15
FEB	4.2	0	37	-8.71	-24.09
MAR	7.4	0	7	-0.46	0.86
API	42.8	6.14	9	-1.56	29.22

(Contd) Table 1

Year/ Month	R/F	SURFACE R/O	AET (by Penman)	Changes of Ground water R/O	Residual
1969					
MAY	103.6	2.06	103	0.47	-1.93
JUN	496.4	105.4	101	0.23	289.77
JUL	468.4	314.72	106	0.99	46.69
AUG	336.6	327.36	86	1.2	-77.96
SEP	236	209.84	99	0.64	-46.48
OCT	122.4	71.04	86	0.58	-35.22
NOV	3.6	20	75	-4.1	-87.3
DEC	0	3	20	6.51	-29.51
JAN	0.2	0	81	-2.51	-78.29
FEB	0	0	20	-3.5	-16.5
MAR	6.4	0	6	-0.07	0.47
API	54.8	0	55	-0.84	0.64

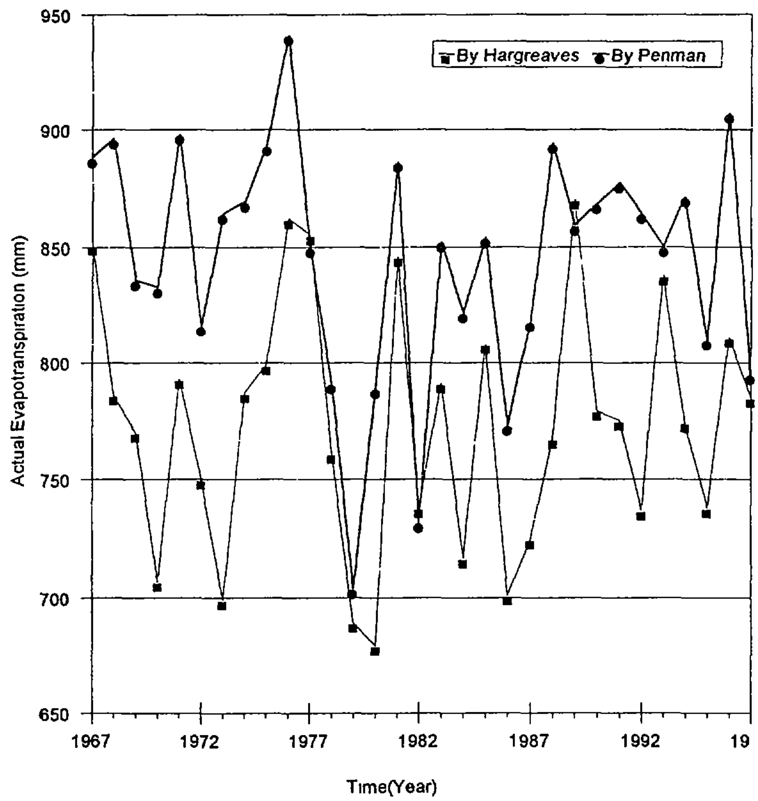

Figure 2. Profiles of AET according to Hargreaves and Penman; Showing the difference between the two methods.

Table 2 Meteorological and Hydrological components for derivation of annual water balance equatuion. (All unit in mm)

YEAR	R/F	AET (Hargreaves)	SURFACE R/O	U.G R/O	CHANGES OF G.W	TOTAL R./O	AET (Penman)
1967	1882	851	960	267		1227	888
1968	2268	786	1251	280	13	1531	869
1969	1855	770	1007	250	-30	1257	836
1970	2149	707	1052	270	20	1322	833
1971	2285	793	1283	280	10	1563	898
1972	1479	750	730	200	-80	930	816
1973	2252	699	1110	285	85	1395	864
1974	2077	787	1291	270	-15	1561	869
1975	2208	799	1192	200	20	1482	893
1976	2115	862	1144	275	-15	1419	941
1977	2328	855	1025	286	11	1311	850
1978	2184	761	925	260	-26	1185	791
1979	1897	689	953	211	-49	1163	704
1980	1992	679	1183	268	57	1451	789
1981	1616	846	852	253	-15	1105	886
1982	1956	738	986	270	17	1256	732
1983	1924	791	954	260	-10	1214	852
1984	2115	717	1172	280	20	1451	822
1985	2171	808	1237	295	15	1532	854
1986	1807	701	920	237	-58	1157	773
1987	2455	725	1281	280	43	1561	818
1988	2412	767	1223	273	-7	1496	894
1989	2150	870	1150	250	-23	1400	859
1990	2405	779	1357	300	50	1657	868
1991	2378	775	1574	280	-20	1854	877
1992	1873	737	1008	190	-90	1198	864
1993	1885	838	1194	220	30	1414	850
1994	1737	774	806	200	-20	1006	871
1995	2073	738	1191	259	59	1450	810
1996	2099	811	897	270	11	1167	907
1997	2094	785	1052	260	-10	1312	795
Normal	64121/31	23988/31	33959/31			42027/31	26200/31
Value	2068	774	1095			1358	848

evaporation would be proportional to potential evaportion and a function of the availability. The two views of potential evaporation, on the one hand as the cause, and on the other as the effect of actual evaporation, are not in compatible. They arise when different sets of factors are considered constant. In terms of the constancy of external factors which are themselves unaffected by actual evaporation, potential evaporation is indeed a negative index of actual evaporation, as stated by Morton, while in Penman's interpretation it remains a positive index of evaporation, under the assumption of constant factors of radiation, wind speed, humidity, air temperature and velocity.

Nash (1989) gave a conclusion remark that despite intial appearances, the only conflict between Morton's views and those of Penman, arise through Moton's rejection of the assumption that when the water supply is limiting the actual evaporation is proportional to the potential evaporation and some function of the water supply. There is no conflict between Penman's and Morton's definitions of potential evaporation, through the latter is clearer and less open to misinterpretation. Morton's use of the complementary relationship is an extension, not a contradiction of Penman's work which enables one to estimate actual rather than potential evaporation, these a voiding the necessity of assuming empirical relationship between actual and potential evaporation as a function of soil moisture deficiency.

Annual water balance equation

The present study was undertaken to provide annual water balance estimates of the catchment that could be compared directly, year by year. The data used were rainfall, evapotranspiration, and runoff data. The rainfall falling on the catchment is represented by the basic equation:

$$P = R \pm \Delta G.W + E$$

Where P is annual average catchment rainfall, E is evapotranspiration, Δ G.W is change in groundwater, and R is surface runoff. These terms are all expressed in millimeter. The average rainfall for each year was computed by arithematic mean of five stations in the Chindwinn catchment. The surface runoff and the change in ground water at Monywa station where then derived. Actual evapotranspiration for annual values were also computed as mentioned before. The water balance for each year at Chindwinn catchment was determined by comparing precipition with actual evapotranspiration, surface runoff and the change in ground water runoff.

In this study, the results indicate that among (30) years of observations, the years 1969, 1972, 1974, 1981, 1991, 1992 and 1993 are deficit years, that is precipitaion is less than sum of other components of water balance equation. On the other hand, the result from most of the years are surplus in rainfall amount. Chindwinn catchment area can be regarded as humid region as the number of surplus water years were much greater than deficit water years according to the annual water balance results. The results of the water balance estimates are summarized in Table 3.

Monthly water balance equation

The monthly water balance of the Chindwinn catchment was determined by a climatic data of rainfall, actual evapotranspiration and hydrologic data of surface runoff, the change in ground water runoff through out the catchment. The following equations used to find monthly water balance residuals.

$$Res = P - R - E \pm \Delta G.W$$

Where Res is Residual, E is actual evapotranspiration, P is monthly average catchment rainfall, R is surface runoff and Δ G.W is change in ground water runoff.

Solutions of the water balance equation for each month can be obtained by using above formula. These relationships are shown in Table 1, with the components of monthly water balance. The deficit amount of rainfall are generally occurred during November and March. The residual values of each month are plotted for the period of water year, i.e. starting from May to April and shown in Figure 3. It was found out that rain water deficit even in August in some cases and in September and October in some cases. This may be due to the lesser amount of rainfall in those periods.

Normal water balance equation

The normal water balance equation of the catchment is also derived by using the annual normal values of rainfall, surface runoff and actual evapotranspiration. A catchment normal water balance equation may be written as

$$P = E + Qs$$

Where P is rainfall, E is evapotranspiration or evaporation and Qs is surface runoff. The residual caused by using Penman method for

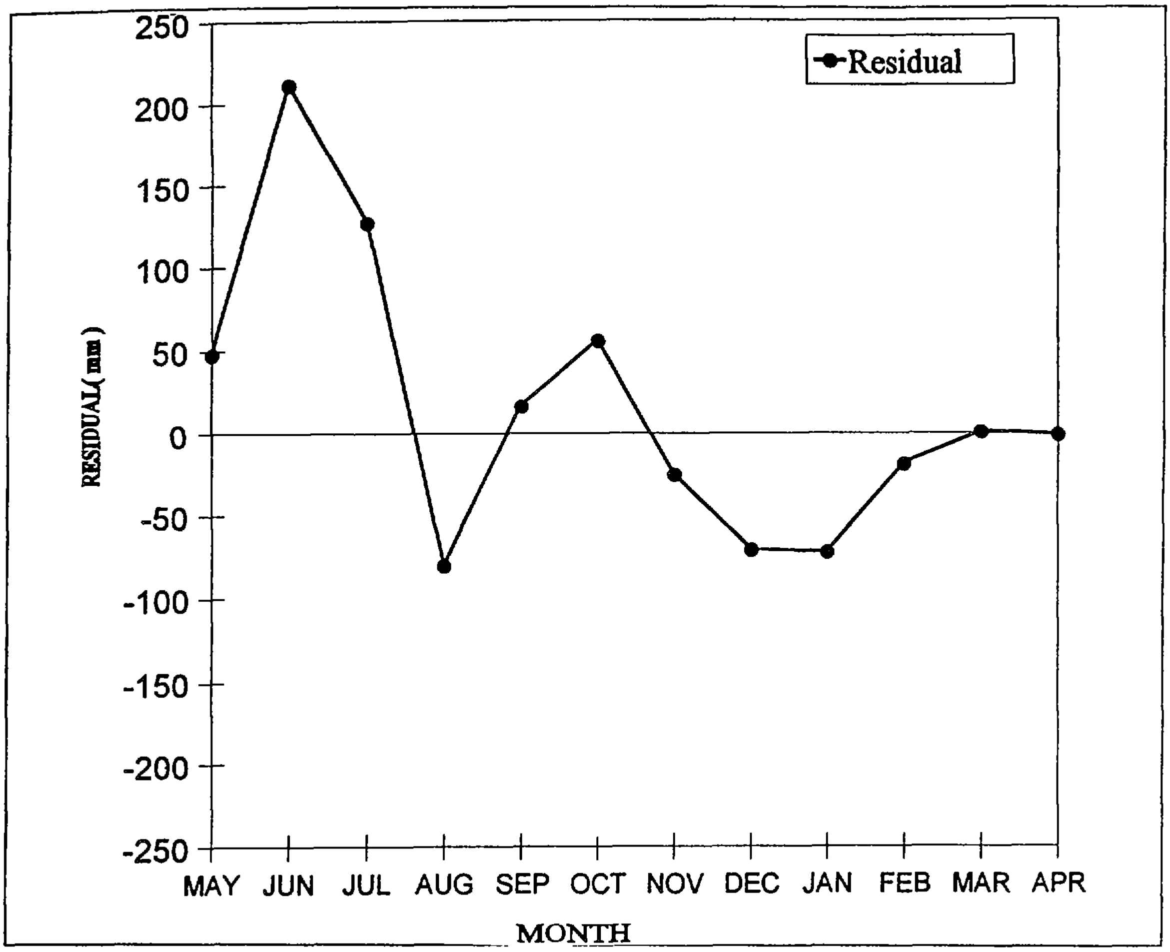

Figure 3. Residual vs Time graph (1970) (Chindwin Catchment Area)

estimation of actual evapotranspiration is about 125 mm, where as using Hargreaves method is about 199mm, and finally used by pan evaporation data is about 39 mm.

3. Discussions

The normal value consider in this study is the normal value derived from 30 years of record. Actually the normal .value should be the average of long term historical data in such a way that the average value should not be altered considerably with further available data. In estimation of actual evapotranspiration, Penman method is the most perferable approach as it consider most of the factors affecting evapotranspiration. It is also liked to recommand to use the value 0.7 for pan-coefficient. The monthly residual values indicate that the deficit of water generally arise during November and April. This occur at August and sometimes at September and October as well. This is also due to the lesser amount of rainfall at those periods.

Table 3 Estimated annual water balance of Chindwinn catchment

YEAR	Precipitation (mm)	Surface runoff ±Δ G.W+ AET (by Penman)	Surface runoff±Δ G.W + AET (by Hargreaves)
1968	2268	2134	2024
1969	1885	1873	1807
1970	2149	1865	1739
1971	2285	2171	2066
1972	1479	1626	1560
1973	2252	1889	1724
1974	2077	2175	2093
1975	2208	2065	1974
1976	2115	2100	2021
1977	2328	1864	1869
1978	2184	1742	1712
1979	1897	1706	1691
1980	1992	1915	1805
1981	1616	1753	1713
1982	1956	1701	1707
1983	1924	1816	1755
1984	2115	1973	1868
1985	2172	2076	2030
1986	1807	1753	1679
1987	2455	2056	1963
1988	2412	2124	1997
1989	2150	2032	2043
1990	2405	2175	2086
1991	2378	2471	2369
1992	1873	1962	1835
1993	1885	2014	2002
1994	1737	1697	1600
1995	2073	1942	1873
1996	2099	1793	1697
1997	2094	1857	1847

4. Conclusion

The monthly residual values indicated that the soil moisture deficiency generally occur during November and April. A few cases of soil moisture dificiency arise at August, September and October. Anyhow overall availability of water in the catchment is quite promissing. The values of actual evapotranspiration estimated by Hargreaves method is lesser than the values estimated by Penman, but most of them are following the same trend. It is also liked to stress here that Penman method is the most appropirate method for estimation of actual evapotranspiration. The appropriate value of pan-coefficient is about 0.7. Although soil moisture could not able to consider in monthly and annual water balance equations, some portions of residual values may be considered as soil moisture. The author do hope that this study will be useful for agricultural purposes in the catchment.

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