CLIMATE CHANGES IN SRI LANKA

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Abstract

Rainfall extremes have adverse impacts on the society and environment of Sri Lanka. Different regions of the country have witnessed either flooding or drought in quick succession in recent years. Some studies attribute such extreme events to climate changed induced by global warming. However, there is a dearth of climatological studies addressing the spatio-temporal trends in rainfall over Sri Lanka in support of such attribution. Using daily rainfall data collected at the 22 main meteorological stations of the Department of Meteorology, this paper identifies spatio-temporal trends in the rainfall received during the four rainy seasons ï i.e. the Southwest monsoon, the first inter-monsoon, the Northeast monsoon and the second inter-monsoon during the period 1961-2002. It translates rainfall trends into trends in water volume by river basin using different GIS techniques, so that the practical implications of climate variability and change in recent decades are clearly identifiable. The study finds that the number of rainy days has decreased at all the meteorological stations except for the Nuwara Eliya station. It also finds that the 2000mm isohyet ï demarcating the wet zone of the country - has shrunk. Water volume by watershed shows a clear dichotomous distribution with watersheds in the north having increasing trends, and watersheds in the south having decreasing trends, in water volume.

1. Introduction

Rainfall is of primary importance to the both physical and cultural landscape of any region.. Of all the standard climatic parameters, rainfall is the most variable parameter in time and space. Rainfall received across Sri Lanka varies dramatically from year to year, ranging from dry periods that can persist for months, to periods of intense downpours, storms and flooding. The temporal and spatial diversities associated with rainfall has provided the basis for dividing the climate year in Sri Lanka into four seasons. Two Monsoon periods and two Inter-Monsoon periods. The Southwest Monsoon (Summer Monsoon) prevails from May to September while the Northeast Monsoon (winter

Monsoon) lasts from December to February. In between these two monsoon periods, two Inter-Monsoon periods exist: March to April - first Inter-Monsoon period and October and November ï second Inter-Monsoon (National Atlas of Sri Lanka, 1988). Westerly winds prevail during the Southwest Monsoon and North-easterly winds prevail during the Northeast Monsoon. The seasonal variations of wind direction and rainfall have a marked influence on human activities.

Sri Lanka has a food crop-oriented agricultural economy. Rainfall is a key determinant of the growing seasons and the types of agriculture practised. Rainfall plays an important role in agriculture as any shortages or excesses of rainfall gives way to a reduction in yields. For instance, rice is the main crop in Sri Lanka and is highly susceptible to rainfall variability. Other crops such as the plantation crops of tea and rubber are also dependant on the amount of rainfall received.

The number of rainy days in a season is of particular importance for tea and rubber crops. Yield decreases can be attributed to an increase in the frequency of droughts and reduction of the number of rainy days. Therefore, examining trends in the variability of the number of rainy days is vital as it is a decisive factor in agriculture. The number of rainy days is also important for industrial activities such as salt production. In recent years salt production in the salterns of southern Sri Lanka has decreased due to the changing pattern of rainy days in the Hambantota district.

Given the importance of agriculture the number of rainy days affects growing patterns and yields. Therefore, it is important to investigate the factors determining the variability of rainfall. There is a dearth of studies on rainfall variability in Sri Lanka. Such studies are essential to evaluate the impact of climate change on agriculture.

Since late-1980s, there appear to have been changes in weather patterns in Sri Lanka with an apparent reduction in rainfall received and more intense wet and dry spells. This paper aims to assess the magnitude and significance of rainfall variability and change over time using

statistical analysis techniques and spatial analysis techniques in Geographical Information Systems (GIS).

2. Objectives

The goal of this study is to obtain evidence of climate change in Sri Lanka over the last four decades. Although there are several climatic variables that could be included in a study of climate change, only rainfall has been selected for the current analysis. The paper has the following specific objectives:

I. Examine overall trends in the number of rainy days
II. Examine trends in the number of rainy days by rainy seasons
III. Examine trends in average annual rainfall by different climatic zones
IV. Analyze the water volume by different watersheds within different climatic regions.

3. Methodology

3.1 Data Sources

This study is entirely based on secondary data available from the Department of Meteorology. Daily rainfall data were collected for the period from 1961 to 2002 for 22 meteorological observatories bearing in mind the minimum 30-year period required for climatological analyses. The twenty two meteorological observatories are well distributed over the entire country by elevation and climatic regions. The stations under study, their elevations and the period which data are available are given in Table 1.

Table 1: Meteorological stations

Wet zone		Dry zone		Intermediate zone	
Station name	Elevation (m)	Station name	Elevation (m)	Station name	Elevation (m)
Colombo	7	Puttlam	2	Kurunegala	116
Galle	12	Trincomalee	3	Badulla	670

Rathnapura	34	Hambantota	16	Diyathalawa	1,250
Kandy	479	Anuradhapura	93		
Nuwara Eliya	1,880	Maha Illupallama	136		
Kalutara		Batticaloa	3		
Ratmalana		Ampara	15		
		Jaffna			
		Mulative			
		Vavuniya			
		Kankasanthurai			

Source: Department of Meteorology, 2006

3.2 Methods of Analysis

Statistical analysis such as linear regression and time series analyses were utilized to examine periodic changes in both annual and seasonal contexts. GIS spatial analysis techniques such as Surface Interpolation, zonal statistics were utilized.

4. RESULTS AND DISCUSSIONS

4.1 Number of rainy days

In order to examine trends in the number of rainy days, the annual number of rainy days was obtained from the original daily rainfall record at each station. Regression analysis was performed on the number of rainy days at each station. See Table 2 for the results.

Table 2: Trends in the number of rainy days for the period from 1961 - 2002

Station	m (Slope)	c (Intercept)	Remarks
Nuwara Eliya	0.0477	107.07	Low
Jaffna	-0.0589	193.83	Low
Kandy	-0.065	312.77	Low
Diyathalawa	-0.1308	420.54	Low

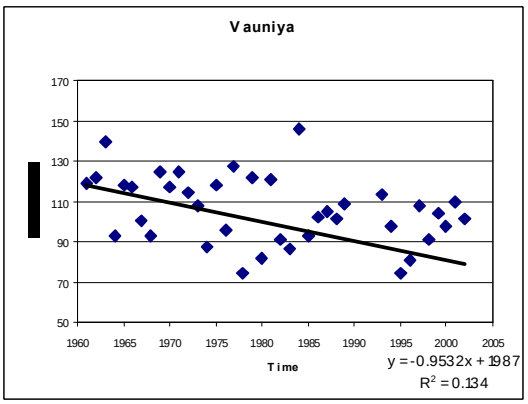
Mahailluppallama	-0.2847	675.88	Low
Badulla	-0.3005	753.36	Low
Rathnapura	-0.3023	833.22	Low
Trincomalee	-0.3216	738.2	Low
Mannar	-0.3472	757.0	Low
Batticaloa	-0.3553	810.04	Low
Rathmalana	-0.3765	926.97	Moderate
Galle	-0.4007	991.91	Moderate
Puttlam	-0.4255	946.8	Moderate
Hambantota	-0.4334	970.21	Moderate
Anuradhapura	-0.4587	1015	Moderate
Kankasanthurai	-0.4874	1040.3	Moderate
Colombo	-0.5375	1238.4	Moderate
Kalutara	-0.5439	1236.6	Moderate
Kurunegala	-0.7069	1566.6	Remarkable
Mullativui	-0.8182	1714	Remarkable
Vavuniya	-0.9532	1072.5	Remarkable
Pothuvil	-0.9718	2013.1	Remarkable

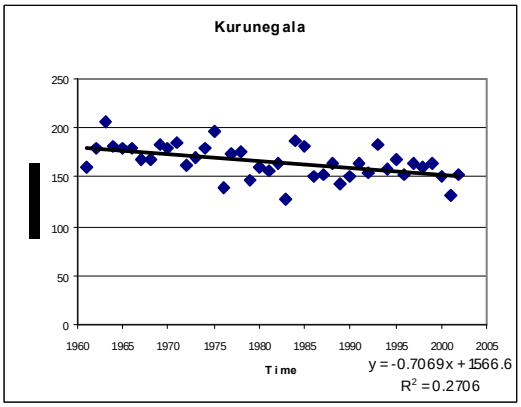
Note: Data have been arranged in descending order according to the slope
Source: Regression results, Prepared by the author,2008

It is observable that all the stations except Nuwara Eliya have a decreasing number of rainy days. Nuwara Eliya is the only station that has shown an increasing trend but it is noticeable that the trend cannot be considered as a significant one as the R^2 value is only 0.0014. It is shown that four stations have had a marked negative trend and it is more pronounced in the Dry Zone Mullativu, Vavuniya and Potuvil have recorded as having the notable decreasing trend while Puttlam, Hambantota, Anuradhapura and Kankasanthurai in the Dry zone have shown a moderate decline in the number of rainy days received during the study period. Wet zone observatories like Galle, Ratmalana, Colombo and Kalutara have slightly less decreasing trends. Kurunegala ï within the Intermediate zone ï has a strong decrease in the number of rainy days. Trends at all other stations were not significant Figure 1). These factors can be clearly displayed in graphical form.

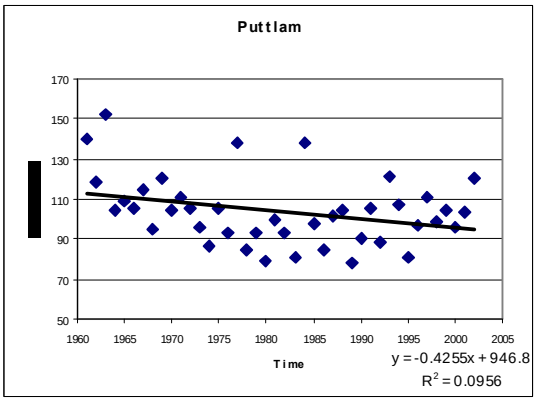
Figure 1

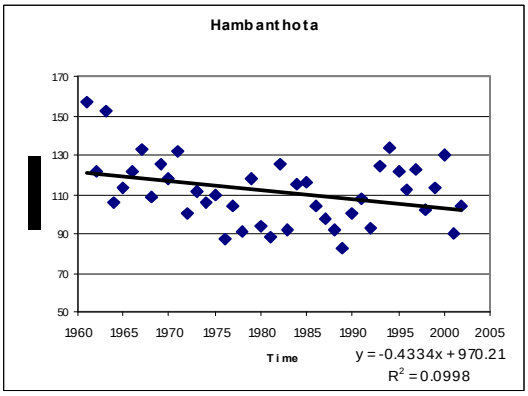
(a) Stations with remarkable negative trends in the number of rainy days

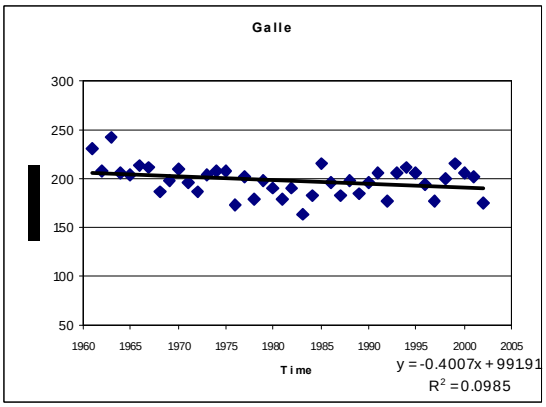


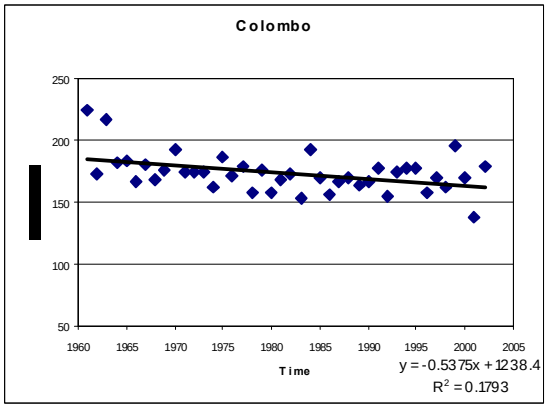


(b) Stations with moderate negative trends in the number of rainy days

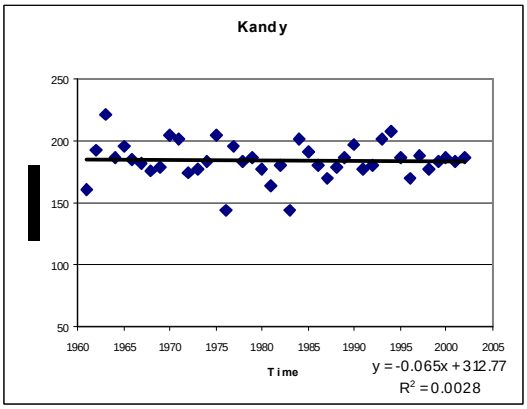


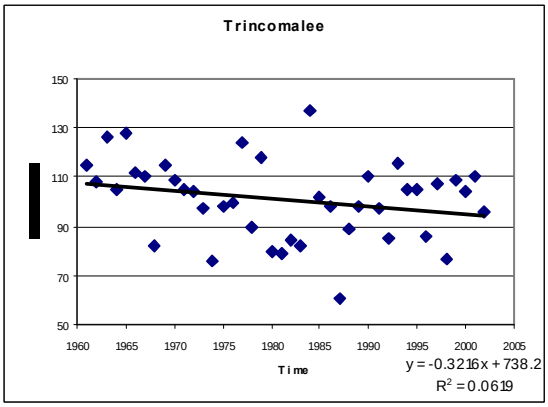




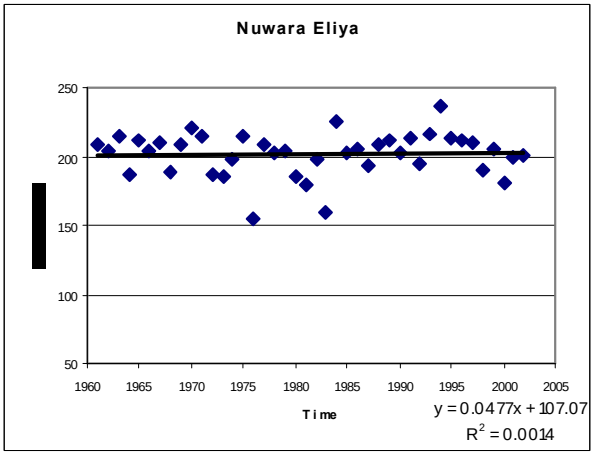


(c) Stations with low negative trends in the number of rainy days





(d) The only station with the positive trends in the number of rainy days



This graphical representation clearly shows that some weather stations have high variability in the recorded number of rainy days.

4.2 Trends in the number of rainy days by season

With regard to the number of rainy days received in each season, the Northeast Monsoon Season (NEMS) has witnessed a negative trend in all the meteorological stations under study. In the First Inter Monsoon Season (FIMS) only the Mulativu observatory has shown a

positive trend while all the other observatories have gained an overall negative trend in the frequency of the rainfall. Mulativu, Nuwara Eliya, Badulla and Kandy have displayed positive trends both in the Southwest Monsoon Season (SWMS) and the Second Inter Monsoon Season (SIMS). Potuvil has depicted a remarkable decline in all seasons except in the SIMS. In the NEMS the decline has been more pronounced in the Central to Eastern parts of the country. During the SWMS, the decline has both negative and positive results for all zones of the country without being confined to one particular area. This result is interesting as the rainfall during the SWMS tends to be confined to the southwest quadrant of the country. Out of the two Inter-monsoon seasons, the FIMS has a comparatively higher rate of decline in the number of rainy days.

In the NEMS the same phenomenon has correlated between the amount of rainfall and the frequency of the rainfall except in the station Mulativu. All stations under study have negative trends in the amount of rainfall that received during a particular season. Despite the reduction in the number of rainy days at all stations during the NEMS, the total rainfall received at Jaffna and Ratnapura has increased.

In the SWMS, the most significant pattern that can be identified is that the all stations, except for Colombo and Ratmalana, with positive trends belong to the Dry and Intermediate Zones. All the other stations in the Wet zone have recorded decrease in rainfall. On the other hand one can assume that since the Dry and Intermediate zones are not greatly affected by the SWMS, the reduction has become more apparent in the Wet zone stations. Therefore, it could be inferred that the rainfall received in the western portion of the country has decreased. In contrast, the SIMS has been characterized with plentiful rainfall for the western part of the country. The SIMS is the period that an evenly balanced rainfall is received by the whole country. Just one station ï the the Galle meteorological observatory ï has a registered a decrease in rainfall during all four seasons.

4.3 Annual rainfall pattern

The annual rainfall of the country is conventionally considered as ranging between 1000mm in the driest parts to more than 5000mm in the wettest parts. There is a marked spatial pattern associated with the mean annual rainfall over Sri Lanka. Domroes has specified that ñ in spite of the unequal length of the seasons - an unevenly ï balanced, seasonally greatly varying distribution of rainfall throughout the year can be derived for the entire island of Ceylonò.

Monthly rainfall at each meteorological station was used to compute annual rainfall totals. Simple regression was then carried out to identify patterns in annual rainfall (Table 3).

Table 3: Annual Rainfall Pattern of the period from 1941- 2002

Station	m (Slope)	c (Intercept)	R^2	Remarks
Jaffna	1.7089	-2299.9	0.0051	
Puttlam	-0.3707	1740	0.0004	Low
Colombo	-0.3835	2853.7	0.0003	Low
Kandy	-1.4293	4513.7	0.0033	Low
Kurunegala	-1.7055	5170.2	0.0048	Low
Rathnapura	-1.7571	6920.5	0.0037	Low
Badulla	-2.4553	6546.6	0.0115	Low
Mahailluppallama	-2.8906	7094.4	0.0205	Low
Ratmalana	-3.1974	8793.8	0.0218	Moderate
Diyathalawa	-3.2762	7912.3	0.0309	Moderate
Batticaloa	-3.4809	8513.4	0.0189	Moderate
Nuwara Eliya	-3.491	8753.8	0.0297	Moderate
Kankasanthurai	-3.9674	9002.3	0.0158	Moderate
Hambantota	-4.4924	9840.9	0.0723	Moderate
Galle	-5.3877	12804	0.0562	Moderate
Trincomalee	-5.9501	13333	0.0453	Moderate
Anuradhapura	-7.1183	15878	0.0507	Remarkable
Mullativui	-8.7556	18539	0.1113	Remarkable
Kalutara	-9.9088	22134	0.0503	Remarkable
Vavuniya	-12.169	25413	0.0988	Remarkable

Note: Data have been arranged in descending order according to the slope

The above tabulation clearly shows that almost all the stations under study have registered negative trends in annual rainfall over time. Only Jaffna has shown a positive trend but it is not a significant relationship as the R^2 accounts for about 0.0051. The negative trend is more remarkable in stations such as Trincomalee, Anuradhapura, Mulativu, Kalutara, and Vauniya. It is seen that both Vavuniya and Mulativu have demonstrated remarkable negative trends in the annual rainfall pattern just as in the number of rainy days (Figure 2). From these results it can be concluded that both these stations have experienced a reduction in the amount of annual rainfall received. In the case of Vavuniya it poses a question whether this high variability signifies more drought or rather increases dry spells. It is notable that Kalutara and Anuradhapura have a moderate decline in the number of rainy days but when it comes to the annual rainfall both stations are having remarkable reduction. The other noteworthy point is both Colombo and Puttalam. Although the number of rainy days at these two stations has decreased, there is no clear trend in the annual rainfall received (Figure 3). It implies that the decrease in rainfall frequency has not affected the total annual rainfall volume.

Figure 2

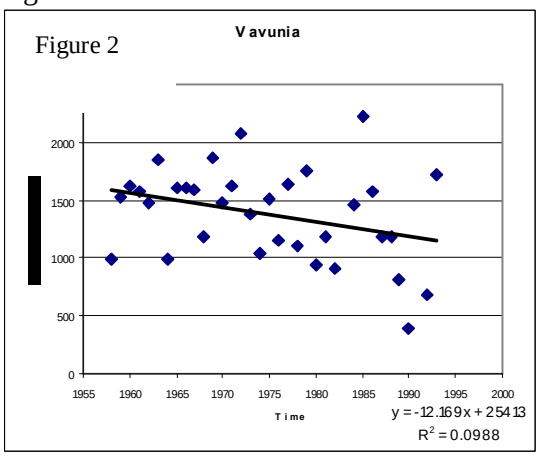
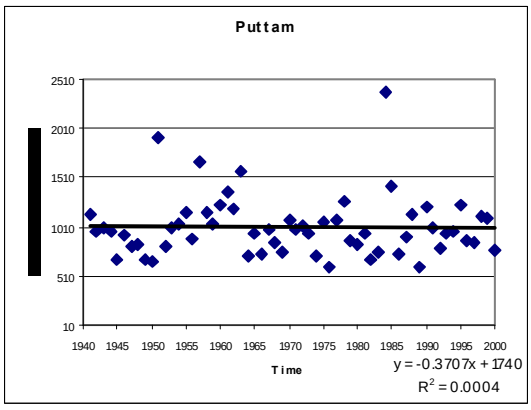
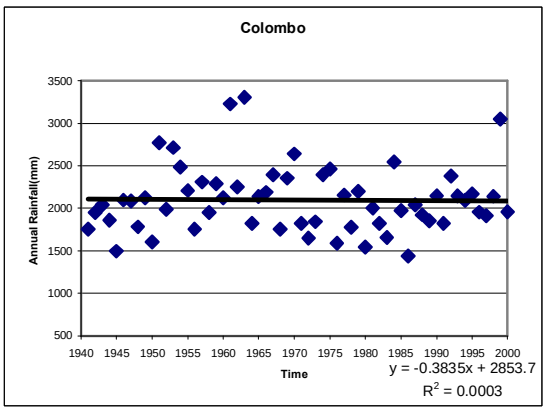


Figure 3: Annual rainfall pattern in Puttalam and Colombo





4.4 Average Annual Rainfall by Different Climatic Zones

For the basis of the present study the isohyets of the distinctive zones have been considered. Thus 2200mm isohyet is taken as the cut-off line between the Wet zone and the Intermediate zone and the 2000mm isohyet as the line between Intermediate zone and the Dry zone. The spatial pattern of the deviations of these lines was investigated using the IDW (Inverse Distance Weighted) Interpolation method available in ArcView 3.2 and the area of each zone is calculated with respect to each year (Table 4).

Table 4: Area under different probable limits

Year	Probable Limits (mm.)		
	Over 2200	Over 2000	Over 1500
1961	13680.75	32009.75	54203.25
1962	10147.50	14677.25	50144.75
1963	41582.75	52538.75	64376.75
1964	9311.75	11715.50	37148.00
1965	20666.25	39862.75	56607.50
1966	7297.00	13894.25	46611.50
1967	15181.25	29578.75	51113.25
1968	4940.25	7974.00	21434.50
1969	9649.00	12091.50	51792.25
1970	11055.00	26714.25	48842.25
1971	17488.00	32951.00	55499.25
1972	14824.00	24993.50	51572.25
1973	6539.50	8682.00	31894.00
1974	9571.00	12228.00	33613.75
1975	11859.75	17892.25	41738.25
1976	6673.25	8872.00	29414.75
1977	11030.25	14719.00	52037.25
1978	11150.00	17116.00	41868.25
1979	9531.75	14228.25	42035.25
1980	2195.00	3988.00	17129.75
1981	2945.75	7003.25	29046.25
1982	11622.25	16287.75	39629.25
1983	5872.00	12383.00	37423.00
1984	32665.75	53990.75	63843.25
1985	11526.75	17397.75	41895.50
1986	5872.00	12383.00	37423.00
1987	7526.25	9929.25	28062.25
1988	8485.25	13162.50	32114.00

1989	9285.50	13468.50	37503.00
1990	6230.50	9359.25	49850.75
1991	6420.00	12649.25	50353.25
1992	7365.25	9703.25	33607.25
1993	11172.25	17748.50	61904.75
1994	10908.00	14283.00	48486.50
1995	9250.00	13350.75	36721.75
1996	5764.25	9871.75	35049.75
1997	14544.25	26041.50	51644.75
1998	8975.25	12569.25	27220.75
1999	9931.00	12026.50	44459.00
2000	6861.00	9428.00	41750.00
2001	4163.25	6635.75	29494.00
2002	3643.25	8546.00	51516.25

Source: Prepared by the author, 2008

According to the figure 4, it is clear that both the 2200mm and 2000mm isohyets have shrunk with the time. In 1963, the 2200mm line has covered a vast area of about 41582.75 km^2 and has even expanded over the Dry zone as well.

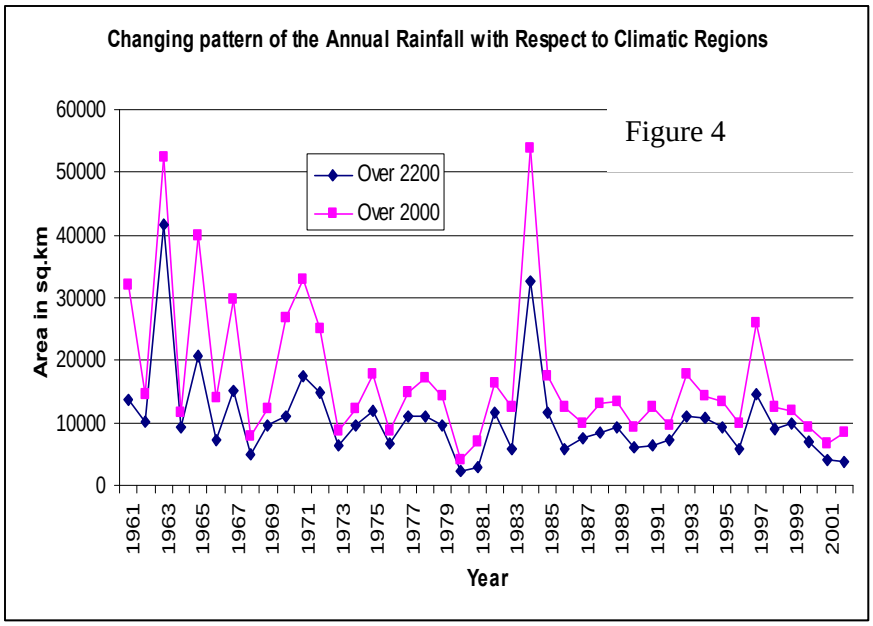


Figure 4

In year 2002 area under the 2200mm probable line decreased by about 37,000 km^2. The changing pattern which is illustrated in the figure 4 clearly shows that there had been an abrupt decline in the area which receives the annual rainfall of about 2200mm. In 1985 there has been a gradual expansion of the area but despite that the overall pattern has acquired a negative trend. With regard to the 2000mm isohyets

too, the identical pattern is apparent particularly after 1975. The most outstanding declining has taken place from 1975 to 1980. The area has reduced by about 8691.11 km^2. Taken as a whole, the total covered area of the 2000mm line has decreased by about 9723 km^2 from 1960 to 2000. 2200mm line and the 2000mm line have conventionally been considered as the demarcation of the Wet zone and the Intermediate zone boundaries. The reduction of the area covered by these two isohyets signifies the importance of the reclassification of the Wet zone and the Intermediate zone boundaries. The shrinking of the area is more pronounced in the Wet zone compared to the Intermediate zone (Figure 5 and 6).

By contrast, the Dry zone has kept on expanding area as a consequence of the shrinking of the other two climatic zones. The Dry zone area has increased from 25323.84 km^2 to 57227.43 km^2. The area has almost doubled during the 40 year period.

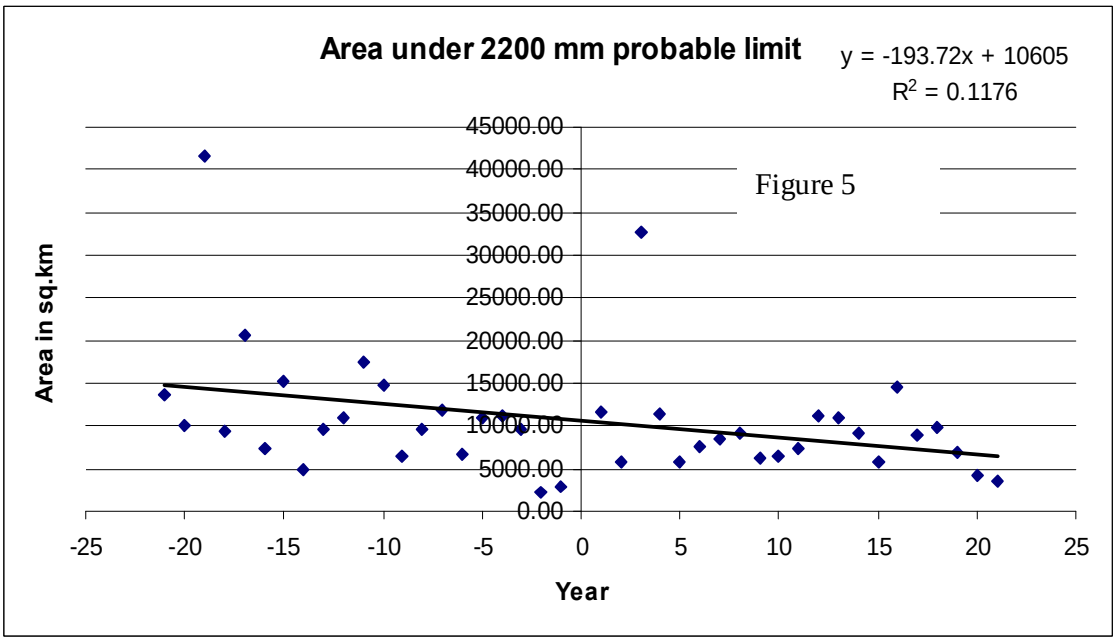


Figure 5

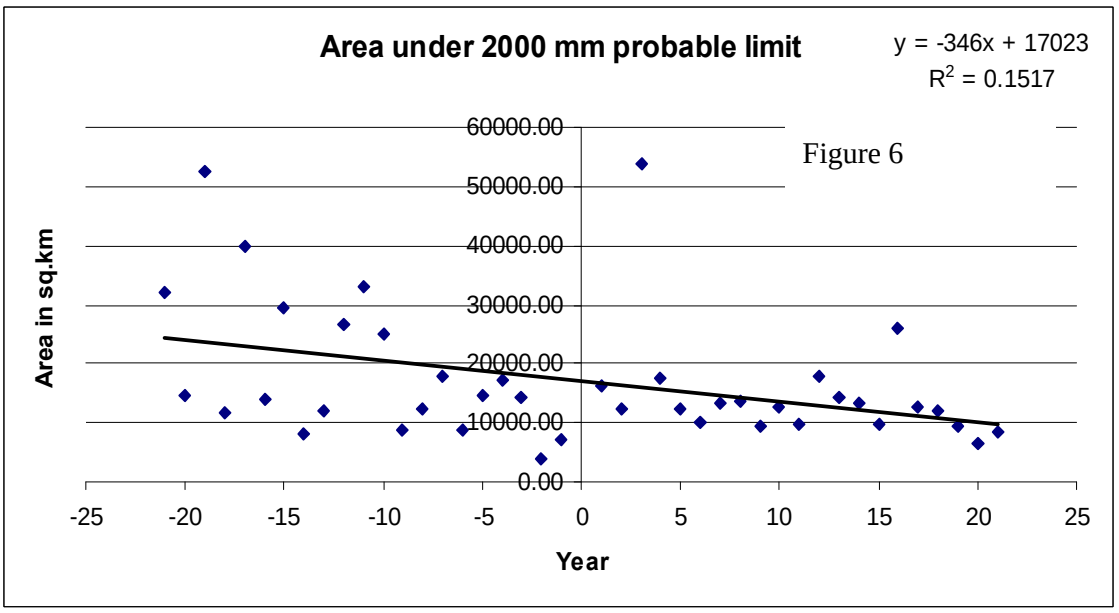


Figure 6

4.5 Water volume by Watershed areas

Since Sri Lanka has an agriculture based economy, the water received in the watersheds is an important factor. This section of the paper attempts to examine the changing pattern of water volume by river basins in Sri Lanka.

Water volume can be defined as the total amount of water received by any particular region assuming there is no water loss by infiltration, runoff and evaporation.. Water volume can be calculated by multiplying the average rainfall in a given season by the area of a watershed. Since there could be more than one meteorological observatories within a watershed, the average water volume has been extracted based on the interpolated surfaces prepared using average annual rainfall at meteorological observatories. For the analysis, average water volume by watersheds was calculated from 1961 to 2002 (Appendix 01).

Most of the wet zone watersheds show marked decreasing trends in water volume while some of the Dry zone watersheds show slight increases in water volume during the period from 1961 to 2002. Water volume in the watersheds of some of the important perennial streams such as the Kelani Ganga, Walawe Ganga, Kalu Gnaga, Bentara Ganga, Madu Ganga, Gin Ganga in the wet zone shows decreasing trends (Figure 7).

Figure 7: Decreasing Trends of Water Volume in selected watersheds in the Wet Zone

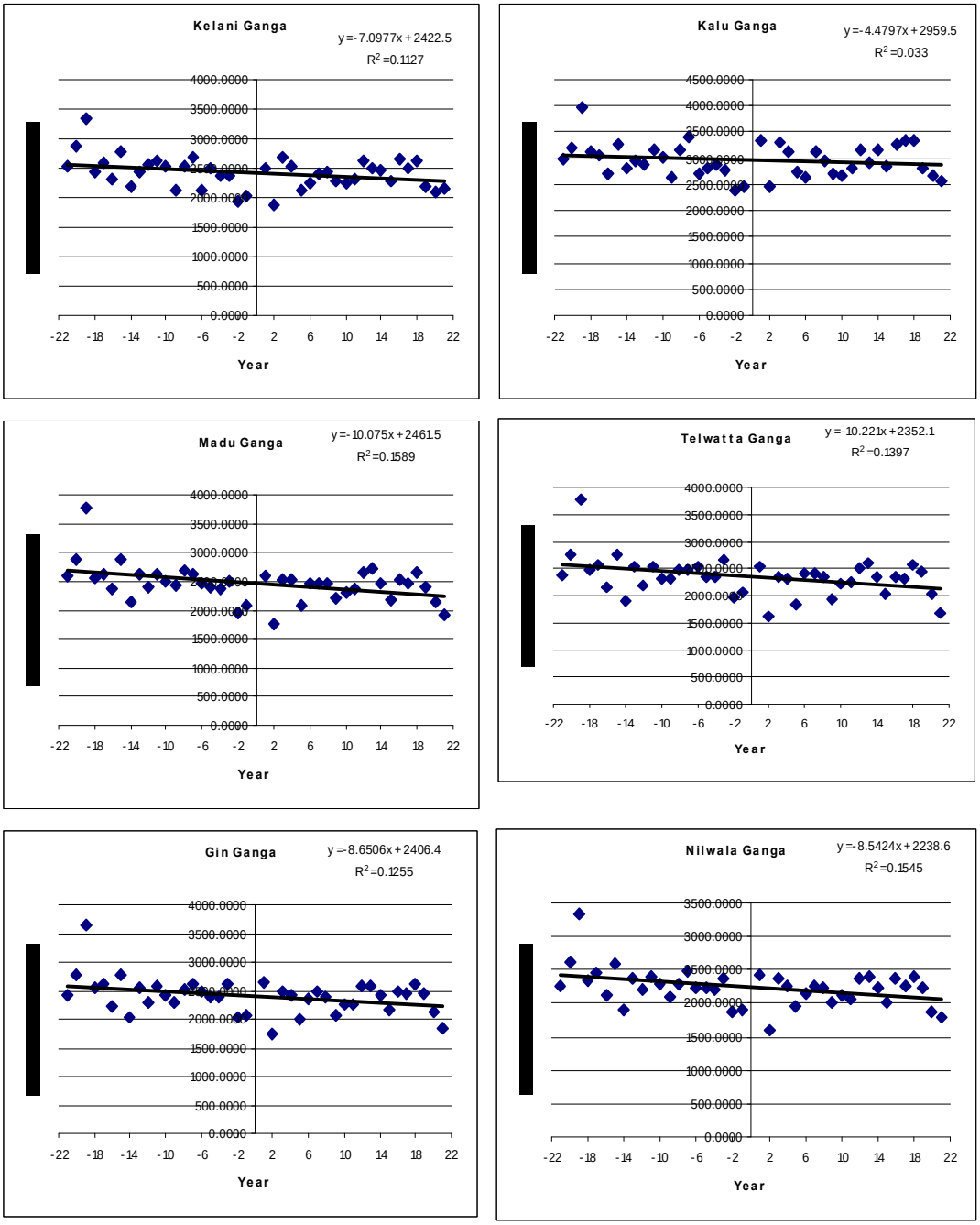


Table 5 shows the first 20 watersheds (in order of decreasing magnitude) with decreasing trends in water volume for last 42 years.

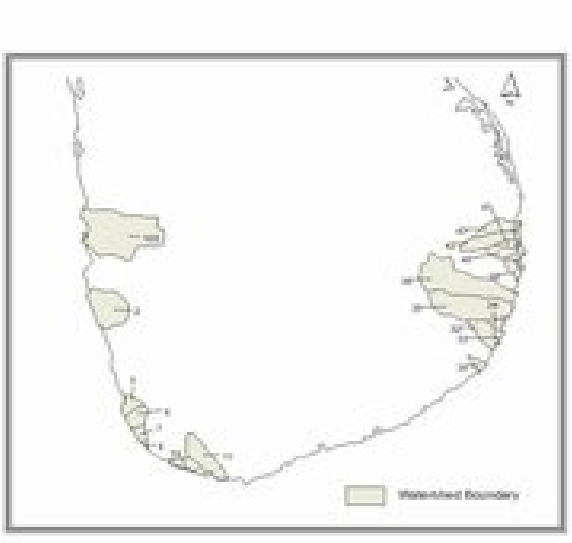
Table 5: Watersheds with decreasing trend of water volume

No	River Basin	Slope (m)	Intercept (a)	Location
1	Semana Aru	-15.573	1692.7	Southern Area
2	Bolgoda Ganga	-14.596	2561.4	Southern Area
3	Tandiadi Aru	-13.935	1684.6	Southern Area
4	Kangikadichi Aru	-13.078	1698.1	Southern Area
5	Helawa Ara	-12.933	1702.5	Southern Area
6	Rufus Kulam	-12.672	1700.7	Southern Area
7	Girikula Oya	-12.161	1707.9	Southern Area
8	Heda Oya	-11.945	1726.9	Southern Area
9	Wila Oya	-11.651	1720	Southern Area
10	Bagura Oya	-11.513	1712.5	Southern Area
11	Pannel Oya	-11.336	1725.2	Southern Area
12	Ambalam Oya	-11.087	1729.8	Southern Area
13	Koggala Lake	-10.614	2306.9	Southern Area
14	Ratgama Lake	-10.412	2329.1	Southern Area
15	Telwatta Ganga	-10.221	2352.1	Southern Area
16	Madu Ganga	-10.075	2461.5	Southern Area
17	Polwatta Ganga	-10.047	2285.2	Southern Area
18	Madampe Lake	-9.9819	2408.3	Southern Area
19	Attanagalla Oya	-9.693	2270.7	Southern Area
20	Karambe Ara	-9.4616	1706.2	Southern Area

Source: Regression Analysis, 2008

As shown in figure 8 all watersheds given in Table 5 located in the Southern Area of the country (Southern area is not the Southern Province. The entire southern part of the country has been considered as the Southern Area).

Figure 8: Spatial pattern of the watersheds with decreasing trend of water volume



See Appendix 1 for names of the watersheds

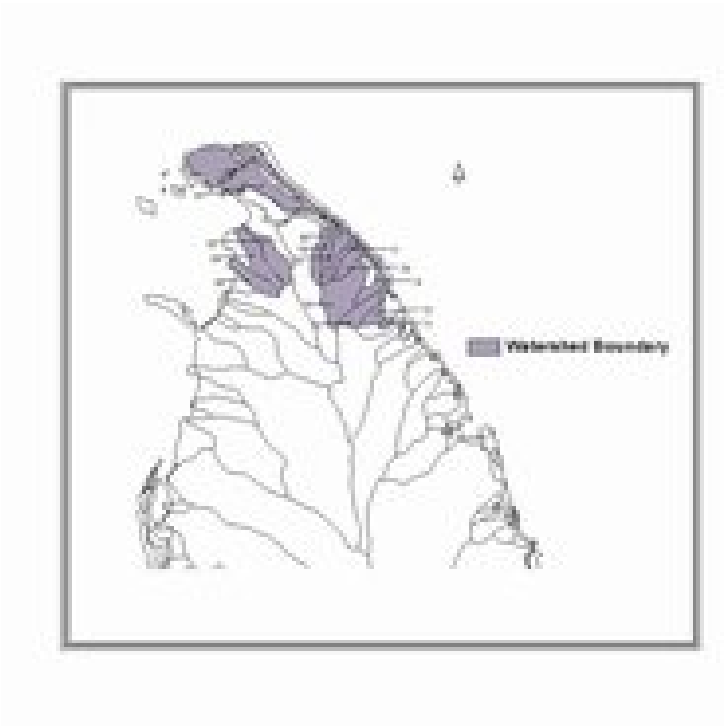
Trends in water volume by watersheds show a significant dichotomous spatial distribution. Most of the Watersheds with increasing water volume are located in the Northern part of the country while those with decreasing water volume are located in the Southern part of the country (Table 6 and Figure 9).

Table 6: Watersheds showing Increasing trend of water volume

River Basin	Slope (m)	Intercept (a)	Location
Pallavarayan Kaddu	0.0681	1246	Nothern Area
Chavar Aru	0.6385	1368.3	Nothern Area
Per Aru	0.8475	1340.2	Nothern Area
Akkarayan Aru	0.9092	1283.8	Nothern Area
Mandakal Aru	0.9179	1265.8	Nothern Area
Manal Aru	0.9208	1350.5	Nothern Area
Palladi Aru	0.9341	1357.4	Nothern Area
Methali Aru	1.1059	1323.3	Nothern Area
Theravil Aru	1.3485	1330.5	Nothern Area
Maruthapillay Aru	1.5772	1332.4	Nothern Area
Pali Aru	1.8358	1333.2	Nothern Area
Kodalikallu Aru	2.4748	1334.9	Nothern Area
Kalwalappu Aru	3.2555	1281.5	Nothern Area
Piramenthal Aru	3.8535	1293.2	Nothern Area

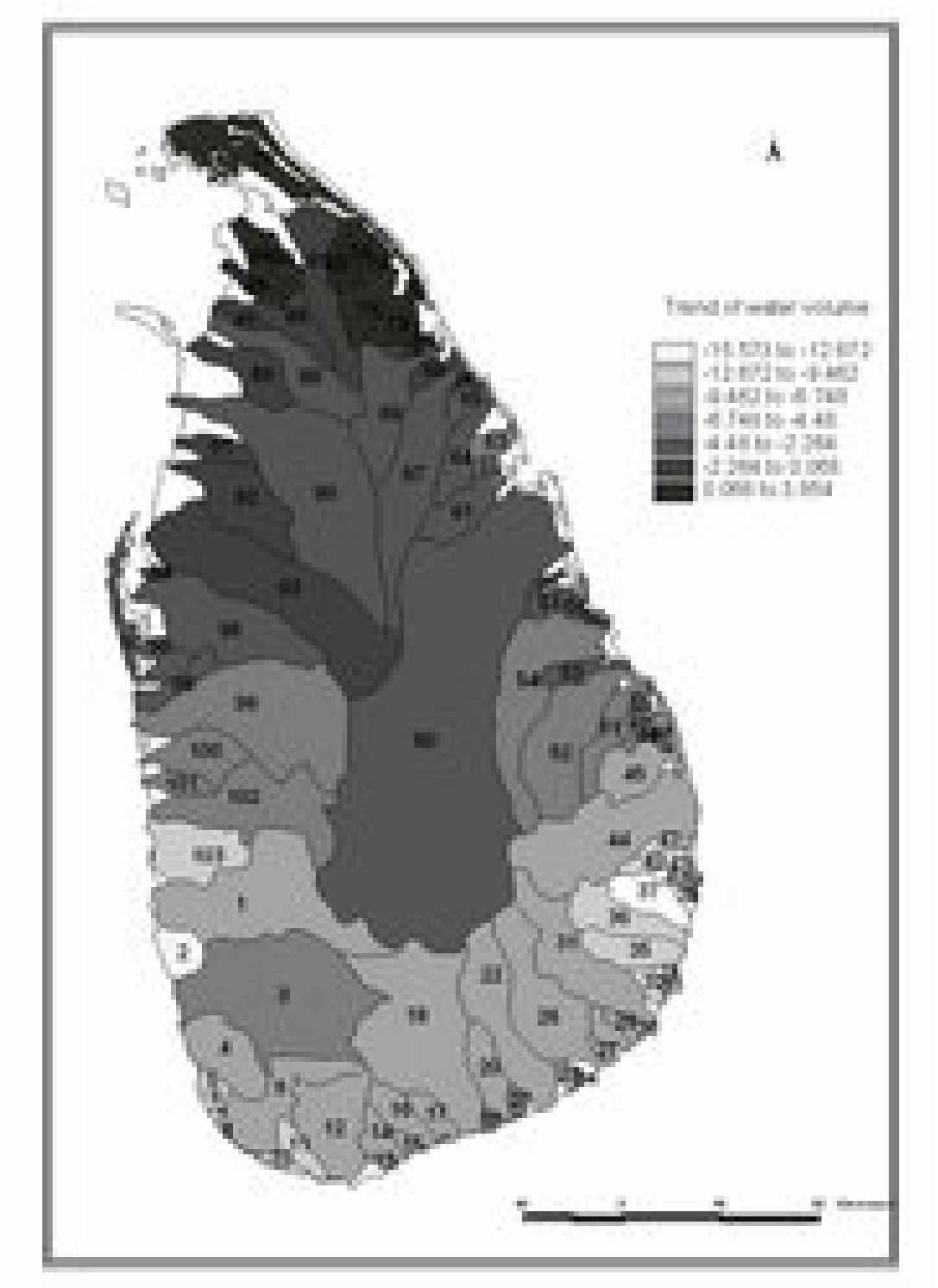
Source: Regression Analysis, 2008

Figure 9: Spatial Pattern of watersheds showing Increasing trend of water volume



See Appendix 1 for names of the watersheds

Figure 10: Changing Pattern of Water Volume by Watersheds



See Appendix 1 for name of the watersheds

5.0 Conclusion

The study finds that although the number of rainy days has decreased except one meteorological station included in the analysis. The total annual rainfall has not decreased ain the all stations. This could indicate that the intensity of rainfall events may have increased together with increased durations of dry spells. The apparent increased incidence of flooding, landslides and droughts in the recent past could probably be attributed to such changes in the temporal pattern of rainfall distribution. Further studies are needed to investigate the relationship between the number of rainy days and total rainfall within a season. These studies should also establish the relationship between local rainfall and global drivers of climate variability and change. Such studies could provide invaluable guidance to decision-making in agriculture and water resources management.

Factors driving the dichotomous spatial trend in water volume by watershed identified in the study are not clearly apparent and warrant further study

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ve year Intervals)

ID	Name of the River Basin	1961	1965	1970	1975	1980	1985	1990	1995	2000
1	Kelani River	2518.6616	2588.1848	2559.9824	2687.0627	1943.5697	2539.1965	2279.5779	2483.3101	2184.5520
2	Bolgoda Ganga	3018.6997	2642.8394	2692.8167	2599.4023	1799.3888	2710.4985	2506.2983	2478.9487	2122.9109
3	Kalu Ganga	2999.3755	3055.4167	2887.2192	3406.1982	2394.2441	3122.3879	2689.7805	3148.2798	2826.0056
4	Bentara Ganga	2742.5142	2692.9773	2520.7144	2739.5168	1984.4292	2671.9231	2334.8589	2591.6855	2456.4666
5	Madu Ganga	2607.7905	2627.1563	2415.8354	2621.4504	1951.8796	2539.1335	2208.9998	2450.9729	2396.2358
6	Madampe Lake	2492.5439	2600.0081	2322.2415	2556.4116	1966.3612	2440.6130	2092.8064	2400.7944	2415.5269
7	Telwatta Ganga	2374.4512	2568.8982	2206.2588	2463.5461	1976.9897	2325.0874	1950.4490	2346.6763	2446.8870
8	Ratgama Lake	2315.1680	2558.3352	2141.1348	2414.4307	1989.8363	2264.8057	1868.6979	2327.5640	2477.3748
9	Gin Ganga	2418.7883	2614.4678	2298.8777	2600.8254	2019.1910	2416.2109	2059.9148	2433.7432	2449.0439
10	Koggala Lake	2283.9277	2543.4919	2116.3704	2394.3784	1983.8704	2237.0085	1843.4320	2309.0364	2466.8813
11	Polwatta Ganga	2288.1465	2517.1599	2151.5349	2417.5137	1945.8234	2254.2781	1904.1136	2284.2085	2386.4614
12	Nilwala Ganga	2273.1040	2465.3083	2206.7163	2468.7322	1881.2970	2272.6858	2008.9956	2240.5200	2234.9746
13	Sinimodara Oya	1967.2925	2172.9382	1949.7134	2184.9497	1659.5760	1965.3143	1825.9810	1888.5798	1917.8197
14	Kirama Oya	2011.3884	2213.7317	1996.9557	2233.9670	1684.9907	2014.4196	1866.2325	1938.3210	1949.5481
15	Rekawa Oya	1767.9546	1984.8143	1782.6045	2029.0897	1531.9086	1781.2703	1715.2798	1687.0609	1733.1620
16	Urubokka Oya	1892.0686	2101.5806	1905.7810	2144.3105	1601.7046	1906.9261	1810.0194	1817.6559	1829.5776
17	Kachchigala	1541.9922	1773.7256	1581.5985	1848.6709	1397.2302	1570.0402	1575.4266	1470.0291	1547.5917
18	Walawe Ganga	1974.9607	2169.8625	2019.3409	2119.9385	1531.2107	1953.0269	1881.1002	1851.2643	1821.2292
19	Karagan Oya	1011.2208	1270.1743	1067.1179	1452.1714	1138.7041	1076.1040	1213.1558	988.6245	1166.3248
20	Malala Oya	1450.4744	1698.1940	1516.0378	1722.0986	1294.7090	1457.6619	1518.9160	1352.2258	1449.3160
21	Embilikala Oya	1155.4441	1411.7717	1214.2499	1546.3722	1196.1199	1206.4830	1313.9222	1112.3374	1265.3652
22	Kirindi Oya	1726.8809	1983.2764	1817.3313	1766.1660	1284.0922	1631.3710	1704.0099	1496.7548	1567.7931
23	Bambawa Ara	1547.3145	1814.9463	1628.9474	1785.5531	1338.8818	1526.2601	1591.9780	1415.6747	1530.5166
24	Mahasiliwa Oya	1576.5950	1845.2769	1659.6212	1806.1031	1352.7770	1544.9713	1612.6915	1434.2286	1553.2251
26	Menik Ganga	1756.6794	2131.6431	1933.5199	1855.8386	1354.4335	1663.5471	1782.7957	1549.3770	1640.9309
27	Katupila Ara	1715.5199	2014.5621	1830.1913	1886.5481	1389.8481	1615.4816	1721.0154	1511.0328	1645.8541
29	Nabadagas Ara	1782.2031	2102.1538	1916.6908	1922.1150	1408.1987	1602.5812	1775.8386	1503.4933	1691.9470
30	Karambe Ara	1793.2025	2111.5339	1926.0515	1934.0631	1417.5804	1576.7981	1782.0482	1481.3732	1704.4611
31	Kumbukkan Oya	1781.4539	2249.2925	2029.5856	1887.4880	1372.2725	1638.2166	1841.6071	1539.5188	1679.9183
32	Bagura Oya	1831.3158	2178.3633	1989.3060	1949.1925	1422.5835	1465.0317	1820.2994	1383.7206	1735.8362
33	Girikula Oya	1836.8978	2176.2312	1988.1886	1957.8529	1430.2889	1427.3901	1819.8378	1350.3250	1742.8584

		4	2191.5505	2002.1302	1958.5547	1429.2888	1378.2295	1827.9070	1306.7708	1749.5544
35	Wila Oya	1835.6351	2224.0466	2027.2028	1938.7189	1410.1763	1455.7261	1841.8635	1376.7111	1735.0066
36	Heda Oya	1837.1161	2258.9275	2054.4207	1940.1965	1410.5222	1435.6376	1856.6691	1364.8082	1737.3894
38	Semana Aru	1868.9537	2241.3306	2046.9325	1972.2859	1437.2914	1231.4689	1851.2943	1178.4135	1766.4967
39	Tandiadi Aru	1843.8282	2223.9858	2008.3246	1928.8519	1413.1417	1280.6978	1822.5579	1218.8654	1759.5096
40	Kangikadichi Aru	1840.6511	2232.3491	2016.6366	1926.6018	1409.9081	1338.3767	1827.9200	1270.7141	1752.3126
41	Rufus Kulam	1839.8917	2227.8022	2007.9601	1920.4725	1407.9912	1354.6321	1820.5140	1290.4100	1749.1199
42	Pannel Oya	1837.1060	2244.1326	2029.0391	1923.1619	1405.7316	1447.8464	1835.3030	1376.9873	1736.6649
43	Ambalam Oya	1846.2765	2237.8779	2035.8901	1921.6979	1404.6743	1467.3226	1838.2593	1395.9432	1727.6222
44	Gal Oya	1803.0927	2267.7637	2048.2786	1895.8191	1381.8364	1626.2821	1850.0314	1541.8746	1691.5331
45	Andella Oya	1788.2549	2194.1394	1979.8799	1863.2162	1369.3806	1629.2571	1809.4681	1548.8754	1688.0345
46	Tumpan Keni	1745.9127	2143.4407	1916.0764	1804.0278	1329.3513	1614.7639	1761.6353	1536.6447	1682.0809
47	Namakada Aru	1738.0610	2139.1636	1919.5181	1802.3657	1320.6608	1621.9193	1756.5660	1543.8237	1678.1461
48	Mandipattu Aru	1744.1127	2144.0828	1919.3170	1803.5143	1327.5270	1635.9508	1760.8295	1556.6765	1676.8842
49	Pathantoppu Aru	1740.7633	2140.1782	1912.0952	1793.9478	1321.7086	1642.7017	1753.1080	1563.7303	1671.6481
50	Vett Aru	1724.4908	2130.3501	1910.5608	1782.4192	1301.8074	1640.6432	1738.7747	1563.3763	1663.8658
51	Unnichchai	1765.4237	2169.7207	1949.2853	1829.4974	1348.2520	1668.6019	1781.0299	1588.3843	1675.1593
52	Mundeni Aru	1775.1239	2177.6582	1962.2404	1839.7792	1357.0686	1708.7179	1787.3450	1626.4553	1670.7532
53	Miyangolla Ela	1724.7616	2112.8882	1882.9291	1728.6823	1278.3774	1670.1924	1707.8746	1592.7629	1629.4694
54	Madura Oya	1745.3866	2136.8320	1910.6934	1769.1016	1313.6011	1671.1919	1737.0253	1620.6498	1633.2822
55	Puliyanpota Aru	1668.3284	2104.1323	1835.7466	1630.3632	1190.5330	1508.2318	1643.9598	1536.7205	1588.5271
56	Kirimechchi Odai	1631.6913	2083.6682	1800.1200	1569.5682	1144.9016	1491.0326	1619.4523	1497.4360	1550.4779
57	Bodigolla Aru	1593.1136	2038.9642	1751.2278	1506.1697	1108.1147	1486.6132	1622.0338	1448.7893	1504.2487
59	Makarachchi Aru	1546.9124	2029.1646	1719.3036	1432.7096	1041.1027	1455.1934	1595.8000	1397.3981	1461.0874
60	Mahaweli Ganga	1769.6428	2119.0391	1930.7104	1818.0808	1341.3840	1779.9634	1773.4579	1691.7220	1634.2351
61	Kantalai Aru	1498.8289	2038.8848	1662.8558	1339.1725	966.2249	1360.2250	1477.1224	1329.4706	1430.8107
62	Palampotta Aru	1462.2466	2246.0276	1779.1957	1300.4569	825.7938	1289.8817	1428.6852	1355.7418	1412.4972
63	Panna Oya	1457.0525	2259.3752	1787.6954	1296.3066	811.4152	1283.6202	1423.5558	1357.3962	1411.0143
64	Pankulam Aru	1464.3632	2024.3843	1671.2906	1328.2656	900.9718	1350.4564	1458.4902	1308.8656	1429.2715
65	Kunchikumban Aru	1425.5059	1904.5894	1651.8873	1340.3151	874.9962	1376.8268	1464.6078	1291.7322	1436.9597
66	Palakattu Aru	1397.9639	1782.7939	1622.3229	1352.6422	876.9744	1404.2728	1477.6313	1272.7355	1443.0820
67	Yan Oya	1489.9845	1820.6421	1536.6781	1345.7296	1018.1202	1393.9325	1475.3751	1264.3107	1456.1816
68	Mee Oya	1380.5659	1622.5842	1570.2903	1374.2399	884.2144	1448.2109	1493.1859	1220.3997	1472.8062
69	Ma Oya	1467.0024	1632.4048	1501.0568	1398.8817	927.5627	1477.4578	1480.8116	1140.3793	1540.3301

		6	1490.3607	1556.4010	1383.9216	864.8973	1472.4772	1506.0083	1189.1008	1487.9740
71	Chavar Aru	1289.2186	1443.7186	1580.4111	1379.9128	845.8708	1471.8733	1508.4840	1213.7133	1467.9456
72	Palladi Aru	1261.4869	1384.4998	1581.6279	1382.4199	833.1288	1480.4047	1513.6853	1198.3439	1471.8383
73	Manal Aru	1250.7952	1354.9794	1578.3157	1384.2491	827.1796	1485.4033	1517.5305	1183.9871	1472.5200
74	Kodalikallu Aru	1151.9609	1222.8094	1628.0099	1382.6239	782.1354	1495.3110	1527.2831	1209.9829	1441.5583
75	Per Aru	1243.6284	1335.0100	1566.0896	1382.1088	823.8836	1484.7931	1525.6226	1174.0200	1445.0957
76	Pali Aru	1185.2057	1262.8268	1596.8052	1382.8204	798.7245	1489.6119	1535.9246	1200.5060	1406.1821
77	Maruthapillay Aru	1210.2821	1292.9926	1574.4696	1383.0365	810.7743	1485.5706	1536.5155	1196.7690	1397.9532
78	Theravil Aru	1235.1998	1321.3304	1549.8602	1383.2456	822.4613	1481.3835	1536.3384	1191.5763	1390.1984
79	Piramenthal Aru	1301.6851	1319.4634	1414.9921	1510.8466	835.2090	1526.2867	1520.7458	1209.0115	1296.9969
80	Methali Aru	1269.1555	1355.3689	1506.7373	1383.2710	837.8646	1474.0784	1535.4904	1181.0742	1370.3945
81	Kanakarayan Aru	1337.9613	1423.6714	1464.2579	1391.9526	862.2971	1475.2869	1523.9976	1148.5887	1405.5577
82	Kalwalappu Aru	1309.9093	1316.5454	1386.1191	1448.8342	852.9091	1474.9336	1524.0525	1186.1343	1268.1653
83	Akkarayan Aru	1303.2635	1364.5242	1398.6868	1365.5608	849.0152	1445.1665	1530.5988	1139.9773	1277.7775
84	Mandakal Aru	1298.5327	1347.9358	1366.4448	1352.7512	844.2632	1431.9028	1529.2917	1124.7183	1233.0057
85	Pallavarayan Kaddu	1285.2694	1346.7559	1330.4476	1288.2133	832.0790	1396.6787	1529.6311	1096.0708	1199.7213
86	Pali Aru	1345.5671	1430.6857	1382.4532	1317.1178	857.5652	1426.6006	1518.3999	1097.0271	1347.5273
87	Chappi Aru	1246.4873	1305.5566	1244.0590	1182.3107	798.3945	1330.6685	1525.0721	1054.6937	1132.3497
88	Parangi Aru	1436.0736	1510.3365	1392.1089	1367.4097	875.6557	1467.8206	1494.9366	1062.6216	1477.2250
89	Nay Aru	1309.2777	1378.4994	1268.2599	1208.1238	826.3603	1354.0530	1501.7843	1051.4420	1244.0885
90	Aruvi Aru	1510.2728	1722.7819	1399.5553	1269.4126	1059.5190	1359.0035	1416.6490	1120.6401	1412.7424
91	Kal Aru	1417.7018	1539.6003	1339.0823	1222.1501	960.8640	1372.9199	1466.9255	1144.3737	1294.9701
92	Moderagam Aru	1522.7716	1708.6088	1374.3344	1173.2131	1080.6924	1342.4089	1397.5529	1094.9094	1309.3989
93	Kala Oya	1559.6869	1819.9474	1458.6118	1350.7379	1230.8805	1399.1050	1478.1621	1389.3417	1390.1927
94	Moongil Aru	1479.9646	1397.1826	1252.3392	1152.7858	1059.9484	1533.5237	1414.4353	1373.7528	1061.0475
95	Mi Oya	1587.9525	1675.9950	1445.0726	1349.7867	1204.4822	1547.6180	1479.4127	1447.9139	1271.6897
96	Madurankuli Aru	1534.6034	1442.5156	1312.2900	1227.3163	1108.5507	1597.8798	1442.5922	1423.4838	1084.6775
97	Kalagamuna Oya	1579.5469	1518.6792	1387.7052	1300.0536	1144.1132	1624.2485	1481.9960	1455.1487	1156.9187
98	Rathambala Oya	1760.1140	1767.9117	1649.2020	1565.1997	1300.1316	1770.5712	1596.4053	1600.7726	1359.0956
99	Deduru Oya	1925.8749	2019.6013	1999.5122	1876.8995	1472.1061	1992.8046	1624.0385	1833.1935	1560.2357
100	Karambala Oya	2057.5310	2111.3289	2115.3181	2007.1608	1543.1735	2100.7083	1746.4966	1930.7747	1640.3491
101	Ratmal Oya	2180.0825	2227.6145	2218.6772	2140.6704	1633.2529	2178.3179	1886.0638	2019.1125	1743.9999
102	Maha Oya	2114.5342	2199.4478	2238.8025	2167.9067	1625.2208	2219.2295	1819.4260	2050.4077	1738.6799
103	Attanagalla Oya	2445.6077	2456.7156	2496.2432	2431.6030	1814.1195	2357.3879	2154.7158	2262.5713	1949.5760

Source: Prepared by the author, 2008