An Analysis of Long-Term Rainfall Variability at Selected Locations in Sri Lanka

T S G Peiris and D T Mathes
(Biometry Division, Coconut Research Institute, Lunuwila, Sri Lanka.)

Abstract *The impact of climate change on agriculture is given attention all over the world. Among the various climatic variables, rainfall variability is considered to be the key factor which influences the yield of tree crops. It is therefore important to identify how the long-term rainfall variability at different locations would affect the crop production. Thirty year daily rainfall data for 15 locations of five agro-ecological regions in the main coconut growing areas in Sri Lanka were analyzed to elucidate changes in rainfall amount, length, and pattern during the last three decades and to highlight the significant important rainfall events in agricultural planning. The rainfall amounts and dry days were analyzed on annual, seasonal, monthly, and weekly base and rainfall probabilities were estimated. There was a significant decline of annual rainfall amounts and duration and rainfall during the recent past has been consistently below the long-term average except in locations in the Dry Zone. The wet areas are characterized by low inter annual variability and dry areas by high inter annual variability. The bi-model pattern usually expected from South-West monsoon during March/April and North-East monsoon during October/November has not changed in many locations, but the pattern of inter-monsoon rains has changed substantially. The rains during October/November are more certain than the rains during March/April. A considerable spatial differentiation was observed in March/April rains. The rains during March/April have shifted towards May. The rainfall during March/April, and May/June have increased in the Dry Zone. The information obtained from this study is useful for assessing the nature and impact of rainfall variability on national coconut production and also for national agricultural planning.*

1.1 Introduction

Sri Lanka covering 6,560,980 hectares lies within southern tropics between (79.5-82)^{0}N and (6-10)^{0}E. It predominates as an agricultural country and coconut is one of the most economically important tree crops. It provides about 20% of the daily calories of the Sri Lankan population, being only second to rice. The total extent of coconut in the country is about 442400 ha and the average national productivity is 5900 nuts per ha. The main coconut growing areas of coconut in Sri Lanka fall within the agro-ecological regions of Low country in the Intermediate Zone (IZLC), Wet Zone (WZLC), and Dry Zone (DZLC) of which 75% expectancy value of annual rainfall is greater than 1000 mm, 1500mm and 750 mm respectivey.

Coconut yields fluctuate extensively within-and-between the agro-ecological regions and within-and-between years as a result of several attributes of which two major factors are climate and soil suitability class for coconut (Somasiri, 1994). Though climate is the result of the simultaneous action of many weather variables, long-term data are available only for rainfall for most of the locations. The knowledge on rainfall variability in coconut growing areas and its impact on coconut yields are very limited (Peiris, *et al*, 1995). Also the long-term rainfall variability has become an important issue for agriculture in recent years (Butterfield *et al*, 1992; Hanson *et al*, 1993; Bengtsson, 1994; Bootsma, 1994; Mikkelsen, *et al.* 1995).

This paper presents rainfall pattern of the 15 locations in the main coconut growing regions during the last three decades to highlight the significant important rainfall events in agricultural planning.

1.2 Rainfall Data

Thirty years (1962-1991) rainfall data from 15 locations (12 within the 'main' coconut triangle and 3 within the 'mini' coconut triangle) were selected (see Table 1).

1.3 Annual Rainfall Variability

The total annual rainfall perhaps is useful in making the comparison of agricultural potentials. Useful statistics on annual rainfall are shown in Table 2.

The results in Table 2 indicate that the critical levels of the agro-ecological regions with respect to

Table 1. ***Station index of the 15 selected locations in coconut growing areas***

Location	Agro Ecological Zone	Latitude (N)	Longitude (E)	Elevation (m)
'Within coconut triangle'				
Ambakelle	IL_1	7^0 35'	79^0 47'	20.5
Bandirippuwa	IL_1	7^0 20'	79^0 53'	30.5
Horakelle	IL_1	7^0 27'	79^0 51'	15.2
Kurunegala	IL_1	7^0 28'	80^0 22'	116.1
Palugaswewa	IL_1	7^0 39'	79^0 52'	12.2
Ratmalagara	IL_1	7^0 33'	79^0 54'	27.4
Nikaweratiya	IL_3	7^0 44'	80^0 06'	30.5
Polonthalawa	IL_3	7^0 42'	80^0 00'	26.2
Mediyawa	IL_3	7^0 53'	80^0 17'	93.0
Ridibendiwela	IL_3	7^0 44'	80^0 14'	56.0
E-saltern	DL_3	8^0 03'	79^0 49'	3.1
Puttlama	DL_3	8^0 02'	79^0 49'	3.1
'Within mini-coconut triangle'				
Kekenadura	WL_4	5^0 59'	80^0 36'	48.8
Hambantota	DL_5	6^0 07'	81^0 08'	18.1
Kirama	$I(L_1$-$L_3)$	6^0 12'	80^0 39'	122.0

annual rainfall are very different from the respective values of the locations within the regions. The plot of coefficient of variation vs total annual rainfall suggests that the wet areas are characterized by the lower variability, and the dry areas by the higher variability (see Fig. 1).

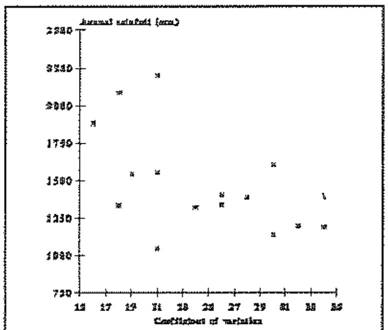

Figure 1. Plot of CV vs annual rainfall of selected locations in the coconut growing areas in Sri Lanka (1962-1991)

Temporal variability of the annual rainfall for each location indicated that there was not a cyclic or seasonal pattern of the rainfall. The total annual rainfall in all stations had a considerable inter-annual variation and rainfall during recent past had been consistently below the long-term average of the respective locations. As a clear decline in rainfall was identified during 1975/1976 onwards rainfall was compared in two scenarios 1962-1976 and 1977-1991. Except three locations in the DZLC percentage drop of rainfall during 1977-1991 as against during 1962-1976 varied from 30% to 5%. In DZLC, rainfall during 1977-1991 had increased by 10%. The nature of decline in annual rainfall was assessed by fitting linear regression models over time. A significant decline ($p < 0.05$) trend in annual rainfall was found at all locations except the three in DZLC.

1.4 Variability in Seasonal Rains

Rainfall varies substantially in amount and timing, and thus monthly values will provide a better guide to seasonal variability of rainfall. The rains in Sri Lanka generally grouped into four seasons namely, first inter-monsoon rains (during Marc/April), second inter-monsoon rains (during October/November), south-west monsoon rains (during May/June) and north-east monsoon rains (during December) (Domros, 1974). The higher percentage of the total rainfall is contributed by the two inter-monsoon rains. The pattern of autocorrelation coefficients indicated that the monthly rainfall were stationary and seasonal with two peaks confirming that rainfall follows a bimodal pattern under the influence of the north-east and south-west monsoons.

The coefficients of variation were computed for March/April and October/November rains for the entire 30 year period and three 10 year periods during 1962-1991. It was found that the inter-annual variation in March/April rains was greater than that in October/November rains irrespective of the period and the locations. The inter-annual variability in October/November rains at all the locations has not changed much over different scenarios. This may be due to changes of atmospheric circulation. A considerable spatial differentiation was found in both amount and duration of March/April rains.

Table 2. *Basic statistics of annual rainfall at the selected locations (based on data 1962-1991).*

Location	maximum	long-term average	minimum	CV	75% prob. value	rainy days
Ambakelle	2389 (84)	1403	850 (89)	26	1153	102
Bandirippuwa	2564 (63)	1880	1191 (86)	16	1672	134
Horakelle	2443 (63)	1551	938 (83)	21	1393	106
Kurunegala	2932 (72)	2087	1403 (89)	18	2122	165
Palugaswewa	2396 (77)	1385	721 (74)	28	1146	89
Ratmalagara	2394 (84)	1542	1035 (83)	19	1371	113
Nikaweratiya	1864 (62)	1333	786 (86)	18	1161	79
Polonthalawa	2264 (84)	1338	679 (86)	26	1152	79
Mediyawa	1854 (62)	1188	45 (82)	34	861	77
Ridibendiela	2063 (62)	1322	411 (85)	24	1118	78
E-saltern	2595 (84)	1195	566 (74)	32	967	89
Puttalam	2179 (84)	1136	351 (89)	30	898	97
Kekenadura	2958 (63)	1601	66 (89)	30	1392	112
Hambantota	1509 (63)	1045	661 (89)	21	867	109
Kirama	3090 (63)	2202	1015 (91)	21	1900	125

(The year corresponds to the highest and lowest rainfall is indicated in parentheses).

Thus it can be hypothesized that the first inter-monsoon rains play a significant role on the yield fluctuation of coconuts between locations.

The 75% monthly rainfall probability plots clearly indicate the second peak occurred during October/November (second inter-monsoon rains) in all the locations. Thus it can be assumed that rainfall during October/November brings about homogeneous wet conditions in many parts of coconut growing areas. The amount of rainfall did not show a significant decline over the years, but has decreased over 10 year periods in all the locations.

The first peak generally expected during March/April (first inter-monsoon rains) has shifted towards April/May. It implies that the start of first inter-monsoon has delayed in recent past. Thus it could be more beneficial to do cultural practices on coconut such as fertilizer application which need post rain, during March and April. The amount of rainfall has increased over 10 year periods in all the locations in DZLC. The first inter-monsoon rains also did not show a decline trend over the years. The amount of rainfall in 10 year period has increased in all the locations in DZLC.

Rainfall in December showed a significant decline ($p < 0.05$) over the years in almost all the stations and the rate of decrease in 10 year periods at all the locations is high.

The rainfall in May/June too did not show a decline trend. But the amount of rainfall has reduced in 10 year periods DZLC. The rate of increase in LCDZ is high ($> 25\%$).

1.5 Variation of Dry Days

January, February, July, August and September can be considered as five dry months in a year with few exceptions in September. The number of dry days during January and February was not significantly different between locations and time and the mean number of dry days was about 48-54. The number of dry days during July-September is significantly different between locations within the regions. It significantly increased over the years in the range of 50 - 80 days per year.

1.6 Rainfall Probabilities

As the mean values often tend to conceal true phenomena of biological importance by masking inter-annual fluctuation, probabilities of receiving certain minimum amount of rainfall on monthly basis and seasonal basis were estimated for rainy months March - June and October - December. These rainfall probabilities are useful to compare the intensity of rainfall between locations and for land use planning for agriculture. Cumulative probability of receiving (200 - 500) mm were used to assess the probability of getting adequate rains during two inter-monsoon rains. It was found that the probabilities are very much different between the locations within regions and also they are different from the critical limits used to classify the agro-ecological region. This reveals the necessity of subdivision of agro-ecological regions.

1.7 Start and Length of Rains

Defining an event like the start of rains is difficult because of the intermittent and patchy nature of tropical rainfall (Peiris & Seneviratna, 1989). Based on the plots of 7 day moving totals from March to June and October to November on yearly basis, start of rain in the first inter-monsoon rain was defined as the earliest possible day after the 01 March with more than 100 mm of rain totalled over 20 days of which at least 10 days should be rainy days and there should not be a dry spell of length 10 days or more in the next 20 days. Similar definition was used for the start of rain in the second inter-monsoon by replacing 100 mm with 150 mm and first day was replaced by the 20 September. The date for end of the rain in first inter-monsoon rains was defined as the first day of at least 15 consecutive dry days after 15th June. The date for end of the rain in second inter-monsoon rains was defined as the first day of at least 15 consecutive dry days after 30 November.

The length of rain for each year was taken by subtracting the date at which rain began from the date on which rain ended. No significant correlation was detected between the dates of beginning and ending of rains. The cumulative probability distributions for the start of rains and length of rain were drawn to each location for comparison. The first inter-monsoon rains in DZLC has started later than that of in IZLC and WZLC. The chance of rains commencing in the first inter-monsoon rains after 15 April in DZLC in 75%. Such a general conclusion can not be made for the date of commence of first inter-monsoon rains in other two regions. The chance of rains commencing in the second inter-monsoon rains during 8-20 October is 75%. However, it is necessary to consider many options to come to a general conclusion.

1.8 Conclusions

The annual rainfall in main coconut growing areas in the Low Country Intermediate and Wet zones significantly declined over the past 30 years. The rainfall in Low Country Dry Zone showed no significant decline and the mean annual rainfall during 1977-1991 had increased by about 10% compared to 1962-1976. At all other locations the mean annual rainfall dropped by 30% to 5% compared to 1962-1976. The wet areas are characterized by low inter annual variability of rainfall, while dry areas by high inter annual variability.

The rainfall distribution in all locations has also changed during the last three decades. The variability of the first inter-monsoon rains is much higher than that of the second inter-monsoon. The first inter-monsoon rains has shifted from March/April to April/May at many locations. The second inter-monsoon rains has been consistent during October and November in all the locations. The rainfall during December also declined significantly over the years. There is thus an urgent need to subdivide the agro-ecological zones. This will be useful to plan the programs for annual crops.

The changes in rainfall amount and its distribution will have a significant impact on coconut. No attempt is made in this study to explain the impact of rainfall change on coconut or on many ecological systems. This study will be reported in a companion paper. The results can be used in development management strategies, and in planning for the best utilization of available water resources in those areas.

1.9 References

Bengtsson, L. (1994). Climate change: climate of the 21st Century. *Agric. and Forest Meteorology*, 72, 3-39.

Bootsma, A. (1994). Long term (100 yr) climatic trends for agriculture at selected locations in Canada. *J. Climatic Change*, 26, 65-88.

Butterfield, Ruth. E. and Morison, I. L. (1992). Modelling the impact of climatic warming on winter cereal development. *Agric. and Forest Meteorology*, 62, 241-261.

Domros Manfred (1974). The Agroclimate of Ceylon. Franz Steiner Verlag Gmbh - Wiesbaden.

Hanson, J. D., Baker, B. B., and Bourdon, R. M. (1993). Comparison of the effects of different climate change scenarios on Rangeland livestock production. *Agricultural Systems*, 41, 487-502.

Mikkelsen, P. S., Nielsen, A., Harremoes, P., Madsen, H., and Rosbjerg, D. (1995). Modelling of regional scale spatial variation of historical rainfall data. *Proceeding of the 6th International Conf. on Environmetrix. Kuala Lumpur, Malaysia, 5-9 December.*

Peiris, T. S. G., Thattil, R. O. and Mahindapala, R. (1995). An analysis of the effect of climate and weather on coconut (Cocos Nucifera). *J. of Experimental Agriculture,* 31 (4), 451-460.

Peiris, T. S. G., Seneviratne, E. K. (1989). An alternative approach for analysis of data from a long-term experiment. *Cocos (J. of the Coconut Research Institute of Sri Lanka),* 7, 14-20.

Somasiri, L. L. W. (1994). Land suitability classifications for coconut. *Coconut Bulletin*. 9(1/2), 13-16.