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Change in Rainfall and Temperature of Low Country Wet Intermediate (IL1) Region of Sri Lanka

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ABSTRACT*. A study of climate variability in Agro-ecological regions (AERs) is important, as agricultural crops are highly vulnerable to local climate change. Rainfall and temperature data in the AER of IL1 (1932 – 2001) were analyzed on annual and seasonal basis to study the significant features of climate variability. ANOVA and Bartlett test confirmed that significant changes in climate has occurred with respect to annual rainfall and maximum, minimum and diurnal temperature. The Man-Kendall non-parametric statistic found that the starting point of significant climate change with respect to the above four climate variables were in 1986, 1983, 1970 and 1988 respectively. Annual rainfall and diurnal temperature showed declining trends while maximum and minimum temperature showed warming trends. Of those four variables, rainfall and maximum temperature are more prominent variables with respect to climate change in this region. The percentage reduction in the mean annual rainfall during 1986 to 2001 compared to the period 1932 to 1985 is 9%. The percentage increase in the mean annual maximum temperature during 1983 to 2001 compared to the period 1932 to 1982 is about 1.4%. The changes in annual climate are not of the same intensity for the four rainy seasons. The impact of reduction in annual rainfall is the reduction of rainfall during NEM (North - East Monsoon) and FIM (First Inter Monsoon). The impact of increase in annual maximum temperature is the increase of maximum temperature during SIM (Second Inter Monsoon). An increase in maximum and minimum temperature will increase the likelihood of increase of daily temperature. Thus adaptation options have to be recommended to mitigate the potential negative impacts due to climate change in IL1.*

INTRODUCTION

With the increase in global warming there is a greater risk in agricultural production in tree crops and short-term crops due to shortage in water availability. This problem is critical in developing countries within sub tropical and tropical areas (Watson, 1995). In view of this situation, studying the changes in climate and response of agricultural production to the climate change with risk assessments have become priority research areas. Such studies help in the national food security plan in implementing the adaptation strategies. Agro-ecological regions (AER) of Sri Lanka are the main representatives of different climatic zones of the country (Domroes, 1974). Thus, with the view of studying climate change in different AER and locations within AER and effect of these changes on agricultural crops, some studies were carried out in Sri Lanka (Peiris *et al*., 1995; Peiris and Mathes, 1997; Peiris and Thattil, 1998;

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Fernando, 2000; Peiris *et al*., 2000; Basnayake and Fernando, 2002; Marambe *et al*., 2002; Peiris and Piyasiri, 2002; Zubair, 2002).

However, no detailed studies were reported on long-term climate change with respect to rainfall and temperature in any of the AERs. Of the 24 AERs in Sri Lanka (Domroes), only IL1 was chosen in this study as this region contributes around 50 percent of the national coconut production. The knowledge of climate change aspects of this region would be beneficial for future projection of coconut production and can be used to predict future climate scenarios in this region.

MATERIALS AND METHODS

Data

Annual and seasonal rainfall (RF) of six stations of Kurunegala (7.47N, 80.35E), Palugaswewa (7.65N, 79.87E), Bandirippuwa (7.33N, 79.88E), Ratmalgara (7.55N, 79.90E), Horakelle (7.45N, 79.85E) and Ambakelle (7.58N, 79.78E) and annual and seasonal maximum (T_{MAX}), minimum (T_{MIN}) air temperature of the two stations of Kurunegala and Bandirippuwa within the IL1 over 70 years (1932-2001) were used in this study (temperature data is not available in other locations in IL1). The four rainy seasons considered are North-East monsoon (NEM: from December to February), first inter monsoon (FIM: from March to April), South-West monsoon (SWM: from May to September) and second inter monsoon (SIM: from October to November). The monthly data were acquired from the climate databank of the Biometry division of the Coconut Research Institute. Data were quality controlled and missing values were estimated using linear interpolation method. Diurnal temperature ($T_{DIF} = T_{MAX} - T_{MIN}$) was also considered as a climate indicator in the analysis.

Statistical analysis

Spatial homogeneity of climate series

Studies on climate change of a particular agro ecological region can be done either on data of each station or on the aggregated data of all stations within the region. It depends on the status of the homogeneity of temporal fluctuation of climate series of stations. Spatial aggregation with equal weights is recommended when the time series of a given variable is homogenous within selected locations. Thus, the spatial homogeneity in aggregation of station data of RF and temperature was tested using standard normal homogeneity test (SNHT, Alexanderson, 1986).

Climate change

Means and variances of 10-year sub periods on annual and seasonal basis were considered to obtain a general idea of the period in which climate change started and the pattern of the change from period to period. Means were tested using ANOVA followed by mean separation test (LSD) and the variances were tested using Bartlett’s test. If ANOVA test indicated a significant climate change, the sequential analysis of non-parametric Man-Kendall (M-K) rank correlation test (Sneyers, 1990; Turkes, 2002) was used to detect exact the starting point of the change and the significant period for such changes.

Man-Kendall (M-K) rank correlation test

The observed series (Y_i, i=1,2,……n) is ranked in sequential order and the rank of the i^{th} year is denoted by R_i (i=1,………,n). Let n_k, (k=1………n) be the number of R_i terms less than to the rank of each year obtained from the starting of the series. The statistic for i^{th} year is defined as,

$$T_i = \sum_{k=1}^{i} n_k$$

It can be shown that Ti is distributed normally with

$$E(T_i) = i(i-1)/4 \qquad \text{and} \qquad var(T_i) = [i(i-1)(2i+5)]/72$$

The test statistic is $U(T_i) = [(T_i - E(T_i))/\sqrt{var(T_i)}]$

If $U(T_i)$ is significant at the 5% probability level for an extended period, it can be considered as a period with significant change. Whether it is an increasing or a decreasing change depends on the sign of the $U(T_i)$ series of the significant period.

The above backward calculation of T_i starting from the end of the series results in the backward series for $U(T_i)$, $V(T_i)$. The time series plot of the $U(T_i)$ and $V(T_i)$ is used to investigate the significant changes in the original series. Intersection of these two series indicates the beginning of the climate change in that series.

RESULTS AND DISCUSSION

Homogeneity testing

The results of SNHT for RF of each station are given in Table 1.

Table 1. Test statistic and critical level in SNHT for RF of each station

Station	Test statistic	Critical level
Kurunegala	3.90	10.1
Bandirippuwa	3.00	10.1
Ratmalgara	9.70	9.85
Horakelle	8.97	10.1
Palugaswewa	8.98	10.1
Ambakelle	5.33	9.25

Results of SNHT in Table1 indicate that test statistic for RF of each station is below the critical level. It clarifies that the most significant shift of rainfall series of each station has not created significant change in mean level before and after the shift compared to the surrounding stations. Similar results were obtained for T_{MAX} and T_{MIN} indicating test statistic for T_{MAX} and T_{MIN} of Kurunegala compared to Bandirippuwa are 8.12 and 7.56 respectively and critical level for both is 9.25.

Since the RF and temperature series of each station is homogenous compared to the other stations irrespective of time scale, climate series can be pooled among the stations. Thus the average of the six stations was taken as a representation index for RF while the average of two stations was taken as a representation index for temperature in IL1 for further analysis.

Annual climate change

Means obtained for 10-year sub periods are indicated in Table 2. Results in Table 2 indicate that there were significant differences among the seven sub periods with respect to all four climate variables. Comparing the climate of the last three sub periods (1972-2001) with the first four sub periods (1932-1971), there was a reduction in RF and the increment in T_{MAX} & T_{MIN}. Such significant reduction in T_{DIF} was in the last sub period (1992-2001) compared to the first six sub periods (1932-1991). But the continuous increment of T_{MIN} during 1972-2001 has been disturbed by the 1982-1991 period reducing the T_{MIN} up to 23^0C. This reduction would have been caused by the unusual weather pattern that occurred throughout Sri Lanka in 1985 (Madan, 2000). Variances of RF and temperature for seven sub periods are given in Table 3.

Table 2. Means of 10-year sub periods of annual RF, T_{MAX}, T_{MIN} & T_{DIF}.

Sub –Period	RF (mm)	T_{MAX} (^{0}C)	T_{MIN} (^{0}C)	T_{DIF} (^{0}C)
1932-1941	1851.7	31.1	22.8	8.3
1942-1951	1669.4	31.1	23.0	8.2
1952-1961	1805.3	31.2	22.9	8.2
1962-1971	1768.4	31.1	23.1	8.0
1972-1981	1627.4	31.6	23.4	8.2
1982-1991	1543.9	31.7	23.0	8.7
1992-2001	1637.3	31.4	23.5	7.9
Significance level	0.1	0.0014	0.0001	0.001

Results of the Bartlett's test (Table 2) indicate that there was no significant difference among the variances of the seven sub periods with respect to RF, T_{MAX}, and

T_{DIF}, but significance was detected for T_{MIN} due to the higher variance in 1982-1991 periods. This significant variance was caused by the sudden extreme lower event in 1985. However, there was no clear direction of continuous increment or the decrement of variance after or before that period. Thus, this sudden increment in variance cannot be considered as a long-term change in variance in T_{MIN}. Change in variance is an indicator for the increase or decrease in the occurrence of extreme events. The non-significance of the change in variance denotes that there was no such significant increment or decrement in occurrence of extreme events in IL1 within the period of 1932-2001.

Table 3. Variances of 10-year sub-periods of annual RF, T_{MAX}, T_{MIN} & T_{DIF}.

Sub -Period	RF(mm)	T_{MAX} (^{0}C)	T_{MIN} (^{0}C)	T_{DIF} (^{0}C)
1932-1941	61157.4	0.08	0.05	0.04
1942-1951	71134.4	0.24	0.03	0.20
1952-1961	61069.6	0.10	0.04	0.08
1962-1971	72857.5	0.13	0.07	0.12
1972-1981	55045.6	0.28	0.05	0.22
1982-1991	77745.6	0.23	0.16	0.20
1992-2001	58176.6	0.13	0.07	0.15
Test statistic	0.437	7.881	12.597	4.339
Significance level	0.999	0.247	0.050	0.631

Thus it can be concluded that the annual climate change of IL1 with respect to RF and temperature is only due to the change in mean but not change in variance. For further clarification of the above results and to identify the exact starting points of significant changes and period with significant change, M-K rank correlation test was applied for the temporal series of annual climate. Time series plots with $U(T_i)$ and $V(T_i)$ obtained for annual RF,T_{MAX}, T_{MIN} and T_{DIF} of IL1 are shown in figure 1. The $U(T_i)$ series of annual RF, T_{MAX}, T_{MIN} and T_{DIF} exceed the critical range ($\pm$ 1.96) from 1986,1983,1970 and 1988 onwards respectively indicating the starting points for the significant changes. Annual RF and T_{DIF} exceed the lower bound of the critical range indicating reduction in RF and T_{DIF} while T_{MAX} and T_{MIN} exceed the upper bound of the critical range indicating increment in T_{MAX} and T_{MIN}.

Although the starting points for significant changes were different among climatic variables, it can be concluded that since 1988 all climate variables changed significantly. The significant change in T_{MIN} has started 10 years (1970) prior to starting the changes in RF, T_{MAX} and T_{DIF}. The results in Table 4 indicate that mean annual rainfall has reduced by around 9% after 1986 compared with the mean prior to when the significant change occurred. The corresponding increase in maximum temperature is

1.4%. Thus, it can be concluded that climate change has resulted due to the reduction in rainfall and increase in temperature. In fact diurnal temperature is significantly correlated with cloud cover. Thus, it further confirms the reduction of rainfall. Nevertheless, in this study the cause for the climate change is not discussed, but it can be assumed that it may be due to increase in green house gasses of water vapour, CO_2, O_3, CH_4 and N_2O and clouds.

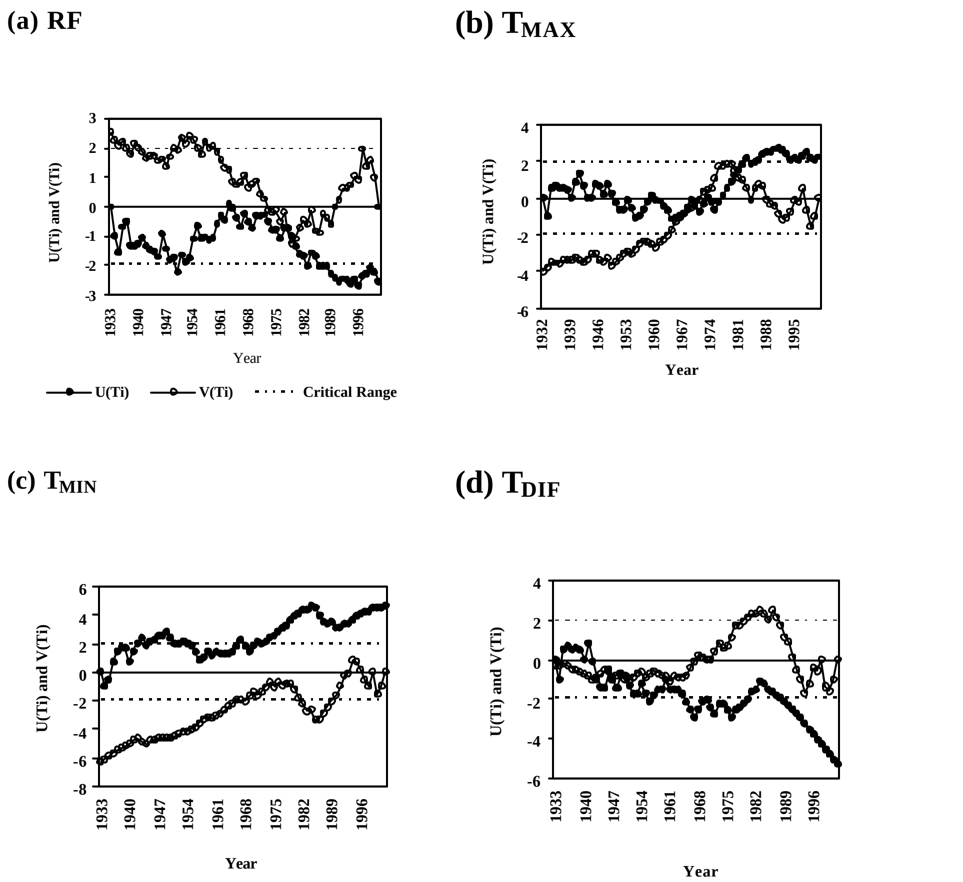

Fig.1. Time series plot with $U(T_i)$ and $V(T_i)$ series obtained from M-K rank.

Linear trend analysis showed that the rate of decrease is higher in RF than T_{DIF} and the rate of increase is higher in T_{MAX} than T_{MIN}. The summary of the annual climate change is given in Table 4.

Seasonal climate change

The changes in annual climate alone is not sufficient in determining the climate change in a region since the change in annual climate may be either due to the changes in all seasons or the changes in some of them. Thus, data were analyzed on a seasonal basis. As in the annual climate series, M-K rank correlation test was applied for the seasonal series of RF, T_{MAX}, T_{MIN} and T_{DIF} and the corresponding series of $U(T_i)$ and $V(T_i)$ were plotted. Based on the pattern of these plots, starting points and the period of the significant seasonal climate change were identified. The summaries of the seasonal climate change of four climate variables are given in Table 5.

Table 4. Comparison of mean climate values between prior to starting point of significant change occurred (period 1) and after the starting point of significant change occurred (period 2).

Variable	Starting year for significant change	Mean values of the variable		% change during period 2 with respect to period 1
		Period 1	Period 2	
RF	1986	1733.4	1578.2	-8.95
T_{MAX}	1983	31.2	31.7	+1.39
T_{MIN}	1970	22.9	23.2	+1.11
T_{DIF}	1988	8.3	8.1	-2.62

Table 5. Comparison of mean climate values between prior to starting point of significant change occurred (period 1) and after the starting point of significant change occurred (period 2).

Season	Variable	Starting year for significant change	Mean		% change during period 2 with respect to period 1
			Period 1	Period 2	
NEM	RF	1989	248.8	209.1	-15.98
	T_{MAX}	No Change			
	T_{MIN}	1998	21.2	22.2	+4.54
	T_{DIF}	No Change			
FIM	RF	1990	328.6	244.0	-25.75
	T_{MAX}	No Change			
	T_{MIN}	1965	23.0	23.2	+1.22
	T_{DIF}	1994	10.4	9.8	-5.49
SWM	RF	No Change			
	T_{MAX}	No Change			
	T_{MIN}	1996	24.2	24.5	+1.24
	T_{DIF}	No Change			
SIM	RF	No Change			
	T_{MAX}	1983	30.7	31.0	+1.03
	T_{MIN}	1996	22.6	23.1	+2.31
	T_{DIF}	No Change			

Of the four seasons, the significant change of RF was in the seasons of NEM and FIM indicating the reduction of annual rainfall of IL1 was due to the reduction in these two seasons. The percentage reduction in rainfall during FIM (25.75%) is higher than that during NEM (15.98%). The U (T_i) and V (T_i) series of SWM & SIM are overlapping within the critical the range (figure 2) confirming that there was significant change for the RF during SWM & SIM. Comparing the results in both Table 4 and Table 5, it can be concluded that 1990 was the turning point for significant climate change in RF.

For T_{MAX} the starting point for significant change was found only during SIM and the corresponding year is 1983. Significant change was found for T_{MIN} during all four seasons. Results showed that the turning point for FIM was 1965 and that for NEM, SWM and SIM were 1998, 1996 and 1996 respectively. Of the four seasons, only T_{DIF} during FIM showed similar changing pattern to annual T_{DIF}. There was no significant change of T_{DIF} in other seasons. Thus, it can be considered that the reduction of annual T_{DIF} was mainly due to the reduction of T_{DIF} in FIM.

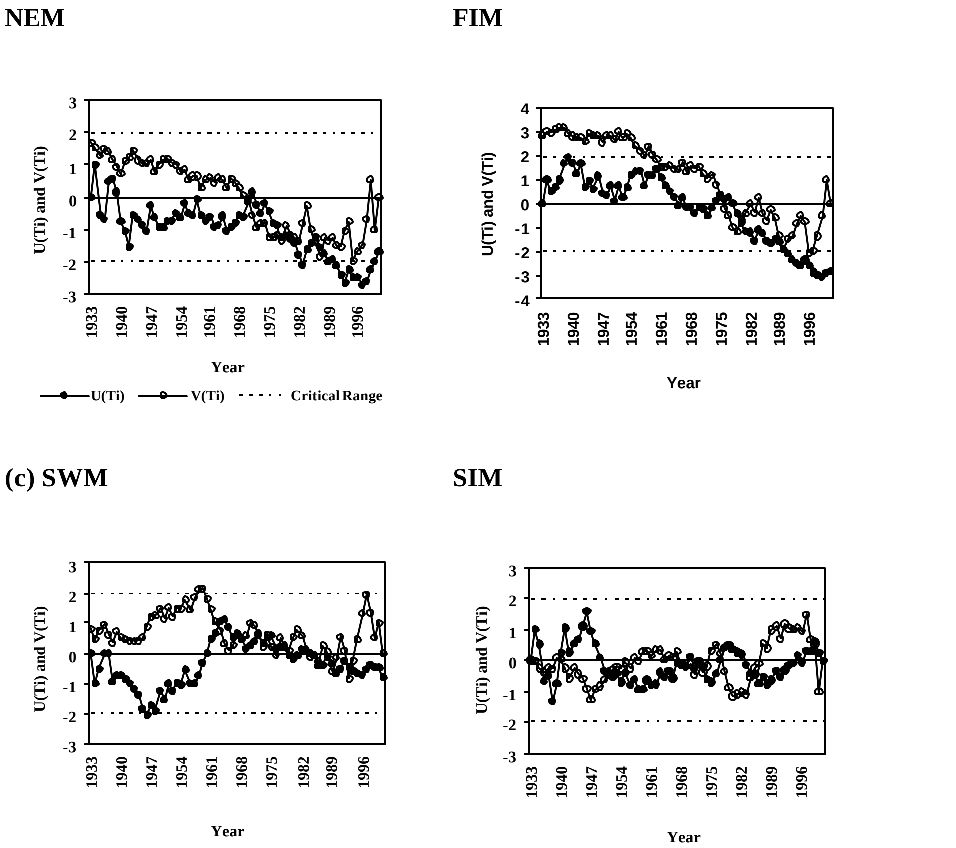

Fig. 2. **Time series plot with U(T_i) and V(T_i) series obtained for M-K rank correlation test for seasonal rainfall of IL1.**

These results show continuous reduction in rainfall in NEM and FIM of IL1. Thus, we need to pay more attention on mitigation techniques for the negative effect of rainfall, warming effect of T_{MAX} in SIM and T_{MIN} in all the seasons in recent years of IL1. Cooling effect of T_{DIF} in FIM may also affect coconut production. Suitable management practices should be applied to overcome the bad effects due to these changes. Also, the results of this study are very useful in identifying the effect of climate change on changing the coconut production of the IL1 region and for model development.

CONCLUSIONS

There was a significant climate change in Agro-ecological region of IL1 of Sri Lanka with respect to annual rainfall (RF), diurnal temperature (T_{DIF}), maximum air temperature (T_{MAX}) and minimum air temperature (T_{MIN}). The years in which significant changes commenced varied among climate variables and the corresponding years for RF, T_{MAX}, T_{MIN} and T_{DIF} were 1986, 1983, 1970 and 1988 respectively. Annual RF and T_{DIF} showed significant declining trends while both T_{MAX} and T_{MIN} showed upward trends. Of the four climate variables RF and T_{MAX} are the most vulnerable parameters which influence climate change. After 1986 mean rainfall has reduced nearly 9% compared to the corresponding mean prior to 1986. After 1970 the mean T_{MAX} has increased by 1.4% compared to the mean T_{MAX} prior to 1970.

The pattern of seasonal climate change is different from the annual climate change. This is due to high variability within year than the between years. Of the four rainy seasons, the reduction in annual rainfall was reflected due to significant reduction in rainfall during NEM and FIM. The increase in annual T_{MAX} was shown due to significant increase during SIM. The T_{MIN} showed significant increase in all four seasons.

The causes for increase in temperature and decrease in rainfall are not known, but it could be due to enhanced green house effects. The increase in temperature and decrease in rainfall would certainly effect the variability of production of any crop between and within years. The change of climate would also lead to change in the weather pattern. Thus, at farm level, farmers should adopt new crop varieties, new harvesting dates etc.

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REFERENCES

Alexandersson, H. (1986). A homogeneity test applied to precipitation data. Journal of Climate 6: 661-675.

Basnayake, B. R. S. B. and Fernando, T. K. (2002). Variation of air temperature and rainfall during the Yala and Maha agricultural seasons. Proceedings of summary reports on recent findings of climate change, Centre for Climate Change Studies, Department of Meteorology, Colombo, Sri Lanka. pp. 12-14.

Domroes, M. (1974). The agroclimate of Ceylon. Franzv Steiner Verlag Gmbh-Wiesbaden.

Fernando, T. K. (2000). Impact of climate change on paddy production in Sri Lanka. Global Environmental Research 3(2): 169-176.

Liyanage, M. de S. (1999). A Guide to scientific cultivation and management of coconut. Hitech Prints, Nugegoda.

Marambe, B., Punyawardena, B. V. R., Basnayake, B. R. S. B., Dinuka, K. R. and Thambawita, G. D. (2002). Assessment of Evidence, Causes and Implications of Change in Daily Temperature Regimes in Sri Lanka, Proceedings of summary reports on recent findings of climate change, Centre for Climate Change Studies, Department of Meteorology, Colombo, Sri Lanka. pp. 10-11.

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

Peiris, T. S. G. and Mathes, D. T. (1997). Rainfall changes scenarios in coconut growing areas in Sri Lanka. Proceedings of the National Committee of Biosphere, Colombo, Sri Lanka. pp. 3

Peiris, T. S. G. and Thattil, R. O. (1998). The study of climate effects on the nut yield of coconut using parsimonious models. Journal of Experimental Agriculture 34: 189-206.

Peiris, T. U. S., Peiris, T. S. G. and Samita S. (2000). Arrival of South-West monsoon rains. Tropical Agricultural Research 12: 265-275.

Peiris, T.S.G. and Piyasiri, C.H. (2002). Impact of climate change on Low Country Wet Intermediate Region. Proceedings of summary reports on recent findings of climate change, Centre for Climate Change Studies, Department of Meteorology, Colombo, Sri Lanka. pp. 8-9.

Peiris, T.S.G. and Piyasiri, C.H. (2002). Impact of climate change on Low Country Wet Intermediate Region. *In*: Proceedings of recent findings on climate change. 15th September, Centre for Climate Change Studies, Department of Meteorology, Colombo, Sri Lanka.

Sneyers, R. (1990). On the statistical analysis of series of observations. World Meteorological Organization (WMO). Technical Note No. 143. Geneva. 192.

Turkes, M., Sumer, M. U. and Demir, I. (2002). Re-Evaluation of trends and changes in mean, maximum and minimum temperatures of turkey for the period 1929-1999. Int. J. Climatol. 22: 947-977.

Watson, T. (1995). Climate change (1995). The scientific basis. Contribution of working Group II to the 2nd assessment report of the Intergovernmental Panel on Climate Change. WMO/UNEP/IPCC. Cambridge University Press, Cambridge. pp. 87-98.

Zubair, L. (2002). El Nino- Southern Oscillation Influences on Rice Production in Sri Lanka. Int. J. Climatol. 22: 249-260.