Seasonality and Periodicity of Trends in Rainfall and Temperature in Sri Lanka

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Abstract

Climatic changes are an important factor especially in view of current global warming scenarios. Study of climatic changes in Sri Lanka is relevant, particularly, as any change in the seasonality of rainfall can affect the country's agricultural productivity. Hence, the present study attempts to separately ascertain whether there have been changes in seasonal rainfall and temperature in the 'dry' and 'wet' zones during the 1870-1999 period.

As there are no cyclic changes or linear trends observed for the whole study period, the period was divided into four sub-periods: 1870-1909,1910-1939, 1940-1969 and 1970-1999. Simple regression coefficients were calculated for those sub-periods. Rainfall and temperature were calculated by spatial averaging. Measurement errors and fluctuations were reduced by averaging the data from different locations. As monthly data do not necessarily relate to seasonality, only typical months for each of the four seasons were selected and the data were averaged for the respective seasons.

The analyses reveal the following trends: a decrease of rainfall of both monsoon seasons and an increase of rainfall of the two inter-monsoon seasons when whole study period is considered. As for temperature, there has been a slight increase all over the island (with the exception of a slight decrease in the dry zone in the 1910-1939 period). The trends were also calculated for four periods.

Introduction

After the Little Ice Age the earth's atmosphere experienced a recovery period in the 20th century. It is recorded that a global rise of temperature about 0.5 C^0 was occurring during the period of 1910 –1940. Extension of growing season, advancement of summer and other phenomena were observed during this period. After 1940 there is a cooling trend. A weakening of the westerly flow is particularly striking since 1950 and Asian monsoon has become less reliable, with potentially serious consequences. Increased variability in climate was disadvantageous for the hybrid strains of wheat and rice introduced in the 1960s (Greg O'Hare and John Sweeney 1992).

Our economic and social programmes have been arranged to fit with some environmental conditions. Especially, the agricultural sector in Sri Lanka is mainly dependent on climatic conditions. But the climate is changing. So the agricultural patterns also should be modified. It is necessary to select varieties tolerable to expected changes. Instability in year to year production of many grain varieties, rice, high value crops, and minor export crops is predicted based on projected increase of temperature between 1.5C^O and 4.5 C^O during the next 40 – 50 years (Panabokke 1986). Temperature increase is referred to the global scenario which further clarify that ".... little change near the equator. In the tropical world, however, dry areas could become drier and the humid areas could become much wetter with more frequent and intense tropical storms". These consequences show the need for further studies in climatic changes in different regions,

particularly it is important to a country like Sri Lanka where the great diversity of agro-ecological situations are encountered.

It is evident that during the last hundred years rainfall has been decreased by 20% in Sri Lanka (Natural Resources of Sri Lanka). Fernando & Chandrapala (1995) found that from 1961 to 1990 rainfall has declined annually at Colombo 35mm, 34 at Batticoloa, 20mm at Galle and 10mm at Katunayaka. However they noted that there is an increasing trend at Puttalam 17mm, Anuradhapura 13mm and Mannar 9mm. Increase of temperature was recorded during the period of 1961 – 1990 at the rate of 0.036 C^0 at Anuradhapura, and 0.010 C^0 at Hambantota per year.

In the formulations in future agricultural strategies it is essential to further study the way climatic change takes place in Sri Lanka. The general objective of this study is to find out whether there are seasonal differentiations of the changes in temperature and rainfall in the Dry zone and Wet zone. It was also aimed at quantifying the difference for 30-year periods for whole instrumental period.

Methodology

A rainfall decrease at 20% in Sri Lanka during the last hundred years was estimated using simple linear regression, in which the years considered as independent variable and rainfall as dependent variable (Baldwin 1991). Rainfall data recorded at Nuwara Eliya Meteorological station for the period from 1870 to 1970 were used. Rainfall and temperature changes during the period of 1961 – 1990 are estimated using also simple linear regression separately for 14 stations (Fernando and Chandrapala 1995).

Published monthly data on rainfall and temperature is available for 20 stations in Sri Lanka for the period from their installation of stations up to 1980 (Yoshino and Suppiah 1982). These data were up dated for this study up to December 1999 using records from the Department of Meteorology. Total monthly rainfall data and average monthly temperature data from 1870 to 1999 are used in this study.

Climatic change is not a straightforward one that always reflects in annual total or average data. Reduction of amounts in one season may be compensated by an increase in the other season resulting in no intra-annual change. Therefore it was assumed that better result could be achieved by considering seasons separately. Moreover, the patterns of rainfall and temperature seasonality have a profound influence on the productivity of the agriculture in Sri Lanka. Four climatic seasons should be considered separately, because different components of the circulation pattern are involved. Identification of seasons by using monthly data is a difficult task. Therefore only typical months for each season were considered in this study. Northeast monsoon season is represented by the mean of December and January data. Southwest monsoon season is represented by the mean of June and July data. For the first Intermonsoon period the month of April and for the second Intermonsoon period the month of October is considered. Selection of months gives another advantage because these are typical months for season.

As the Dry zone and Wet zones of Sri Lanka receive most of their rainfall from different components of circulation patterns, namely Wet zone from Southwest and Dry zone from Northeast monsoon, the zones should be considered separately. The Dry zone in this study is represented by the average of data

from Puttalm, Anuradhapura, Trincomalee and Hambantota stations; and the Wet zone is represented by the average of data from Galle, Ratnapura, Nuwara Eliya and Kandy stations. This type of spatial averaging also gives two other advantages: the first is reduction of the unsystematic fluctuations and the second is the reduction in errors related with measurements and the changing locations of the stations.

No cyclic or linear pattern can be observed looking at the scatter plot of temperature and rainfall data against the time series in most stations by calculating simple linear regression slopes, it was assumed that better results could be achieved by dividing the total period in to sub periods. It was also considered that those periods should be thirty years or more because we have expected to compare results with other studies, 1910, 1940 and 1960 considered as suitable demarcation years. The four periods were identified as follows: the first period from 1870 to 1909, the second period from 1910 to 1939, the third period from 1940 to 1969 and the fourth period from 1970 to 1999. This division into periods gives another advantage, that one can separately study the characteristics of each seasons' separately and changing behaviour seasons as a process.

Simple linear regressions were calculated for above data classes and values of slopes of the lines considered as annual amounts of changes. However, those amounts can not be used to calculate total seasonal and annual amounts because only the representative months are considered. Microsoft Excel package is used for data entry and processing.

Results

The slopes in simple regression line were calculated using Microsoft Excel package. The independent variable is years and dependent variables were rainfall and temperature averages of four seasons and in the Dry and Wet zones. The slopes were calculated separately for four seasons. Then the slopes show the trend of change within the given period. The first four tables show the changes in rainfall and temperature in the Dry zone and Wet zone within each four seasons. The next four tables focus the attention on all changes within the given periods. The table 9 concentrated on the total changes in separate seasons during the whole period studied.

The process of Changes in Seasonal Amounts

Northeast monsoon rainfall for the Wet Zone had a decreasing trend before 1940 for 70 years continuously, having a rapid decrease during the period between 1910 and 1939 (Table 1). After 1940 Wet Zone rainfall experienced a slight increase within this season up to 1999 for the last 60 years. Regression coefficient of aggregated data representing North-east monsoon during the whole 130 years show a slight decrease (regression coefficient = -0.42). This is mostly due to the rapid decrease during 1910 - 1939 (r = -2.07). Therefore it is difficult to predict whether the North-east monsoon rainfall for the Wet Zone will continue to increase as it had taken place during the last 60 years or decrease as before 1939. However it is clear that the amount has been reduced.

After 1910 the Dry Zone rainfall has been continuously decreasing during the last 90 years. When the regression coefficient for whole observed period is considered, it is clear that the Dry Zone revealed a considerable reduction in rainfall during the past 130 years period. Highest decrease was calculated during the period of 1910 to 1939. This coincided with the same rapid decrease in the Wet Zone. Therefore it can be concluded that in this season there was a drying trend all over the island during the period of 1910 to 1939. Totally, when compared to the period before 1870, north east monsoon rainfall in the Dry Zone possess a considerable decrease, that is actually slightly less than that of the Wet Zone. Therefore it is difficult to predict whether the decreasing trend observed during last 90 years will continue with the coming years.

Table 1: Regression coefficients showing changes in the North East Monsoon Season

Period	Rainfall mm \ year		Temperature C^0	
Years	Wet Zone	Dry Zone	Wet Zone	Dry Zone
1870 – 1909	-0.48	0.27	0.017	0.004
1910 –1939	-2.07	-1.01	0.010	-0.002
1940 – 1969	0.64	-0.30	0.004	0.016
1970 – 1999	0.25	-0.42	0.020	0.042
Whole period	-0.42	-0.32	0.013	0.014

The trends of temperature in North-east monsoon period posses relatively homogeneous pattern. Northeast monsoon season temperature in the Wet Zone has increased during the analysed period, the highest being during the period 1970-1999. However it is remarkable that the increment gradually reduced up to 1969 and increased afterwards being slightly higher than the original value at the end of the studied period. It seems that the same increasing trend in temperature will continue to repeat in the near future in the Wet Zone.

During the period of 1910-1939 the temperature in the dry Zone showed a slight decrease, experiencing rapid increase in temperature afterwards. It is interesting to note that this decease in temperature in the Dry Zone coincides with the increased role of North-east monsoon rainfall in both Zones. Highest increase in temperature is recorded in the period of 1970-1999 in Dry Zone. When compared to the original situation in the both Dry and Wet Zones, temperature has been increasing showing a slight higher value in the Dry Zone. Despite the general trend in increasing temperature, there may be periods with decreasing trend that coincide with strong North- east monsoon, However, in general an increase of North-east monsoon period temperature is observed and it will further continue to grow in the near future.

For the whole island southwest monsoon rainfall has been reducing during the period from 1870 to 1940 (Table 2). This decreasing trend continued up to 1969 in the Wet Zone, after which a remarkable increase was experienced. For the Dry Zone this increasing trend started in 1940s, but the increment is insignificant. When compared to the initial period, Wet Zone rainfall has been drastically reduced while the Dry Zone experienced only slight decrease.

Table 2: Regression coefficients showing changes in the Southwest Monsoon Season

Period	Rainfall mm \ year		Temperature C^0	
Years	Wet Zone	Dry Zone	Wet Zone	Dry Zone
1870 – 1909	-0.980	-0.010	0.010	0.0050
1910 –1939	-2.400	-0.860	0.010	-0.0070
1940 – 1969	-2.010	0.440	-0.008	0.0117
1970 – 1999	1.609	0.004	0.004	0.0120
Whole period	-0.95	-0.99	0.0045	0.0054

The air temperature over the whole island during the studied period showed an increasing trend except the period 1910-1939 in the Dry Zone and 1940-1969 in the Wet Zone.

Both Wet and Dry zones experienced an increasing trend as seen in the first Inter-monsoon season rainfall during the period from 1870 to 1939(Table 3). This situation coincides with South-west monsoon rainfall's decreasing trend in the country. After 1940 both zones experienced a decreasing trend. The amount of decrease is higher in the Wet zone. The period between 1910 and 1939 had a decreasing trend in temperature in both zones, while all the other periods experience slight increase in temperature.

Table 3: Regression coefficients showing changes in the First Intermonsoon Season

Period	Rainfall mm \year		Temperature C^0	
Years	Wet Zone	Dry Zone	Wet Zone	Dry Zone
1870 – 1909	0.79	0.236	0.010	0.0035
1910 –1939	1.72	1.920	-0.005	-0.0360
1940 – 1969	-1.23	-0.890	0.011	0.0160
1970 – 1999	-0.92	-0.730	0.016	0.0200
Whole period	0.14	0.14	0.0082	0.0011

Second Intermonsoon season rainfall in the Wet zone increased during the first thirty years of the studied period, after which it decreased continuously for sixty years followed by a rapid increase in the last thirty years(Table 4). But in the Dry zone this increasing trend during the thirty-year period was always followed by a thirty-year period of decrease. Compared to the initial values of the study period, the second Intermonsoon rainfall has increased in both zones. Increasing trends in temperature in both zones have accelerated during the last thirty years with a slight decrease in the second period in the Dry zone. The total increase in temperature at the end of the study period in both zones is almost equal.

Table 4: Regression coefficients showing changes in the Second Intermonsoon Season

Period	Rainfall mm \year		Temperature C^0	
Years	Wet Zone	Dry Zone	Wet Zone	Dry Zone
1870 – 1909	1.85	2.18	0.0120	0.005
1910 –1939	-2.43	-1.49	0.0040	-0.008
1940 – 1969	-1.04	2.36	0.0004	0.009
1970 – 1999	2.78	-1.22	0.0100	0.022
Whole period	0.41	0.59	0.007015	0.006846

3.2. Periodicity of Changes

Wetting Period (1870 – 1910)

The first period studied (1870 –1910) can be recognized by the decreasing trends in both monsoon rainfall and also by the increasing trends in both Intermonsoon rainfall in the Wet zone (Table 5). This increasing trend in rainfall in both intermonsoon periods is characteristic of the Dry zone too, but in the Dry zone Northeast monsoon rainfall can also be seen to increase very slightly. As a result at the end of the period a distinct increase in rainfall all over the island was experienced. The increase is higher in the dry zone. Temperature has increased in both zones for all the seasons, with the total a little higher in the Wet zone.

Table 5: Seasonal Trends in the Wetting Period (1870 – 1909)

Season	Rainfall mm \year		Temperature C^0	
	Wet Zone	Dry Zone	Wet Zone	Dry Zone
North East	-0.48	0.27	0.017	0.0040
South West	-0.98	-0.010	0.010	0.0050
1st Intermonsoon	0.79	0.236	0.010	0.0035
2nd intermonsoon	1.85	2.18	0.012	0.0050

Drying and Cooling Period (1910 – 1939)

The decreasing trend in both monsoon rainfalls in both zones observed in the first period was found to continue during the second period (1910-1939) too. This reduction during the second period combined with the reduction of rainfall in the second Intermonsoon period, marking a very high reduction value in the Wet zone. Totally, the second period was a drying one for both zones. This second period was a cooling one for the Dry zone in all four seasons. Within the Wet zone temperature showed an increasing trend was continuing, except in the first Intermonsoon season, when very slight reduction was observed.

Table 6: Seasonal Trends in the Drying and Cooling Period (1910 – 1939)

Season	Rainfall mm		Temperature C^0	
	Wet Zone	Dry Zone	Wet Zone	Dry Zone
North East	-2.07	-1.01	0.010	-0.002
South West	-2.40	-0.86	0.010	-0.007
1st Intermonsoon	1.72	1.92	-0.005	-0.036
2nd intermonsoon	-2.43	-1.49	0.004	-0.008

The Period of spatial Contrast (wetting of Dry zone and drying of Wet zone 1940 – 1969)

The third period (1940 –1969) is distinguished by a clear contrast of rainfall trends between the two zones: North east monsoon rainfall was increasing in the wet zone and reducing in the dry zone; South west monsoon rainfall was reducing in the wet zone and increasing in the dry zone; Second Intermonsoon rainfall was reducing in the Wet zone and increasing in the dry zone. Only first Intermonsoon rainfall was reducing in both zones. The contrast is also marked with the total, being a high reduction in the wet zone and an increase in the dry

zone. Temperature continues to increase slightly in both zones. An exception is observed during the Southwest monsoon period when highest reduction in rainfall is marked.

Table7: Seasonal Trends in the Period of spatial Contrast (*wetting of Dry zone and drying of Wet zone* 1940 – 1969)

	Rainfall mm \year		Temperature C^0	
Season	Wet Zone	Dry Zone	Wet Zone	Dry Zone
North East	0.64	-0.30	0.0040	0.0160
South West	-2.01	0.44	-0.0080	0.0117
1^{st} Intermonsoon	-1.23	-0.89	0.0110	0.0160
2^{nd} intermonsoon	-1.04	2.36	0.0004	0.0090

The Recovering Period(1970 – 1999)

A distinct increase of rainfall for the Wet Zone in second intermonsoon season was observed in this period resulting in a total increase. The increase of both monsoon rainfalls is also responsible for this total increase. However there is a reduction of the first Intermonsoon rainfall in the Wet zone. Dry Zone rainfall was also found to decrease as a result of the decreasing trend of three seasons, except the Southwest.

Table 8: Seasonal Trends in the Recovering Period
(*Wetting of Wet zone and Drying of Dry Zone) 1970 – 1999*

	Rainfall mm \year		Temperature C^0	
Season	Wet Zone	Dry Zone	Wet Zone	Dry Zone
North East	0.250	-0.420	0.020	0.042
South West	1.609	0.004	0.004	0.012
1^{st} Intermonsoon	-0.920	-0.730	0.016	0.020
2^{nd} intermonsoon	2.780	-1.220	0.010	0.022

Total Changes in the seasons

The grand totals of the changes during the four periods for each season are given in table 9. The table clearly shows that the changes gradually happened during the whole period of study. Both monsoon rainfalls have been reduced in both zones. The highest decrease is estimated for the Southwest monsoon rainfall in the wet zone. The reduction of Northeast monsoon rainfall is almost equal for both zones, being a little higher for the Wet zone. Both Intermonsoon rainfalls have increased for both zones, owing a higher increase in the second Intermonsoon period. Increase of rainfalls in the Dry zone within both Intermonsoon seasons is higher than that for the Wet zone. The resulting amounts show that during the last 130 years period the Wet zone rainfall has been drastically reduced and the Dry zone rainfall has been slightly increased.

Table 9 Total Changes in the seasons (1870-1999)

Season	Wet Zone Rainfall	Dry Zone Rainfall	Wet Zone Temperature	Dry Zone Temperature
NE Monsoon	-0.42	-0.32	0.013	0.014
SW Monsoon	-0.95	-0.99	0.005	0.005
1st Intermonsoon	0.14	0.14	0.008	0.001
2nd Intermonsoon	0.41	0.59	0.007	0.007

During this total period the air temperature was increasing in all four seasons in the both zones. The highest increase is marked in the Dry zone for Northeast monsoon season while the lowest is in the first Intermonsoon season in the Dry zone. The highest increase of air temperature in the Wet zone is estimated also in the Northeast monsoon season, the lowest being in the Southwest monsoon season. The temperature in both zones has increased during the total period the amount being a little higher in the Wet zone.

As already mentioned the above temperature showed increasing trends except in the Dry zone during the second period, when the zone experienced a decrease. The intensity of increase had been reduced in the first hundred years continuously followed by a rapid change in the last period.

Conclusions

Northeast monsoon rainfall showed a decreasing trend from 1870 up-to 1939 in the Wet zone, after which it experienced an increasing trend from 1940 to 1999 and then a slight decrease at the end of the studied period. The Dry zone experienced a decreasing trend in rainfall of northeast monsoon for last 90 years continuously starting from 1910. However, at the end of the whole period the degree of decrease has been less than in the Wet zone.

The wet zone experienced a continuous decrease in rainfall from Southwest monsoon during 90 years up to 1969, followed by an increasing trend. The Dry zone experienced a slight increase of rainfall for last 60 years after 70 years decrease. The amount declined from the season is higher than that of the North-east monsoon season.

Both wet and dry zones a showed a decline of rainfall from the first Intermonsoon season for last 60 years after another 60 years of increase. The resulting amounts at the end of the studied period in both zones show an increase. During the last 30 years rainfall from the second Intermonsoon period was increasing for the Wet zone and decreasing for the Dry zone. Resulting amounts in the both zones at the end of the studied period are higher than that from first Intermonsoon season.

The first 40 years studied period was a wetting one for both zones. The second 30-year period was a drying one for both zones having higher rate in the Wet zone. The third period continued drying the Wet zone and for the Dry zone was a wetting one. The fourth, last thirty years period was a wetting one for the Wet zone and Drying one for the Dry zone.

The air temperatures experienced a slight increase during whole the periods for all four seasons. A remarkable exception was only in the second period from 1910 to 1939 when the Dry zone experienced a temperature decline in all four seasons.

A reduction of rainfall in two major rainy seasons and continuous increase of temperature have taken place during the last 130 years in Sri Lanka. It is also important to note that there is an increase of rainfall during the both Intermonsoon seasons. On this basis it is possible to conclude that Equatorial conditions with evening out of rainfall maximums in monsoon periods are going to dominate over Sri Lanka. An increase of the role of Intermonsoon also suggests that the increase of the number and the role of thunder storms, increase of rainfall intensity, and increase of surface runoff leading to the scarcity of water in the upper parts of watersheds should take place in the future.

Increase or decrease of rainfall was not a continuous phenomenon in Sri Lanka. During the instrumental period the direction of change had changed. The same may be in the future. Perennial crops, which require well-distributed rainfall around the year, may give better yields. However, as in the Wet zone rainfall may reduce and the conditions will not be so suitable for those types as now. With the increase of temperature, in upper boundaries of coconut growing area may migrate further up. The boundaries of Intermediate agro climatic zones with less rainfall may shift in both directions – to the wet zone and to the Dry zone, and also with the increase of temperature to the direction of up country.

Discussion

The general increase of air temperature after the Little Ice Age is also observed in Sri Lanka. The highest increases were observed in the last thirty years (1970 – 1999) in both Dry and Wet zones. This high increase may be related with the increased green house effect as in the whole globe. However the amounts are low compared to the global amounts. This study also shows that the temperature changes in Sri Lanka are not proportional to that of the globe or northern hemisphere. During the period from 1910 – 1940 experienced a global rise of temperature at about 0.5 C0 and also recorded 0.4 to 0.6C0 increase in the northern hemisphere (O'Hare and John Sweeney 1992). Parallel to this change, after 1940 Northeast monsoon rainfall was increasing in the Wet zone and Southwest monsoon rainfall was increasing in the Dry zone and also first intermonsoon rainfall was decreasing in both zones. During the above period The Dry zone of Sri Lanka experienced a cooling trend in all four seasons and also there was a cooling trend in the first Intermonsoon period in the Wet zone during the same period. However very slight increase in temperature is shown in the Wet zone in other three seasons. During the period of 1940 – 1965 northern hemisphere experienced a cooling trend that is also not observed in Sri Lanka.

The global prediction which states that in the tropical countries 'dry areas could become drier and the humid areas could become much wetter' was not proved. Instead, Wet zone became drier and Dry zone became wetter. However only very slight increase of rain is observed in the Dry zone. 'More frequent and intense tropical storms' is possible because in both zones both the Intermonsoon rainfall have shown an increase. It is more significant to note that 'Equatorial conditions' are going to be dominant with high temperature and distributed rainfall around the year as both monsoon rainfalls are reduced in both zones and both intermonsoon rainfalls have increased for both zones.

A rainfall decrease of nearly 20% at Nuwara Eliya was estimated and remarked the absence of rainfall decline in the Dry zone earlier (Baldwin 1991). It is evident from our study that in whole the Wet zone rainfall has been reduced in lower amount than Nuwara Eliya. This is due to the decrease of rainfall in both monsoon seasons. It is also evident slight increase of rainfall in the Dry zone.

The results achieved by Fernando and Chandrapala could not be compared with this study because of the disagreement in the selected years between two studies and spatial averaging adopted in this study. However the results agree with the general trend worked out in this study – increase of rainfall in the Dry zone and decrease of rainfall in the Wet zone.

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