Proceedings of the Technical Sessions, 25 (2009) 7-12
Institute of Physics – Sri Lanka

Climate change in the hill country of Sri Lanka

G.J. De Silva and D.U.J. Sonnadara
Department of Physics, University of Colombo, Colombo 3

ABSTRACT

This paper describes an analysis of long term changes in precipitation and temperature over 5 stations in the hill country of Sri Lanka during the period 1869 – 2006. The trend is predicted by a least squares regression analysis and the significance of the observed trend is calculated by using the Mann Kendall technique. The results suggest that there is a statistically significant reduction in annual rainfall, particularly that of the South West monsoon (385 mm over the last 100 years) and advocates the need for better planning and rationalization. In particular, the reduction in rainfall is leading to low yields and drop in productivity in tea plantations. The mean annual temperature has also increased by more than 1°C in Nuwara Eliya. Contribution to annual temperate increase is higher from the North East monsoon period compared to the South East monsoon period.

1. INTRODUCTION

To a country with substantial dependence on domestic agriculture consistency in rainfall is an important factor to consider when managing water resources, which are under pressure from growing demand, population increases and economic development. Hydropower has been the main form of power generation utilizing the country's natural reservoirs and waterfalls. It continues to be the cheapest and environmentally friendly method as compared to thermal power which is still not being fully utilized. Nuclear power has not yet been considered and currently no indications are present of future development. Due to the volatile weather patterns the country is faced with routine blackouts and energy rationalization. This has severely affected industrial development and has held the country back for many years.

Generally, rainfall trends have shown to vary across regions. A study by Forland et. al. [1] on precipitation in the North Atlantic region suggests, for Europe a positive precipitation trend in the north and a negative trend in the south. South East Asia and South Pacific from 1961 onwards annual rainfall has found to be decreasing [2]. For certain regions, cases of increasing rain intensities while total precipitation decreased have also been discovered [3].

Five stations have been considered for this study with elevation from sea level 650 meters to 2500 meters. The terrain is mainly mountainous covered with virgin forests and grasslands. The plateaus and mountain slopes are used for cultivation especially tea plantations. The area is home to many indigenous species of flora and fauna and is famous for its sambhur population (local specie of deer).

2. METHODOLOGY

2.1 Data sample

Sri Lanka has a tropical climate with temperature ranging from a low of 16 °C (61 °F) in Nuwara Eliya to a high of 32 °C (90 °F) in Trincomalee. Climate is described by 4 main monsoon systems. South West and North East monsoon systems and two inter monsoon periods.

Hill country is placed in the wet zone, commonly defined as an area receiving more than 1905 mm of rainfall. The region boasts great ecological diversity in flora and fauna and is favorite destination for tourists with its mild climate. The rocky hills are home to nearly all of the country's waterfalls and many major rivers originate in and around its locality.

Five stations have been selected from the region, namely Badulla, Ratnapura, Diyatalawa, Kandy and Nuwara Eliya. Kandy, Nuwara Eliya and Ratnapura receive rain, predominantly from the South West Monsoon, Badulla from the North East monsoon and Diyatalawa is equally affected by both systems. Monthly rainfall and temperature data were collected for the period 1869 – 2006 from the Department of Meteorology of Sri Lanka which archives them. Monthly data has been further categorized according to timing of monsoons for further analysis.

2.2 Statistical technique

Annual and seasonal rainfall and temperature time series are computed for each station. The trend is estimated using least squares regression analysis for each station. Temporal changes in the annual and seasonal values were also analyzed by Mann Kendall statistics [4] to confirm the significance of test. A significance of 5% (Z=1.96) was considered satisfactory for this study.

<u>The Mann Kendall statistics</u>

The Mann Kendall statistic S is calculated using the formula,

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k)$$

Where

$$\begin{aligned} \operatorname{sgn}(x_j - x_k) &= -1 \quad if \;\; x_j - x_k > 0 \\ &= \;\; 0 \quad if \;\; x_j - x_k = 0 \\ &= -1 \quad if \;\; x_j - x_k < 0 \end{aligned}$$

Using normal approximation;

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5) \right]$$

Where q is the number of tied groups and t_p is the number of data values in the p^{th} group. The test statistic Z is computed as.

$$Z = \frac{S-1}{\sqrt{VAR(S)}} \quad if \quad S>0$$
$$= 0 \quad if \quad S=0$$
$$= \frac{S+1}{\sqrt{VAR(S)}} \quad if \quad S<0$$

A positive (negative) value of Z indicates an upward (downward) trend. The statistic Z has a normal distribution. At α level of significance Null hypotheses (assumption of no trend) is rejected if the absolute value of Z is greater than $Z_{1-\frac{\alpha}{2}}$.

3. RESULTS AND DISCUSSION

3.1 Annual trends

The result of the least squares and Mann Kendall statistics on annual rainfall and temperature trends are presented in Table 1. The annual rainfalls for all 5 stations show a decreasing trend. For Kandy and Nuwara Eliya the observed trend was significant at 0.05 level and for Badulla at 0.1 level. However it is observed there is no significant trend in Diyatalawa and Ratnapura. Annual temperature data show a positive trend for all stations except for Diyatalawa. Baduall, Ratnapura and Nuwara Eliya showed trends significant at 0.05 level.

Table 1: Annual rainfall

Station	Annual rainfall		Annual temperature	
	Linear equation	MK statistic	Linear equation	MK statistic
Badulla	Y=5507-1.905X	-1.82	Y=7.331+0.008X	+7.66 *
Diyatalawa	Y=2944-0.673X	-0.84	Y=4.828+0.008X	-0.84
Kandy	Y=7585-2.868X	-3.72 *	Y=23.39+0.001X	+0.72
Ratnapura	Y=5101-0.658X	-0.71	Y=17.71+0.005X	+6.30 *
Nuwara Eliya	Y=12146-5.153X	-6.10 *	Y=-4.90+0.011X	+10.6 *

*Significant at 0.05

The results for annual rainfall and temperature trends are shown in Figure 1. Compared to other stations, a clear difference in the reduction of annual rainfall in Nuwara Eliya is seen.

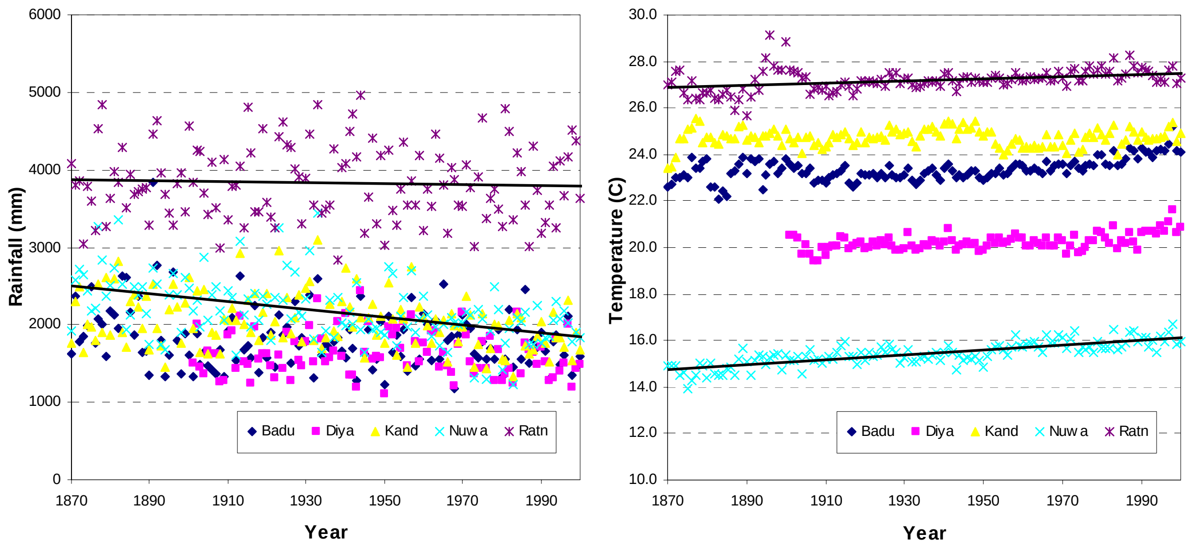


Figure 1: Annual rainfall and temperature trends.

3.2 Seasonal trends

The results for each monsoon system are presented in Table 2 and 3 for South West monsoon and North East monsoon respectively.

South West monsoon

The South West monsoon rainfall shows a generally decreasing trend other than Diyatalawa which is not statistically significant. Kandy and Nuwara Eliya have a decreasing trend at 0.05 levels with Ratnapura only at 0.2 level. Statistically significant temperature trends were seen at Badulla, Ratnapura and Nuwara Eliya. Nuwara Eliya continues to show decreasing trend in rainfall and increasing trend in temperature.

Table 2: South West monsoon rainfall and temperature

Station	Rainfall		Temperature	
	Linear equation	MK statistic	Linear equation	MK statistic
Badulla	Y=814-0.212X	-0.71	Y=4.986+0.010X	+8.45 *
Diyatalawa	Y=-90.87+0.268X	0.79	Y=5.471+0.008X	+0.79
Kandy	Y=5095-2.222X	-4.32 *	Y=23.38+0.001X	+0.74
Ratnapura	Y=4568-1.362X	-1.51	Y=20.36+0.004X	+4.62 *
Nuwara Eliya	Y=8604-3.891X	-5.77 *	Y=-1.43+0.009X	+9.01 *

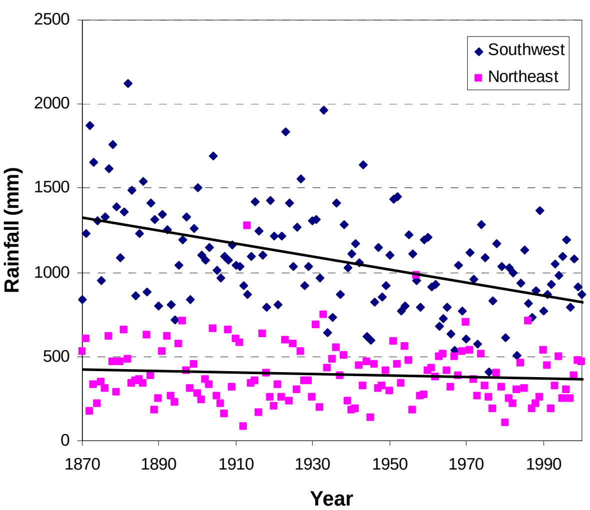
North East monsoon

For North East rainfall, a negative trend is observed at Diyatalawa and Kandy which is significant only at 0.2 levels. Therefore it can be inferred that there is no significant change in the North East monsoon rainfall. However, a positive trend significant at 0.05 level was observed at Badulla, Ratnapura and Nuwara Eliya for temperature.

Table 3: North East monsoon rainfall and temperature

Station	Rainfall		Temperature	
	Linear equation	MK statistic	Linear equation	MK statistic
Badulla	Y=2561-1.012X	-1.11	Y=11.00+0.006X	+4.31 *
Diyatalawa	Y=1916-0.775X	-1.48	Y=3.769+0.008X	-1.48
Kandy	Y=1512-0.574X	-1.54	Y=24.65+0.000X	-0.34
Ratnapura	Y=-458+0.497X	0.48	Y=13.19+0.007X	+6.39 *
Nuwara Eliya	Y=1316-0.477X	-1.25	Y=-7.81+0.012X	+8.65 *

Figure 2 shows the rainfall and temperature trends at Nuwara Eliya for South West and North East monsoons. It can be clearly seen that South West monsoon rainfall has reduced significantly (385 mm) over the last 100 years, North East monsoon has remained more or less constant (47 mm reduction over the 100 years). Thus, the contribution for annual rainfall reduction is mainly caused by the reduction in South West monsoons. On the other hand, temperature has increased both in South West and North East monsoon periods. From 1901 to 2000, mean annual temperature has increased by more than 1°C in Nuwara Eliya. The data shows that contribution for annual temperate increase is higher from North East monsoon period compared to South East monsoon period.



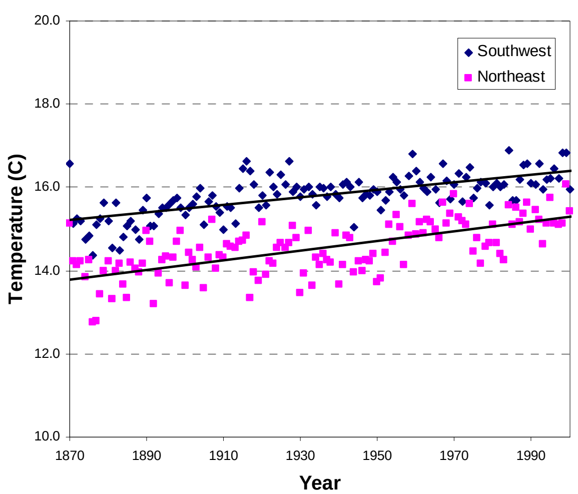


Figure 2: Annual rainfall and temperature trends at Nuwara-Eliya.

4. CONCLUSIONS

An important aspect of the present study is the significant reduction in rainfall which is prominent at Nuwara Eliya. The South West monsoon's predictability as the main rainfall provider to the region and the country is failing due to its gradual decrease over time. If the current trend continues, another 100 years, Nuwara Eliya will receive same amount of rainfall from South West monsoon and North East monsoon. There is no significant change in North East monsoon at any of the stations.

Herath and Ratnayake [5] have observed a decrease in the number of rainy days in the central mountainous region and attribute it to an overall reduction in annual rainfall. A reduction in rainfall would eventually lead to a drying up of the many reservoirs in the region and would take longer to recharge. Immediate repercussions would be felt in the agriculture industry the two paddy growing seasons in the hill country normally depends on monsoonal rainfall. Furthermore export market for products such as tea will be affected by loss of production due to the variability in rainfall.

It has been suggested that the monsoon systems affecting the country is interrelated to the climatic signals associated with El Nino Southern Oscillation and the present reduction is a routine occurrence and would eventually subside. However, since all stations are not affected at the same level, the study indicates that there are local affects that are affecting the monsoon rainfall. North East monsoon periods show a faster increase compared to South West monsoon period. Observed increase in temperature for this region is comparable to the global increase. However, due to the country's dependence on water resources for agriculture and hydro power generation effective management of local water resources and rationalization is of paramount importance.

Acknowledgements: Financial assistance given by the National Research Council, Sri Lanka for the research grant number NRC 06-18 is greatly acknowledged.

REFERENCES

1. Forland, E.J. et. al. (1996), Change in normal precipitation in the North Atlantic region, DNMI Rport, 7/96, Kalima
2. Manton M.J. et. al. (2001), Trends in extreme daily rainfall and temperature in Southeast Asia and the South Pacific: 1961-1998, International Journal of Climatology, 21, 269-284.
3. Groisman P.Y. et. al. (1999), Changes in the probability of heavy precipitation: Important indicators of climate change, Climate Change, 42, 243-283
4. Dietz E.J, Kileen A. (1981), A nonparametric multivariate test for monotone trend with pharmaceutical applications, J. American Statistical Association, 76, 169-174
5. S. Herath and U. Ratnayake (2004), Monitoring rainfall trends to predict adverse impacts: A case study from Sri Lanka (1964 – 1993), Global Environmental Change Part A, 14(1), 71-79