Research Report No. 15

ICRISAT Research Program
Markets, Institutions and Policies

Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience

Climatic trends in Sri Lanka Agro-climatic Analysis

KHMS Premalal, Frank Niranjan, NPC Uddika, Cynthia S Bantilan and Naveen P Singh

ICRISAT Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

CARP Sri Lanka Council for Agricultural Research Policy

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Abstract

The threats related to climate change are apparent across the globe. It has beenis accepted that the worst to be hit in the coming future are going to be the agricultural communitiesy. MTherefore it a need for micro-level studies studies will therefore be necessary to understand community perceptions and actions to serve as a guide in devising viable adaptation strategies. Through the capability approach and using a grounded theory as the method of analysis, this paper tries to understand the perceptions of the farmers to climate change, and the impacts and the adaptation strategies and behaviour that they are demonstrateing based on theseir perceptions. In doing so, the paper draws attention to certain constraints that the communities in the six study villages are facing and the implications on their capabilities and capacity to adapt. The six villages representing the first generation ICRISAT Village Level Studies (VLS) sites, are unique as the presence of longitudinal data on them enables the understanding of perceptions of both the first generation (old) and second generation (young) of farmers. The study showed that climate change/variability is becoming a major concern for the farming and non- farming community. As a result of their perceptions, they have been adapting and have developed coping strategies to shield themselves against climate uncertainties. Diversification into short duration crops, commercial crops like sugarcane and soyabean along with experimenting with vegetable growing, indigenous methods of soil conversation, the involvement of women in farm activities, and caste- based professions have emerged as effective strategies that have come to be accepted socially and culturally at the local level.

At the institutional and the community level, there are serious constraints towards adapting to what may be a more challenging future resulting from climate change. The lack of collective feeling will and action has hindered bargaining for better market prices and the development of alternate livelihood options. The minimal impact of ICT as an information dissemination tool is also a source of concern. As climatic conditions are changing it is important to acknowledge that there needs to be robust medical and health care systems and facilities which that can take care of health issues, particularly which will be on the risethose that arise due to changing climatic conditions. The need for better financial inclusion and access to more formal systems of finance is pertinent not only to increasing the capabilities of the women but also the overall adaptive capacity of the household, especially during crisis situations or climatic shocks. The current study is an attempt to represent the understanding of the farming community to climate change and therefore the starting point for sensitising the policy makers to work towards aiming to enhancinge capabilities on adaptation measures of farmers in the semi-arid regions of India and mainstreaming of successful adaptation strategies in the agricultural development agenda.

Key Words: Perception, Capabilities and Entitlements, Adaptation Behaviour, Constraints

This publication is an output from the research project Asian Development Bank (ADB).

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CARP SRI LANKA COUNCIL FOR AGRICULTURE RESEARCH POLICY

2013

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Dr Frank Niranjan
Country Co-ordinator of the Project
Sri Lanka

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Executive Summary

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Sri Lanka Council for Agricultural Research Policy (SLCARP), recognized the complimentarity of their objectives and the need to facilitate the implementation of the research project on natural resources management, entitled ''Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience'' in seven Asian countries, including India, China, Sri Lanka, Bangladesh, Pakistan, Vietnam and Thailand. Accordingly, they have been working together to implement the project in Sri Lanka. Farmers in the Asian countries need to adjust to climate that is changing and accordingly adapt with layers of resilience in their farming practices and investment decisions. Climate change is the most important global environmental challenge facing humanity today.

The overall objectives of the project are to improve understanding of the climate variability and its impact on the rural poor in Sri Lanka, identify the best practices and institutional innovations for mitigating the effects of climatic change and develop strategies to address socio-economic problems relating to climatic change. The aim of the project is to identify and prioritize the sectors most at risk and develop gender equitable agricultural adaptation and mitigation strategies as an integral part of agricultural development in these less-favored areas. This includes innovations in agricultural institutions, the role of women, social capital and social networks.

Three districts were selected for this study from the dry zone in Sri Lanka, namely Puttalam, Hambantota and Anuradhapura. Climate and climate change analysis have been done for these three districts. For agro-climatic analysis, Eluwankulama and Angunakolapelessa agromet station data were used from Puttalam and Hambantota districts, respectively. One of the major aims for this study is to map vulnerability for agriculture and the people living in these villages, due to climate change. Basic climatic trends have been studied for these districts and special attention given to climate extremes as consecutive dry days, consecutive wet days, maximum and minimum temperature, cold days, cold nights, warm days, warm nights, and diurnal temperature range.

According to the Intergovernmental Panel on Climatic Change, hot days, hot nights and heat waves have become more frequent (IPCC 2007). Also it says that heat waves are associated with marked short-term human mortality. According to the recent analysis of climate data, it is found that climate extremes are established over Sri Lanka and continuous dry days, continuous wet days, cold days, cold nights, warm days, warm nights and diurnal temperature change are some of the climate extremes. Refer appendix no.3 for further information on these indicators.

Both the Maximum and Minimum temperatures have increased over the years. Extreme temperatures (No. of days with reported higher temperature) also increased with the increase in temperature. Crop damage and yield reduction can be expressed if the atmospheric temperature exceeds the optimum temperature of different crops. Detailed temperature analyses have to be done to identify the above mentioned impacts. Once this is done, it is not difficult to adapt by introducing suitable varieties that are resistant to high temperatures.

Behavior of rainfall pattern is erratic. Even though Decadal Variability has decreased for some climatic seasons, inter seasonal variability may be high. It may cause undesirable impact upon rain-fed agricultural practices. But, soil water storage methods can be introduced to avoid the impacts from rainfall variability. In addition, rainwater harvesting and other indigenous technologies are also possible as adaptation methods.

The onset and withdrawal of Yala and Maha seasons during 1977–2008 were found to be delayed by 3 to 4 weeks; agricultural drought occurred 19 times in Yala season and 2 times in Maha Season during the period. Meteorological drought has not been experienced during the period under reference. Length of growing period was computed, which showed that year-round cultivation is possible in the study regions. Supplementary irrigation requirement has increased, more significantly in the Yala Season, for growth and mid stage of the crops in both stations (Eluwankulama and Angunakolapellessa) over the period 1976–2008.

In Sri Lanka, farmers' knowledge about weather, climate and climate change is very poor. Therefore, proper mechanism has to be introduced to enhance the knowledge of farmers about weather and climate and grassroot level applications are recommended to counter this issue.

1. Introduction

In Sri Lanka, meteorological data observation was started in 1850, but taking systematic observations was started in 1865. The Department of Meteorology (DOM) was established in 1948 and later in 1951 it obtained membership in the World Meteorological Organization. In 1976, the Agricultural meteorological (Agro-met) network was started and presently, the department has 20 meteorological stations representing all the districts, about 35 agro-met stations and about 350 rainfall stations (Figure 1). These stations are maintained by the Government Departments, private organizations and some estates.
The meteorological data were observed every three hours, agro-met data were taken twice a day and rainfall data were recorded daily at 08.30 am. In addition to the three hourly data, self-record charts were also maintained for temperature, relative humidity, solar radiation and atmospheric pressure. The Department started recording its computerized meteorological data in 1986/87 using CLICOM software. At present, daily rainfall, maximum and minimum temperatures are computerized in all stations except the agro met stations.

Sri Lanka provided meteorological data observed from seven (7) meteorological stations (Trincomalee, Puttalam, Kurunegala, Colombo, Nuwara Eliya, Hambantota and Batticaloa) to the Global Climatic Observation Network (GCOS) (Figure 2). Meteorological data includes atmospheric pressure, temperature, relative humidity, wind speed and direction, etc, while agro-meteorological data includes sunshine hours, soil temperature, minimum on grass and solar radiation. The Department of Meteorology was able to digitize rainfall, maximum and minimum temperatures from 1861 to date, but the three hourly data are still in the form of hard copies. In addition, self-recording instruments are also

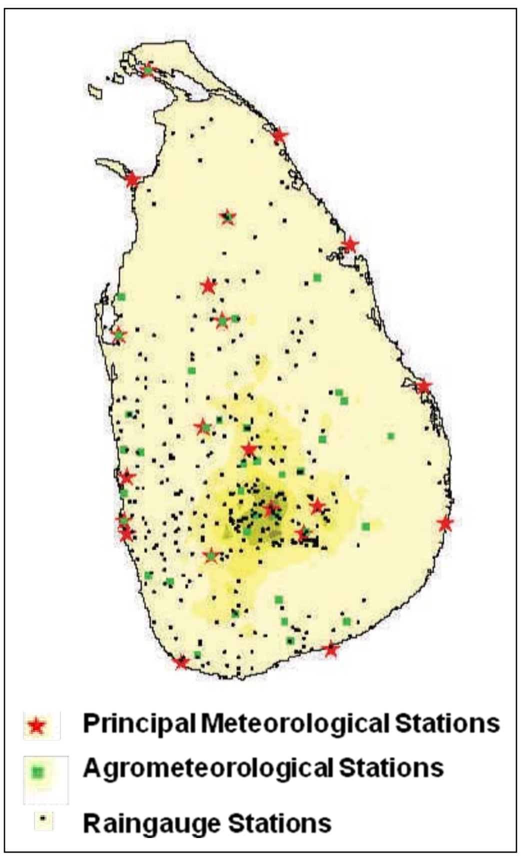


Figure 1. Meteorological, agro-meteorological and rain gauge network in Sri Lanka.

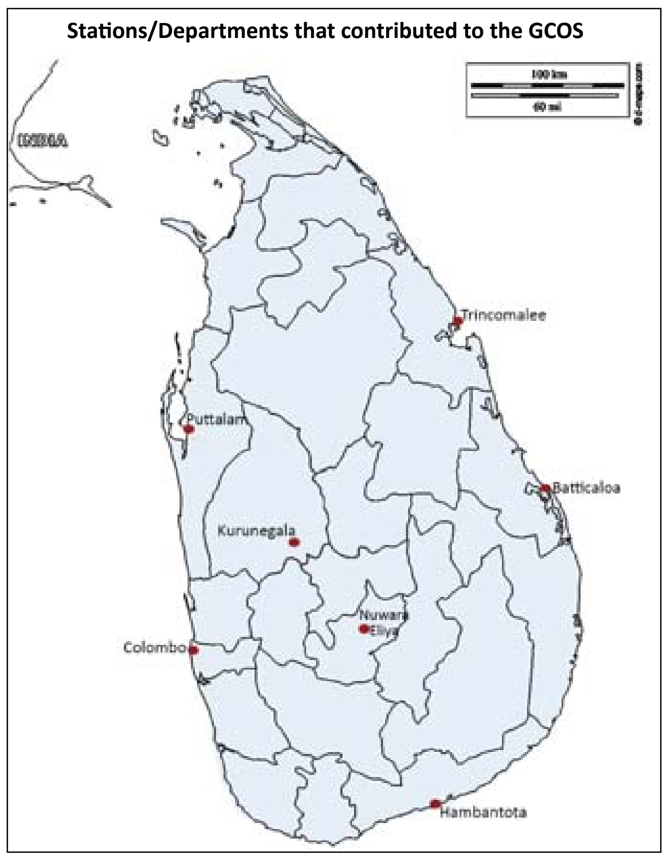


Figure 2. Sri Lanka provides its observation to Global Climatic Observation Network (GCON).

available to continuously measure rainfall (Pluvio graph), atmospheric pressure (Barograph), relative humidity (Hygrograph), temperature (Thermograph) and solar radiation (Actinograph), which provide the information in the form of charts (Figure 3).

2. Rainfall Distribution in Sri Lanka

2.1 Annual rainfall distribution

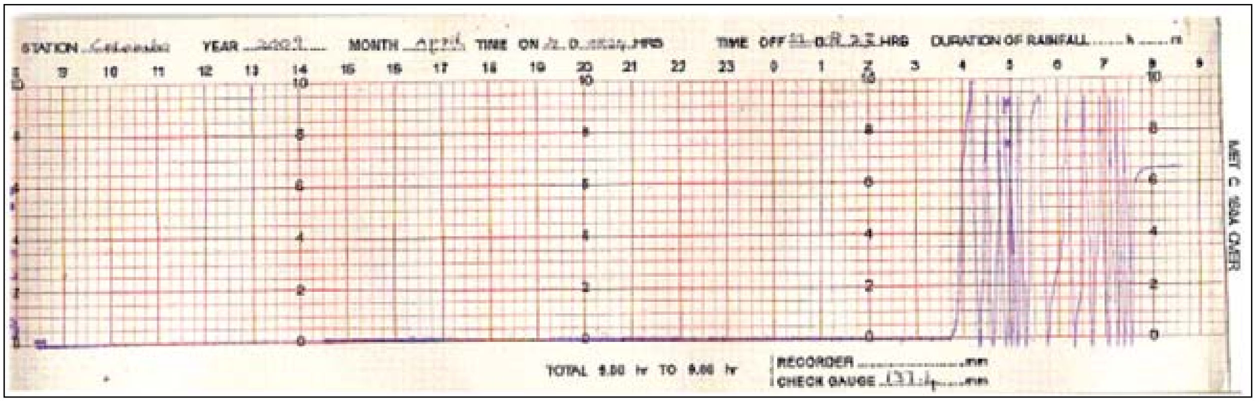
The climate of Sri Lanka can be divided into four seasons, based on four monsoon rainfalls, namely, First Inter-Monsoon (March–April), Southwest Monsoon (May–September), Second Inter-Monsoon (October–November) and Northeast Monsoon (December–February) according to the rainfall pattern. The highest total regional rainfall was received during the Southwest Monsoon and the Second Inter-Monsoon periods. About 60% of the total rainfall is received during these two monsoon periods. The rainfall received during these two periods are crucial for the economy of Sri Lanka, because 40-45% of the power demand of Sri Lanka is generated by hydro power and the reservoirs of the highlands mainly recharge during these two seasons. The lowest rainfall is received during the First Inter-Monsoon. The total annual regional average rainfall in Sri Lanka is 1,861 mm and it is equivalent to 122 km^3 by volume. Agriculture is one of the major income avenues of the people. Almost all consumer needs of rice and vegetable crops are cultivated in Sri Lanka. Based on the annual total rainfall, Sri Lanka can be divided into 3 regions, namely Wet zone (Total Rainfall > 2500), Intermediate zone (Total Rainfall in between 1750 and 2500) and Dry zone (Total Rainfall <1750 (Figure 4). Dry zone is the most vulnerable for the drought conditions.

2.2 Agro-ecological regions in Sri Lanka

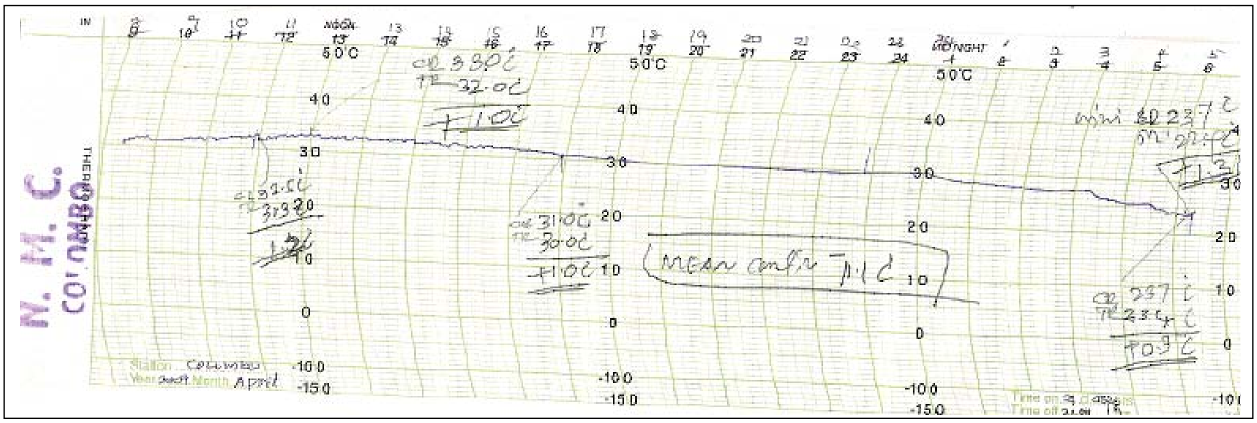
The first map on Agro-ecological Regions was developed by Dr CR Panabokke in 1975. It contained 26 different agro ecological zones in three major climatic zones such as Wet Zone, Intermediate Zone and Dry Zone. Agro-ecological regions of this map were differentiated based on the rainfall, temperature and the soil structure (Figure 5). However, this map was revised in 2003 by a team of scientists at the Natural Resources Management Centre of the Department of Agriculture. The new map has 46 agro-ecological regions identified under the three main climatic zones mentioned above. In each sub zone, distinguishing characteristics such as 75% expectancy value of annual rainfall (mm), terrain, major soil groups and land use patterns were precisely identified (Figure 6).

The Dry Zone occupied the largest extent of farm land and major agricultural area in Sri Lanka. The Intermediate Zone also has agricultural lands, but the Wet Zone is a densely populated area, which has relatively less lands for agricultural purposes (De Silva et al. 2007).

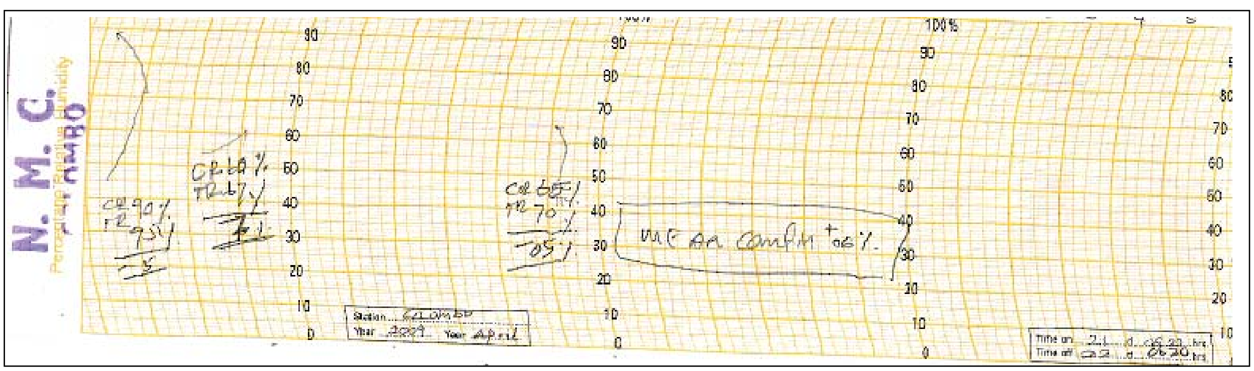
The spatial distribution of annual rainfall in Sri Lanka indicates that a majority of the area receives rainfall of 1000–1500 mm while the other areas receive rainfall of 2000–2500 mm. Western parts and some West to Central parts receive a rainfall of 3000 mm and above. The highest rainfall is received in the central hills in the country. The maximum rainfall is received in Watawala area in the Central part, which gets up to 5500 mm (Figure 7).



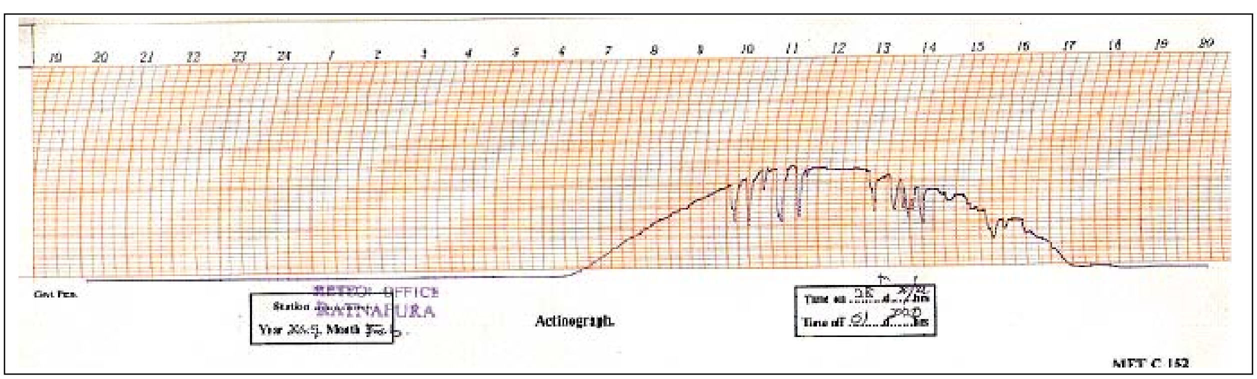
(a) Pluviograph



(b) Thermograph



(c) Hygrograph



(d) Actinograph

Figure 3. Self-recording Instrument Charts.

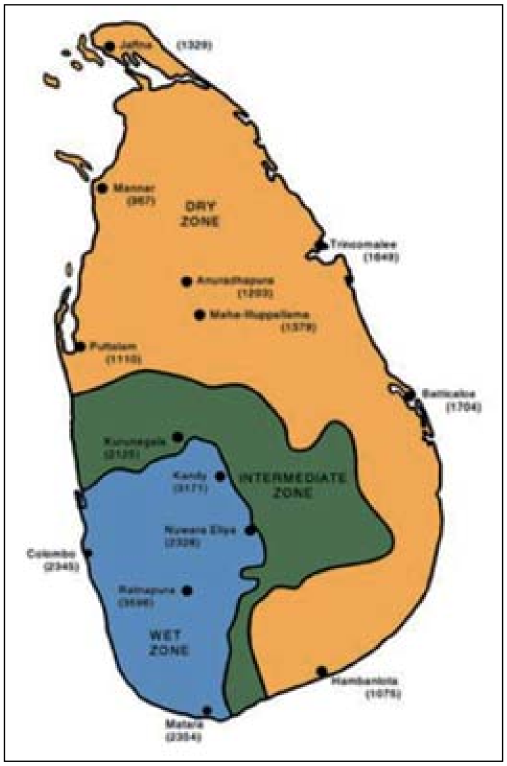


Figure 4. Map of climate zones.

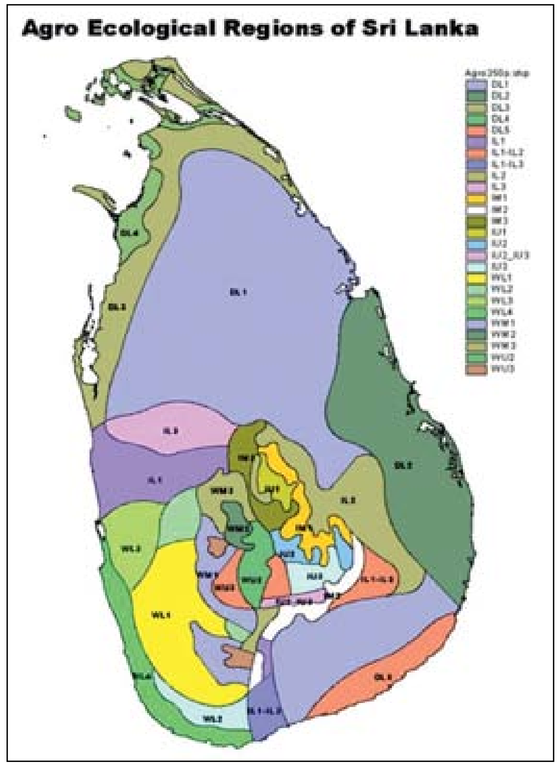


Figure 5. Agro-ecological map developed in 1975.

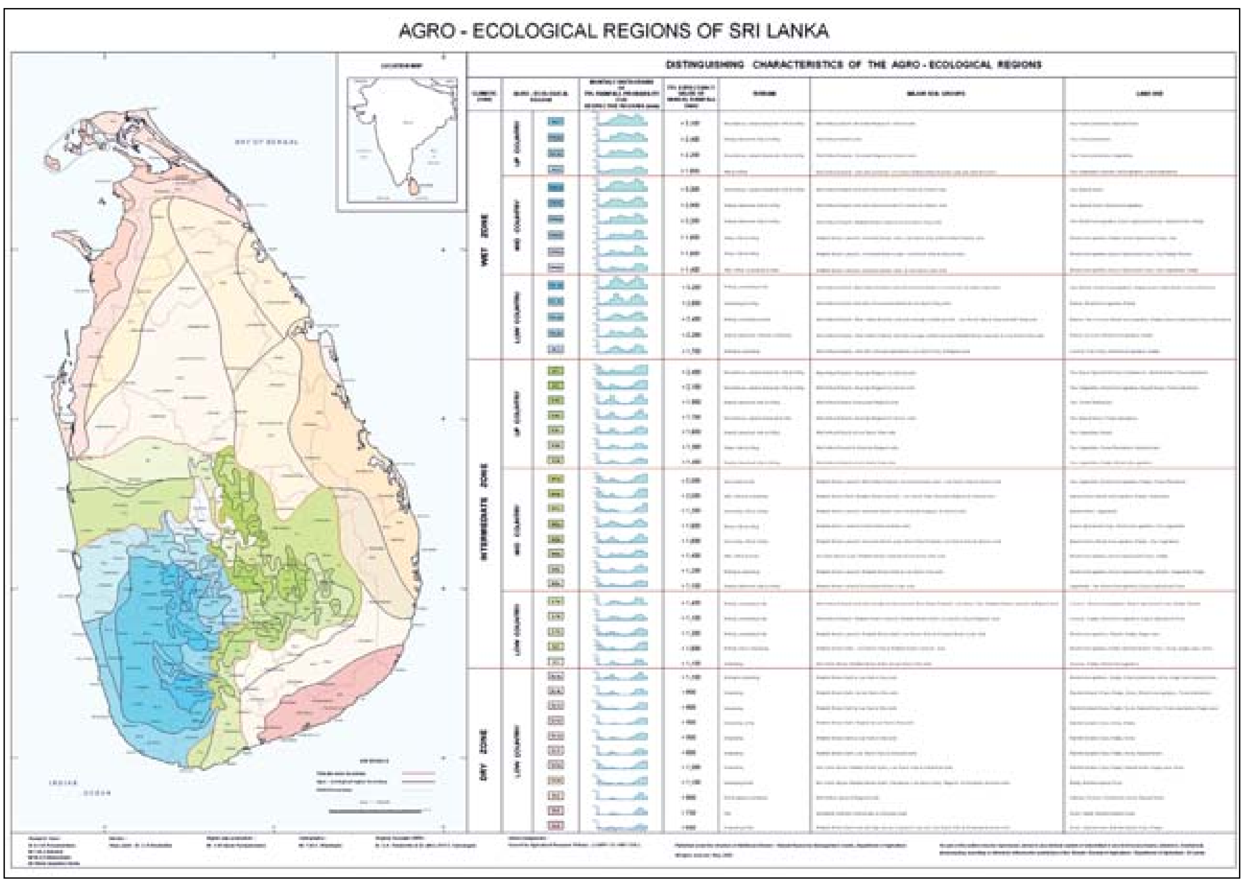


Figure 6. Revised agro-ecological map-2003.

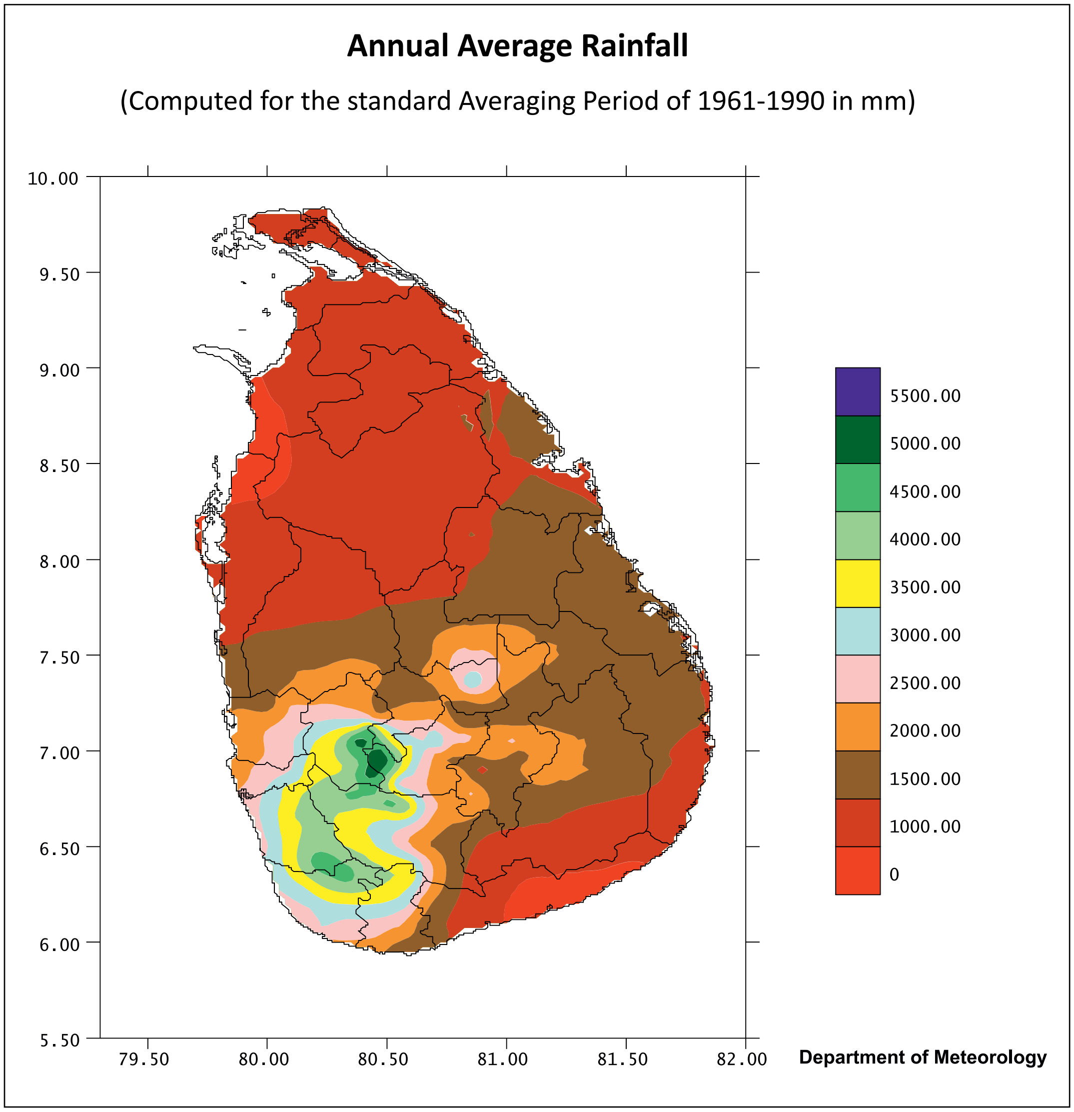


Figure 7. Mean annual rainfall distribution in Sri Lanka.

Monsoon	Months	Season
First Inter Monsoon	**March-April**	*Yala*
Southwest Monsoon	**May-September**	
Second Inter-Monsoon	**October-November**	*Maha*
Northeast Monsoon	**December-February**	

Box 1. Monthly duration and agricultural seasons in Sri Lanka.

2.3 Agricultural seasons

As mentioned earlier, Sri Lanka experiences rainfall from four rainfall seasons, namely First Inter-Monsoon, Southwest Monsoon, Second Inter-Monsoon and Northeast Monsoon. For agricultural activities, these four seasons can be combined into two seasons, namely Yala and Maha. The Yala season is from March to September and includes the First Inter-Monsoon and Southwest Monsoon, while the Maha season is defined from October to February and includes the Second Inter-Monsoon and Northeast Monsoon. Based on the four monsoonal rainfalls, monthly duration and agricultural season in Sri Lanka are shown in Box I. There are important conditions set by the Department of Meteorology to identify the onset of the four different monsoonal rainfalls in Sri Lanka and these conditions are indicated in Box 2.

Box 2. Important Conditions to Identify the Onset of the Four Different Monsoonal Rainfalls in Sri Lanka.

First Inter-Monsoon and Second Inter-Monsoon

- No significant pressure gradient between Colombo to Trincomalee
- A wind along the island is calm.
- Develops afternoon thunder showers in most parts of the island
- Week monsoon wind with easterlies above 1000 feet.
- Formation of mild tropospheric vortices between 700 and 300 hpa levels in the vicinity of Sri Lanka.
- Spitting of the tropical easterly jet at 200 hpa level with one limit lying south of 10^{o} N and the other around 22^{o} N.

Onset of Winter Monsoon (North-East monsoon)

- At least 1.5 hpa pressure gradient across the island (from Colombo to Trincomalee in the Northeasterly direction)
- Tropospheric easterlies descending to the surface.
- Occurrence of rain at least for two consecutive days at Batticaloa, Badulla and Trincomalee
- Appearance of 200 hpa ridge axis around Sri Lanka latitude. (not clear)

Southwest Monsoon (Summer Monsoon)

- At least 2.5 hpa pressure gradient across the island (from Colombo to Trincomalee in the Northeasterly direction)
- Extending of Southwesterly winds from surface to at least 18,000 feet.
- Formation of surface low or tropospheric vortices in the vicinity of the island or southwest Bay of Bengal.
- Occurrence of rainfall on at least two consecutive days at Galle, Colombo, Ratnapura and Nuwara Eliya in the Southwest quarter of the island.
- Occurs about 5-10 days after the first appearance of tropical easterly jet (over 40 kts) around Sri Lanka latitude.

Source: Department of Meteorology, 2010.

2.3.1 First Inter-Monsoon season

Rainfall is received due to local convection process during the First and Second Inter-Monsoons. The average rainfall for Sri Lanka is 260 mm during the First Inter-Monsoon period. Most rainfall is confined to the southwest region of Sri Lanka during this period. The highest rainfall for this period is more than 500 mm along the western slopes of Sri Lanka, while the lowest rainfall is less than 100 mm along the northern and eastern parts of Sri Lanka. The First Inter-Monsoon occurs during the months of March and April (Figure 8).

2.3.2 Southwest Monsoon season

A wind blows from the southwest of Sri Lanka during the Southwest monsoon period and more rainfall is received along the western and southwestern parts of Sri Lanka than in other parts of the country. The average rainfall over Sri Lanka is 546 mm and it varies from 100 mm to more than 3000 mm along the western slopes of the Central hills. The lowest rainfall received is less than 100 mm along the southeastern and northwestern parts of Sri Lanka (Figure 9).

2.3.3 Second Inter-Monsoon season

The amount of rainfall is higher during the Second Inter-Monsoon period than the First Inter-Monsoon because a low pressure area develops in the Bay of Bengal during this period and it brings much rainfall for Sri Lanka. The average rainfall over the southwestern slopes in the Central hills varies between 750-1200 mm during this period. The lowest rainfall is received along the southeastern coast and the northwestern coast (Figure 10).

2.3.4 Northeast Monsoon season

A wind blowing from the northeast of Sri Lanka during the Northeast monsoon period and more rainfall is received along the eastern and northeastern slopes of Central hills of Sri Lanka. The average rainfall over Sri Lanka is 459 mm and the maximum rainfall received is about 1400 mm along the eastern slopes of Central hills (Figure 11).

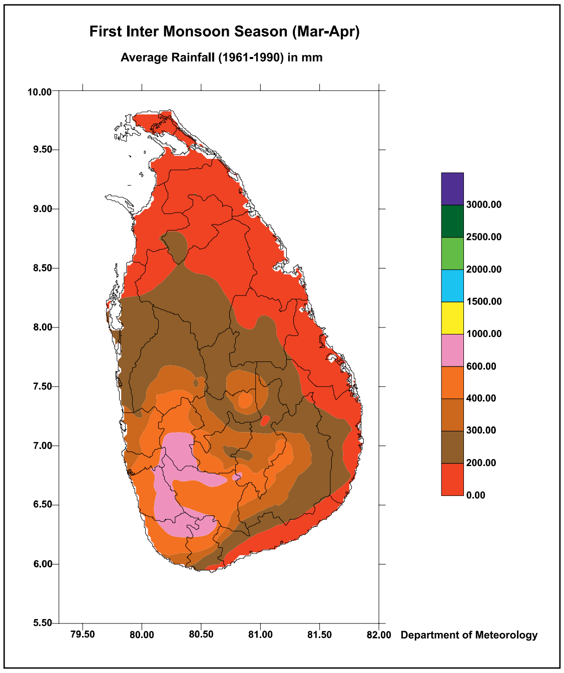


Figure 8. Rainfall distribution in First Inter-Monsoon season of Sri Lanka.

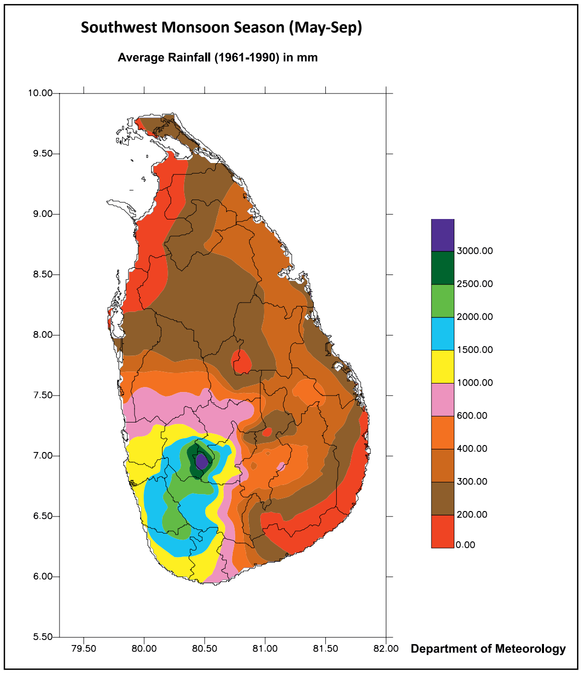


Figure 9. Rainfall distribution in Southwest Monsoon season of Sri Lanka.

2.4 Annual average number of rainy days

The annual average number of rainy days in the Dry Zone is generally around 100 days. In some parts of Hambantota and Puttalam Districts in the Dry Zone, the number of rainy days even goes below 60. The number of rainy days in the Intermediate Zone ranges from 100 to 180, while it is around 180 or above in the Wet Zone districts of Sri Lanka (Figure 12).

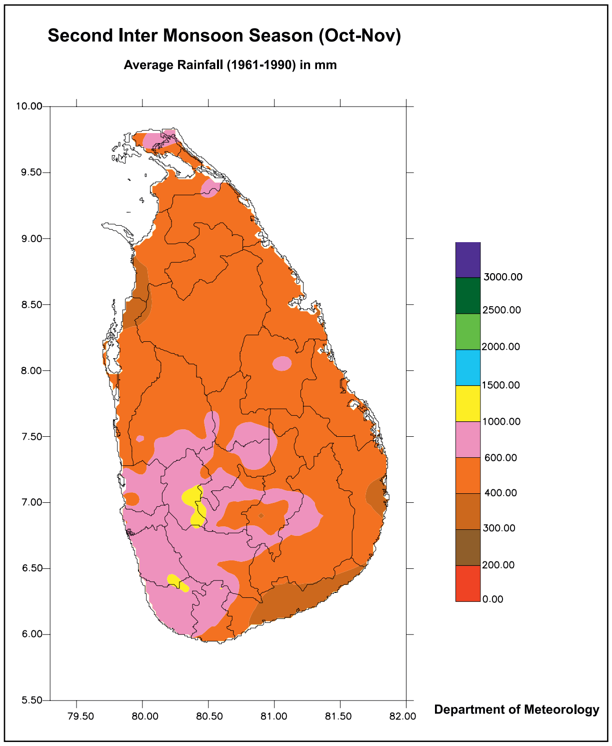


Figure 10. Rainfall distribution in Second Inter-Monsoon season of Sri Lanka.

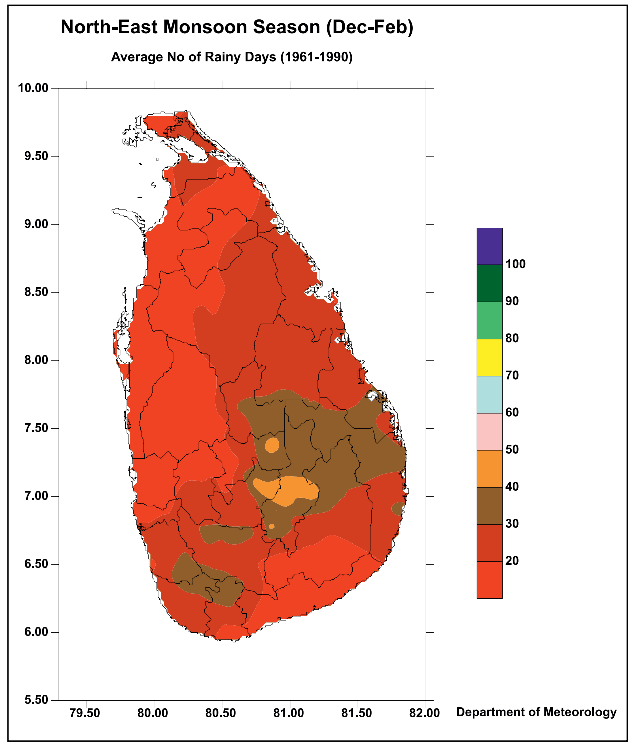


Figure 11. Rainfall distribution in Northeast Monsoon season of Sri Lanka.

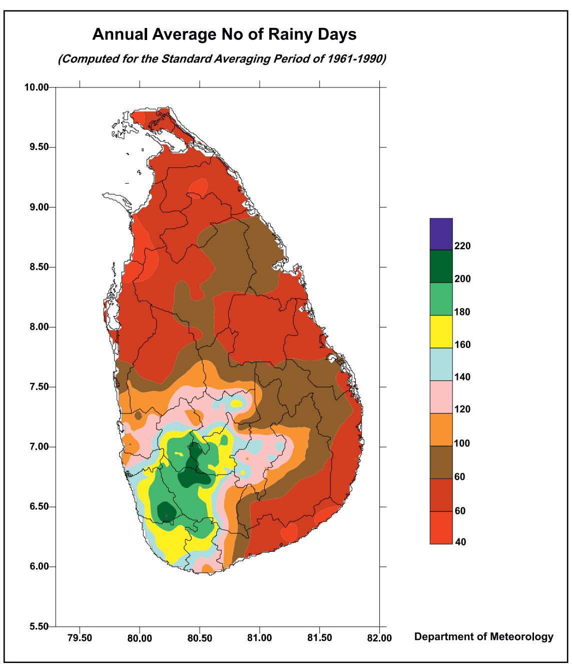


Figure 12. Distribution of annual average number of rainy days in Sri Lanka.

2.4.1 Normal dates for onset of monsoons

The Department of Meteorology has documented the days of onset of monsoon for four monsoon seasons from 1946 to 2009 based on the criteria set by the Department to identify the monsoon onset days. Accordingly, onset days for the first inter-monsoon most often take place in the month of March, while the onset days for the Southwest Monsoon generally take place in the month of May. Similarly, onset days for the Second Inter-Monsoon generally take place in the month of October, while the onset days for the Northeast monsoon take place in the month of December (Table 1).

Table 1. Normal dates for onset of monsoons over Sri Lanka.

	Monsoon onset dates			
Year	1st Inter Monsoon	SW Monsoon	2nd Inter Monsoon	NE Monsoon
1946	3rd Week March	9-May	2nd week Oct	14th week Dec
1947	March	May	Last week Oct	Last week Nov
1948	April	End of April	*	Dec
1949	*	June	End of Oct	Nov
1950	March	16-May	20-Sep	22-Nov
1951	April	May	End of Oct	17-Dec
1952	End March	2nd half May	25-Sep	Dec
1953	1st half February	May	Oct	13-Nov
1954	4th Week February	May	3rd week Oct	Mid Nov
1955	13-Mar	21-May	8-Nov	3rd week Dec
1956	*	May	*	*
1957	March	18-May	11-Oct	Nov
1958	*	9-May	*	*
1959	*	17-May	*	*
1960	*	1st Week May	*	*
1961	*	7-May	10-Oct	*
1962	*	12-May	*	*
1963	*	20-May	10-Oct	*
1964	3-Mar	20-May	2nd week Oct	25-Nov
1965	2-Mar	20-May	1st half Oct	16-Dec
1966	April	5-Jun	2nd half Oct	1st week Dec
1967	March	13-May	Oct	Nov
1968	*	*	*	*
1969	April	7-May	24-Sep	*
1970	April	1st Week June	*	7-Nov
1971	March	15-May	Nov	17-Nov
1972	*	16-May	21-Sep	*
1973	*	27-May	*	*
1974	3-Mar	22-May	25-Oct	Dec

Continued

Table 1. Normal dates for onset of monsoons over Sri Lanka *continued.*

	Monsoon onset dates			
Year	1st inter Monsoon	SW Monsoon	2nd Inter Monsoon	NE Monsoon
1975	*	26-May	*	*
1976	*	27-May	28-Sep	*
1977	*	28-May	14-Sep	*
1978	*	26-May	6-Oct	*
1979	*	12-May	*	*
1980	*	26-May	1st half sep	*
1981	*	*	*	*
1982	*	27-May	End of Sep	*
1983	*	24-May	7-Oct	*
1984	*	27-May	18-Oct	*
1985	*	22-May	*	*
1986	*	16-May	*	*
1987	*	28-May	*	*
1988	*	27-May	*	*
1989	2-Mar	24-May	End Sep	Nov
1990	*	24-May	9-Oct	30-Nov
1991	*	30-May	*	*
1992	*	16-May	30-Sep	27-Nov
1993	*	25/26 - May	16-Oct	24-Nov
1994	*	28-May	8-Oct	28-Nov
1995	*	7-Jun	17-Oct	4-Dec
1996	*	12-Jun	8-Oct	18-Dec
1997	*	10-Jun	9-Oct	3-Dec
1998	*	19-May	*	Mid Dec
1999	*	21-May	*	Mid Dec
2000	29-Mar	27-May	*	8-Dec
2001	5-Mar	28-May	*	10-Dec
2002	16-Mar	30-May	*	9-Dec
2003	17-Mar	13-May	*	15-Dec
2004	*	19-May	16-Oct	22-Nov
2005	21-Mar	29-May	3-Oct	13-Dec
2006	17-Mar	20-May	13-Oct	24-Nov
2007	*	8-Jun	10-Oct	5-Dec
2008	23-Mar	1-Jun	5-Oct	16-Dec
2009	*	22-May	*	21-Dec

Source: Department of Meteorology, 2010.

3. Distribution of Maximum and Minimum Temperature

The analysis of average temperature (average of both the maximum and minimum) shows a significant trend during the past few decades. The average trend is 0.2°C (Figure 13) per decade for the period 1951-2006, but it is 0.3°C (3°C per century) for the period 1981-2006 (Figure 14). The Fourth Assessment Report of IPCC (IPCC AR4, 2007) also stated that the increasing trends have been observed across the seven sub regions of Asia. The observed increases in some parts of Asia during recent decades ranged between less than 1°C to 3°C per century. By considering the periods 1951-2006 and 1981–2006, it is clear that the increasing trend is higher in the recent past than the preceding few decades (Premalal 2010).

The trends of temperatures do not show similar behavior when considering the individual stations. The increasing trend of minimum temperature is high in the highlands and it shows 0.02°C per decade, but the trend of maximum temperature is high in the coastal areas (Figure 15).

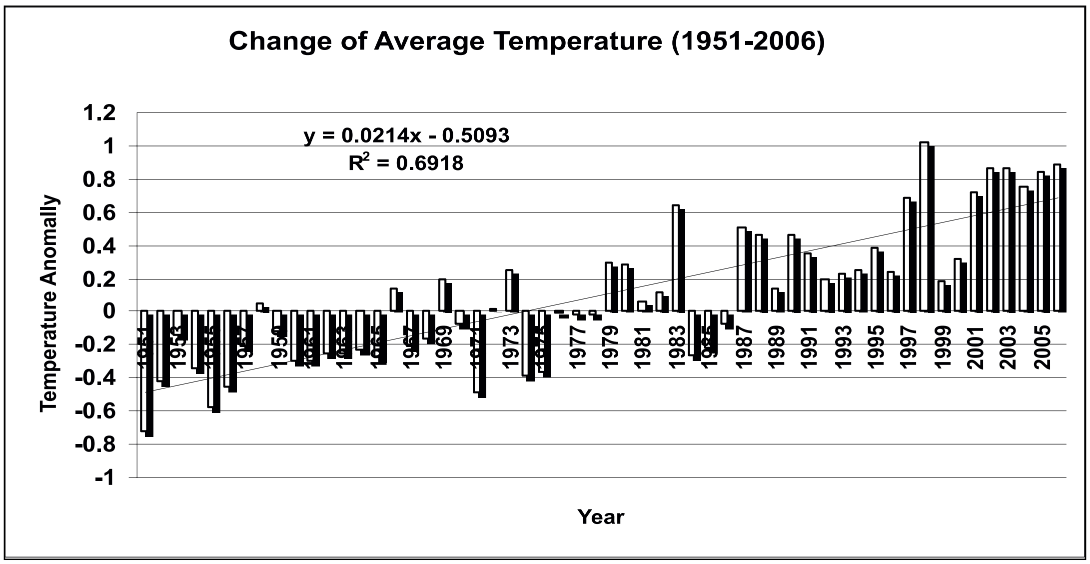


Figure 13. Change of temperature anomaly, 1951–2006.

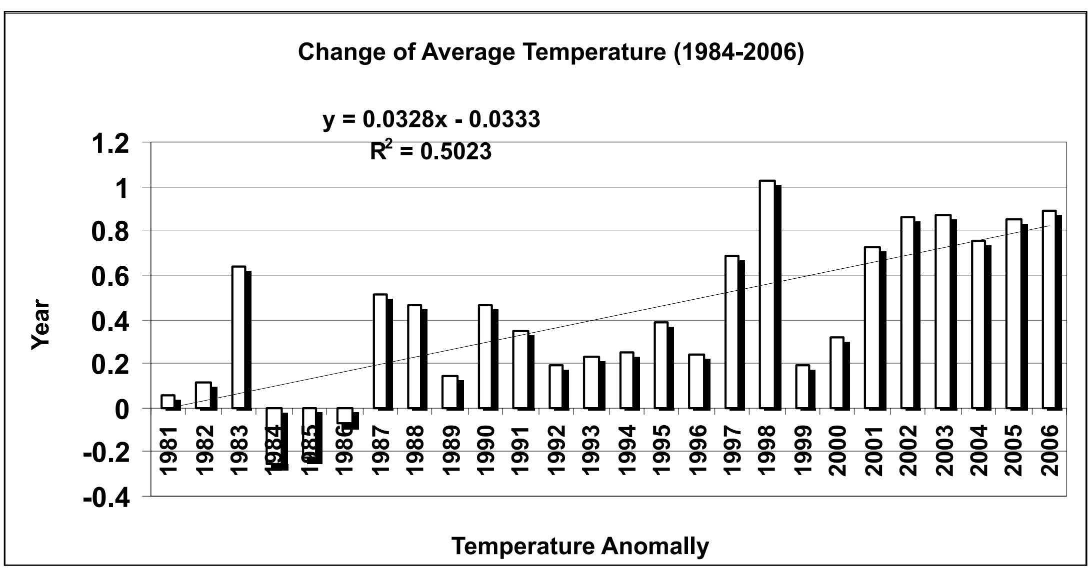


Figure 14. Change of temperature anomaly, 1981–2006.

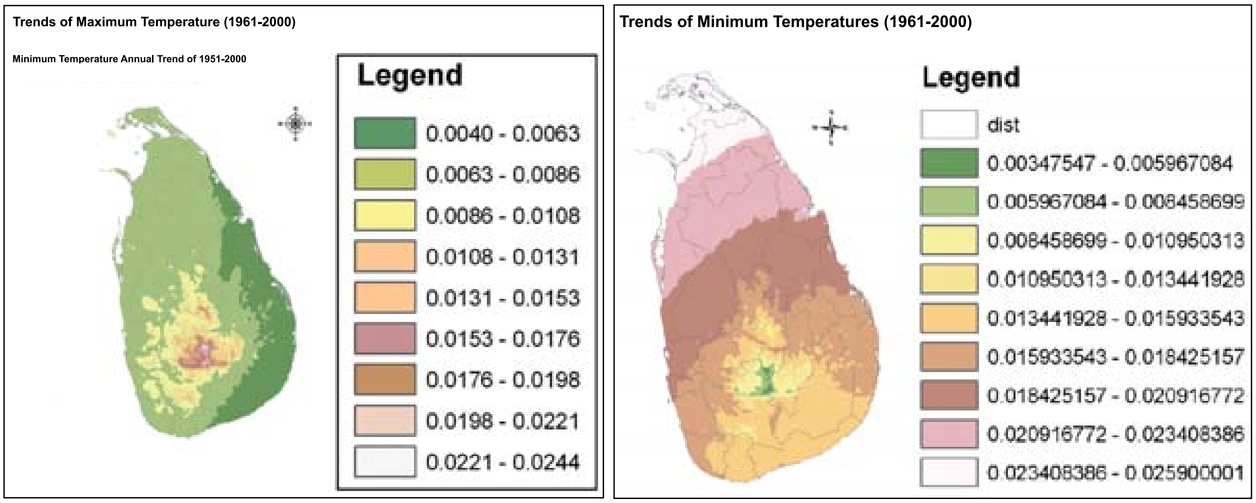


Figure 15. Trends of maximum and minimum temperatures (1961-2000).

Impact of High Temperatures on Agriculture

Kropff et al. (1993) pointed out that rice yields decrease 9% for each 1°C increase in seasonal average temperature. Also high temperatures adversely affect the highland vegetable cultivation. Climate change analysis indicates that the Diurnal Temperature Range (DTR) (difference between day maximum and night minimum) is decreasing in Nuwara Eliya in Sri Lanka. Therefore, it is obvious that higher temperatures have real impact on the agriculture field and will escalate the world food crisis.

Change of Rainfall

Time series analysis from 1951-2008 has shown a decreasing trend of rainfall in every district (Premalal 2010). A decreasing trend of rainfall pattern that continues will have an adverse impact on the agriculture, water resource, energy sector and health sector. In addition to the decreasing rainfall, the following changes have also been established in Sri Lanka.

- Variability of rainfall pattern (Dry zone is very vulnerable due to high rainfall variability)
- Increasing trend of consecutive dry days in most places of the Dry Zone
- High rainfall events in wet zone, especially in the western slopes of Central hills

Agriculture of any kind is strongly influenced by the availability of water. Climate change will modify rainfall, evaporation, runoff and soil moisture storage. Changes in total seasonal precipitation or in its pattern of variability are both important. Recent analysis of rainfall variability pointed out that it has increased everywhere and the variability is high in the dry zone (Premalal 2010). The high variability of rainfall explains the erratic rainfall pattern and also more flood and more droughts. The occurrence of moisture stress during flowering, pollination and grain-filling is harmful to most crops. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress; as a result, there will be a need to develop crop varieties with greater drought tolerance.

4. Methods

4.1 Area of study

Two study sites were selected from the Dry Zone to study the vulnerability to climatic change in Sri Lanka. The two study sites selected were Angunakolapellessa in Hambantota District and Eluwankulama in Puttalam District. The detailed description and data availability of the study areas are listed in Table 2. In each site, one or two Grama Niladhari (GN) Divisions have been selected for detailed study. In Angunakolapellessa Divisional Secretariat, the two GN Divisions selected were Bata-Ata South and Sooriyapokuna, whereas in Eluwankulama, Bandaranayakepura and Mangalapura GN Divisions were selected.

4.2 Sampling design

Stratified sampling technique is employed in selecting the study areas. The main thrust of this study was to assess vulnerability to climatic change in the semi-arid tropics, which is mainly found in the Dry Zone of Sri Lanka in Hambantota and Puttalam Districts. This was the first stage of this sampling. The second stage was the choosing of an agro-meteorological station. Angunakolapellessa was selected to represent Hambantota district and Eluwankulama was selected to represent Puttalam District. The third stage was the selection of the Divisional Secretariat in a district. Ambalantota and Angunakolapellessa Divisional Secretariat in Hambantota District and Eluwankulama Divisional Secretariat in Puttalam District were selected based on the rainfed nature of agriculture. Two Grama Niladhari Divisions (Bata-Ata South in Ambalantota DS and Sooriyapokuna in Hambantota District were selected. Similarly, Bandaranayakepura and Mangalapura Grama Niladhari Divisions in Puttalam District were selected to capture the variability in the district. The villages selected were Bata-Ata South in Bata-Ata Grama Niladhari Division, Sooriyapokuna in Sooriyapokuna Grama Niladhari Division in Hambantota District and Bandaranayakepura and Katu-Puliyankulama in Bandaranayakepura Grama Niladhari Division and Mangalapura in Mangalapura Grama Niladhari Division in Puttalam District.

4.3 Sources of data

The main source of climatic data was the Department of Meteorology in Colombo, Sri Lanka followed by Natural Resources Management Centre (NRMC) of the Department of Agriculture. Soil parameters such as water holding capacity and bulk density were obtained from Dry Zone research institutes such as Field Crops Research and Development Institute (FCRDI) at Mahailluppallama, and Angunakolapellessa.

4.4 Data collection

Daily data for all possible weather parameters from 1976 to 2008 were gathered from the Department of Meteorology in Colombo and some data were obtained from the Natural Resources Management Centre (NRMC) of the Department of Agriculture.

4.5 Data analysis

Annual and monthly average rainfall data for the period 1976-2008 were graphed and presented. Data for temperature and other parameters were also gathered and presented. Interpretation of results was based on these graphs. Agro-met analysis was performed using a designed software called Weather Cock provided by ICRISAT. Interpretations of results were done using the results sheets obtained from the Weather Cock. Qualitative information gathered was also utilized to explain the results.

Table 2. Details of the study sites.

Agro - ecological regions	District	Annual rainfall (mm)	Area under irrigation (%)	Terrain	Major soil groups	Land use	Data type and availability	Period (years)	Selected agro meteorological station
DL1b	Hambantota	>900	9.6	Undulating	Reddish brown earth and low humic gley soils	Rainfed upland crops, paddy, scrub, mixed home gardens, forest planta-tions	Rainfall	1975-2008	Angunakola-pellessa
							Temperature-Min. Max.	1975-2008	
							Humidity	1975-2008	
							Pan Evaporation	1975-2008	
							Sunshine hours	1975-2008	
							Wind speed	1975-2008	
							Soil Temperature (5/10cm)	1975-2008	
DL3	Puttalam	>800	5.5	Flat and slightly cudulating	Red yellow latosol and regosol soils	Cashew, coconut, condiments, scrub, natural forest	Rainfall	1975-2008	Eluwankulama
							Temperature-Min. Max.	1975-2008	
							Humidity	1975-2008	
							Pan Evaporation	1975-2008	
							Sunshine hours	1975-2008	
							Wind speed	1975-2008	
							Soil Temperature (5/10cm)	1975-2008	
DL1b	Anuradha-pura	>900		Undulating	Reddish brown earth & low humic gley soils	Rainfed upland crops, paddy, scrub, mixed home garden, forest planta-tions	Rainfall	1975-2008	Vavuniya
							Temperature-Min., Max.	1975-2008	
							Humidity	1975-2008	
							Pan Evaporation	1975-2008	
							Sunshine hours	1975-2008	
							Wind speed	1975-2008	
							Soil Temperature (5/10cm)	1975-2008	

5. Climatic Trends and Agro-climatic Analysis

5.1 Climatic trends and agro-climatic analysis of study districts

Three districts were selected for this study from the Dry Zone in Sri Lanka, namely Puttalam, Hambantota and Anuradhapura. Climate and climate change analysis have been done for these three districts. For agro-climatic analysis, Eluwankulama and Angunakolapelessa agromet station data were used from Puttalam and Hambantota districts, respectively. One of the major aims for this study is to map vulnerability of agriculture and the people living in these villages to climate change. Basic climatic trends have been studied for these districts and special attention given to climate extremes as consecutive dry days, consecutive wet days, maximum and minimum temperature, cold days, cold nights, warm days, warm nights, and diurnal temperature range.

According to the Inter-Governmental Panel on Climate Change, hot days, hot nights and heat waves have become more frequent (IPCC 2007). Also, it says that heat waves are associated with marked short-term human mortality. According to the recent analysis of climate data, it is found that climate extremes are established over Sri Lanka and continuous dry days, continuous wet days, cold days, cold nights, warm days, warm nights and diurnal temperature change are some of the climate extremes. Summary of temperature indices in Sri Lanka is given in Table 3.

Table 3. Summary of temperature indices (Sri Lanka).

Indices	Puttalam	Colombo	Hambantota	Ratnapura	Apura	Badulla	Nuwaraeliya
txx	0.021	0.024	0.004	-0.01	0.061	0.072	0
tnn	0.054	0.05	0.029	0.06	0.061	0.04	0.064
txn	0.029	0.004	0.025	-0.009	0.03	0.046	0.027
tnx	0.027	0.02	0.004	0.003	0.013	0.046	0.008
tx10p	-0.225	-0.284	-0.267	0.138	-0.364	-0.353	-0.045
tx90p	0.448	0.251	0.377	-0.184	0.524	0.809	-0.01
tn10p	-0.339	-0.321	-0.187	-0.234	-0.516	-0.178	-0.292
tn90p	0.642	0.498	0.338	0.212	0.369	0.348	0.387
wsdi	0.6	0.329	0.459	-0.176	0.4	1.055	0.113
csdi	-0.001	-0.061	-0.061	-0.156	-0.464	-0.129	-0.062
dtr	-0.006	-0.013	0.009	-0.031	0.061	0.029	-0.025

5.2 Climatic behavior in Puttalam District

Climatological behavior (1961-1990) of maximum, minimum temperatures, rainfall and Diurnal Temperature Range is shown in Figure 16. In Puttalam, highest maximum temperature was reported in the months of March and April. Behavior of minimum temperature is different from maximum temperature and the highest minimum temperature occurs during May to July. Rainfall pattern is bi-model as in Anuradhapura and Hambantota. The total average annual rainfall at Puttalam is 1198 mm. There are also two peaks of rainfall in April and October during the First Inter-Monsoon and Second Inter-Monsoon in Puttalam. After receiving high rainfall during the Second Inter-Monsoon, the rainy condition prevails until the early part of the Northeast monsoon. Higher Diurnal Temperature Range (DTR) values were recorded during January, February and March. The DTR values are almost similar to that of Anuradhapura. Even though the climatological behavior at Puttalam is indicated above, following are the changes and variability identified by long term analysis.

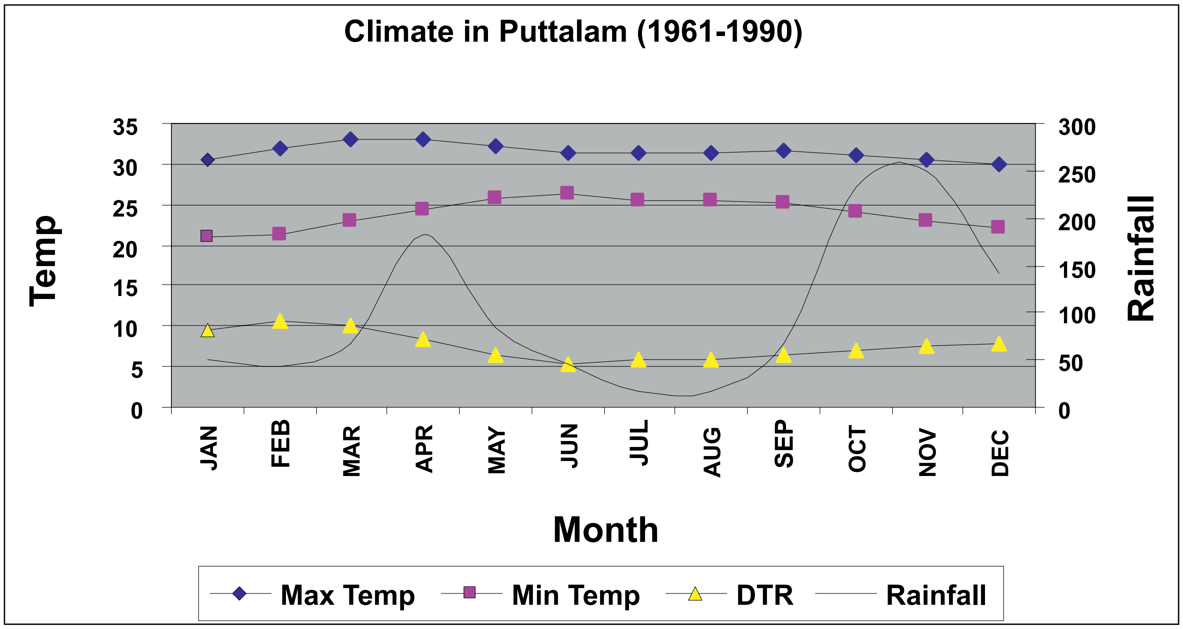


Figure 16. Averages of rainfall, maximum temperature, minimum temperature and diurnal temperature range

5.2.1 Change of temperature at Puttalam District

Figures 17 (a) and (b) show the annual average minimum temperatures during different seasons. Minimum temperature does not show any trend during the period 1961-1990, but Figure 17 (b) shows a sudden increase after 1990. Figure 18 (a), (b) and (c) show the annual average maximum temperatures during three different periods.

Even though the minimum temperature has not been increased during the period 1961-1990, maximum temperature has increased by 0.0331 Celsius/year. Analysis of Minimum temperature during 1990-2007 shows a decreasing trend.

5.2.2 Change of rainfall pattern at Puttalam District

Total annual rainfall distribution in Puttalam Meteorological station during three different periods is shown in Figures 19 (a), (b) and (c). It indicated the slight decreasing linear trend. But the polynomial trend shows a slight increasing trend after 1994. Even though the long term trend shows a decreasing trend, the short term trend does not show a similar behavior.

Change of Diurnal Temperature Range (DTR) is shown in Figure 20. It indicated that there is no long term trend, but it shows a decreasing trend at present.

Extreme climatic Indices established in Puttalam area are as follows.

All extreme indices show a long term increasing trend, but recently it is showing a decreasing trend.

- Maximum of minimum temperature has been increased (Figure 21)
- Maximum of maximum temperature has been increased (Figure 22)
- Number of warm days (Percentage of days when Maximum (TX) >90th percentile) have been increased (Figure 23)
- Number of warm nights (Percentage of days when Minimum (TX) >90th percentile) have been increased (Figure 24).

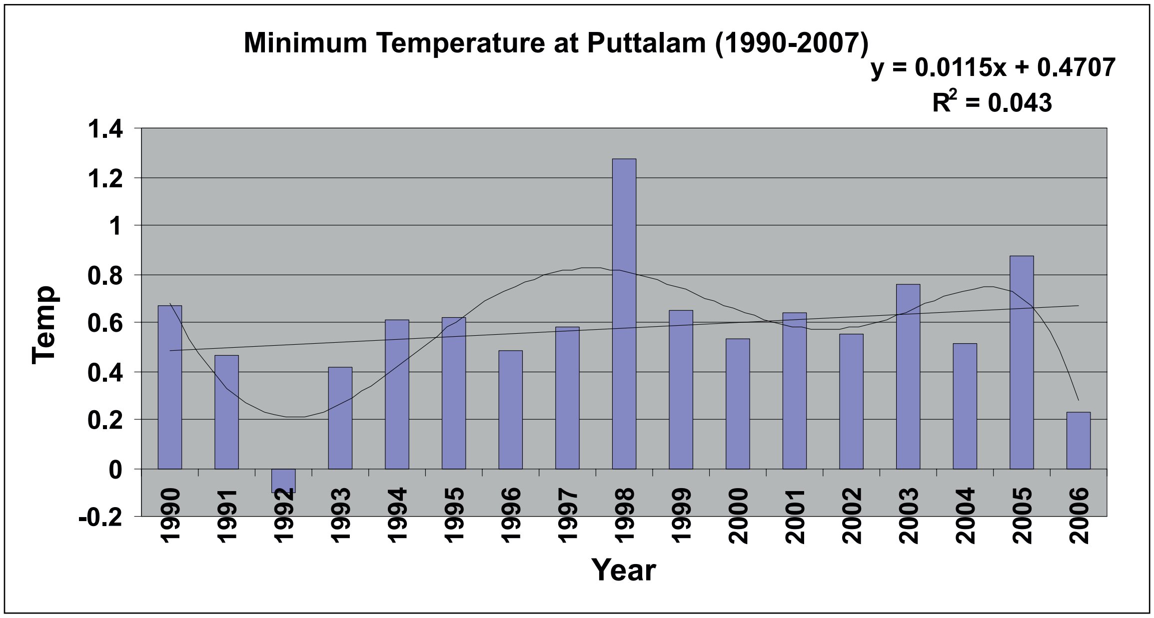


Figure 17(a). Minimum temperature anomaly trend for 1961-1990 (Base period 1961-1990).

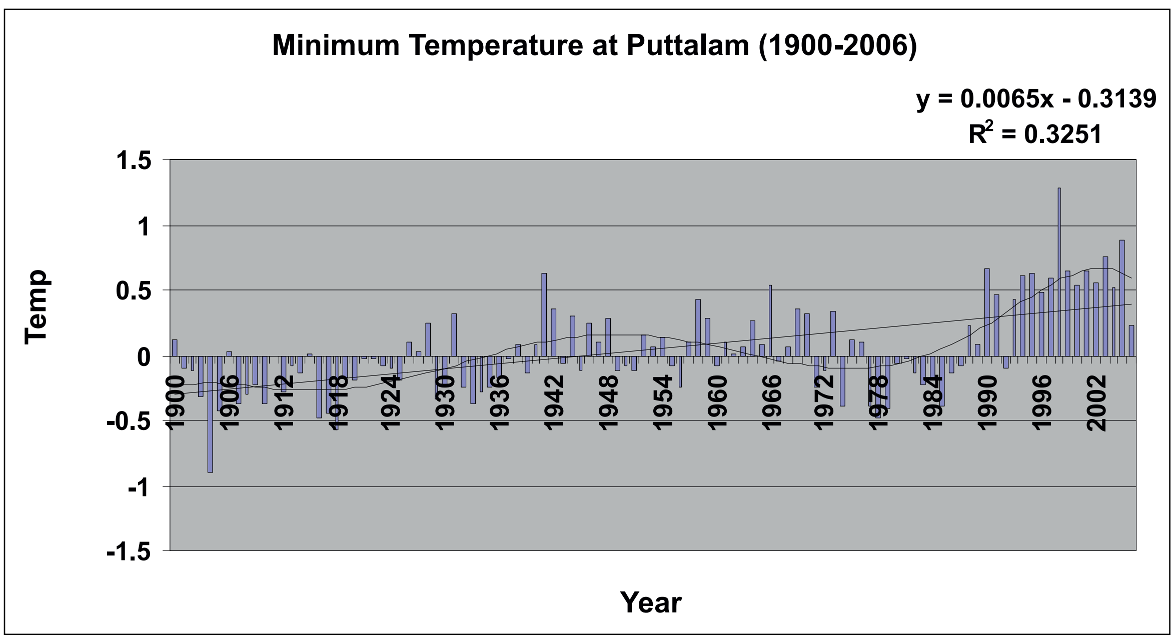


Figure 17(b). Minimum temperature anomaly trend for 1900-2007 (Base period 1961-1990).

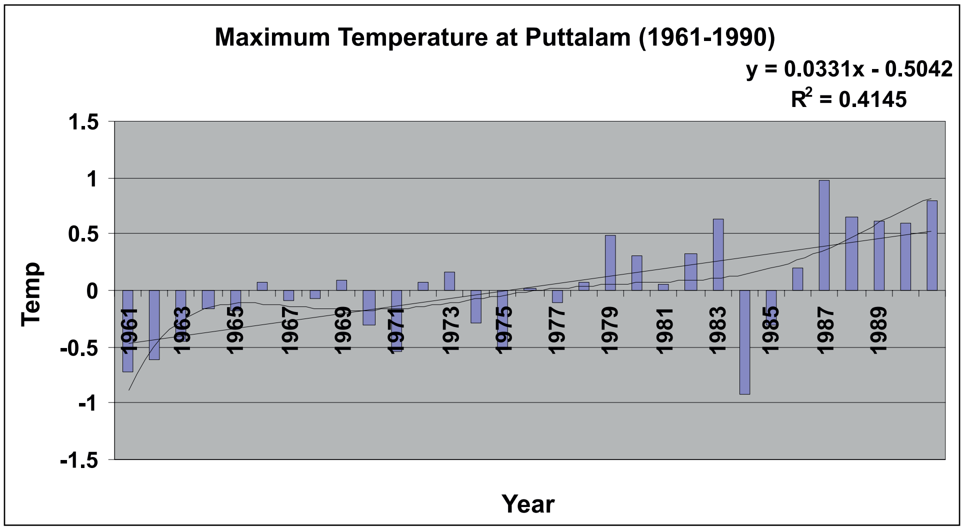


Figure 18(a). Maximum temperature anomaly trend for 1961-1990 (Base period 1961-1990).

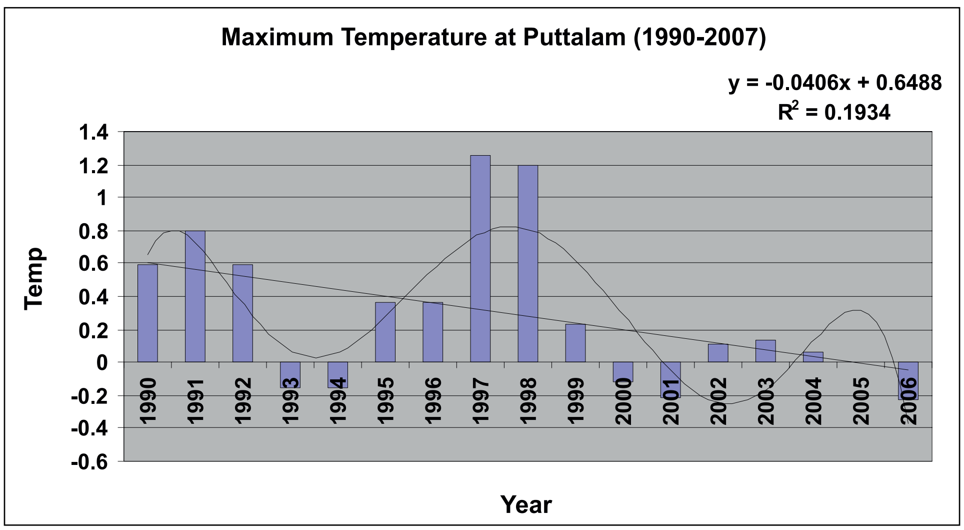


Figure 18(b). Maximum temperature anomaly trend for 1961-2007 (Base period 1961-1990).

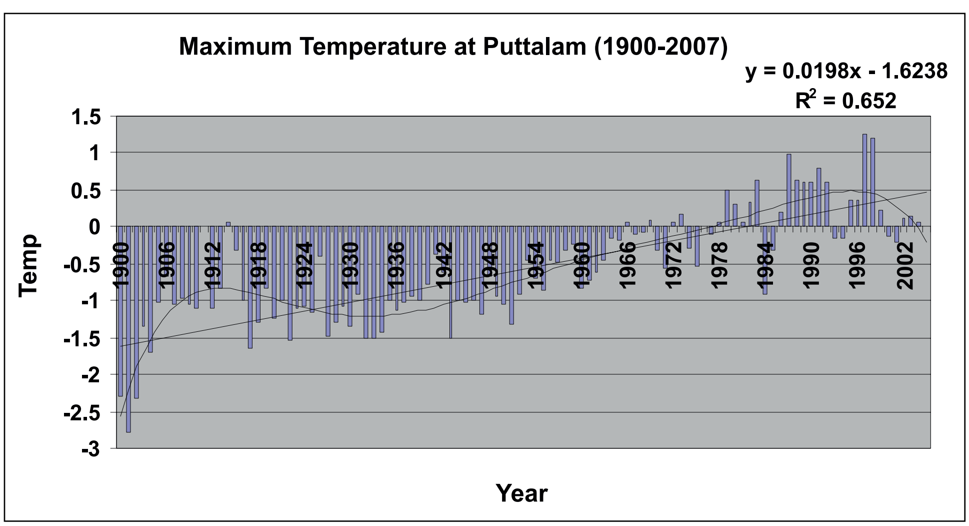


Figure 18(c). Maximum temperature anomaly trend for 1900-2007 (Base period 1961-1990).

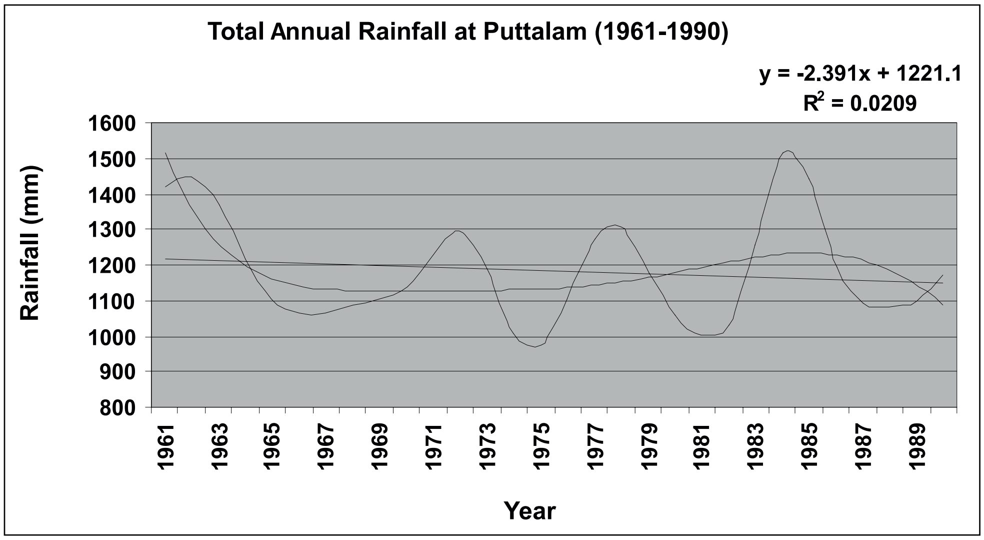


Figure 19(a). Total annual rainfall in Puttalam (1961-1990).

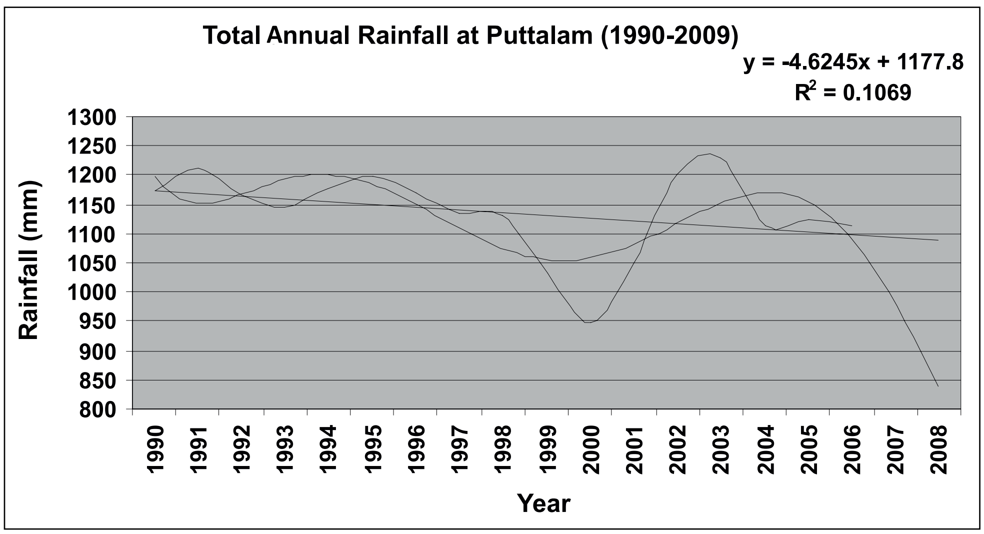


Figure 19(b). Total annual rainfall in Puttalam (1990 – 2008).

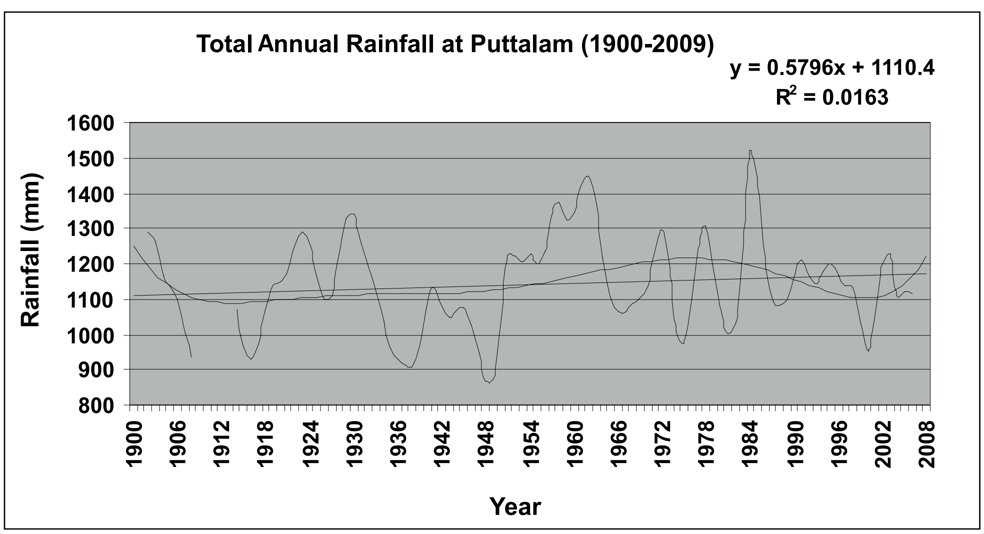


Figure 19(c). Total annual rainfall in Puttalam (1900-2008).

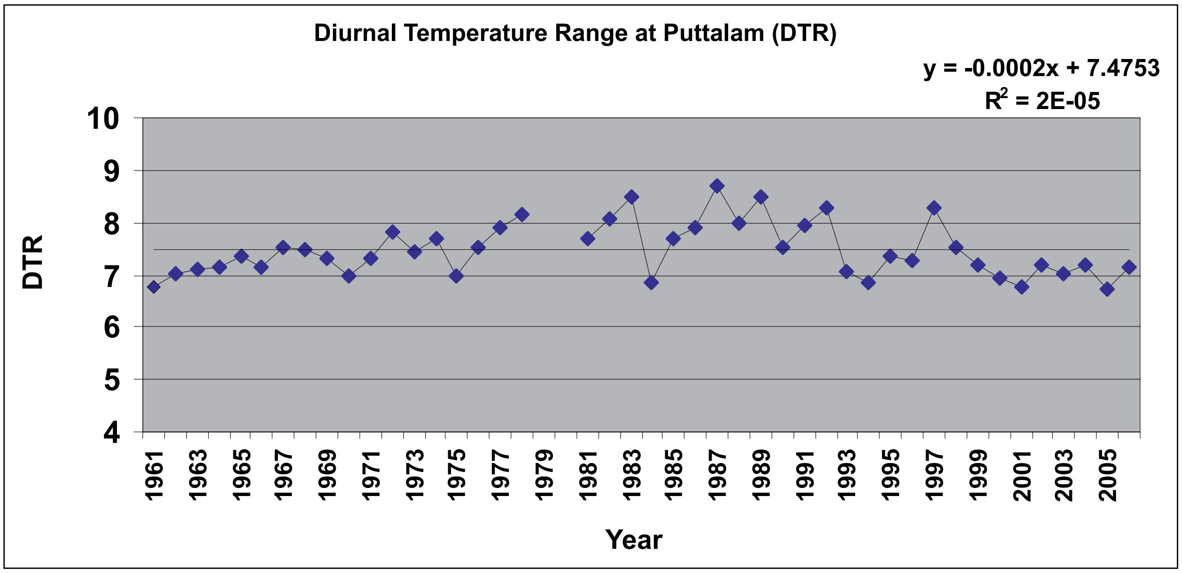


Figure 20. Diurnal temperature range.

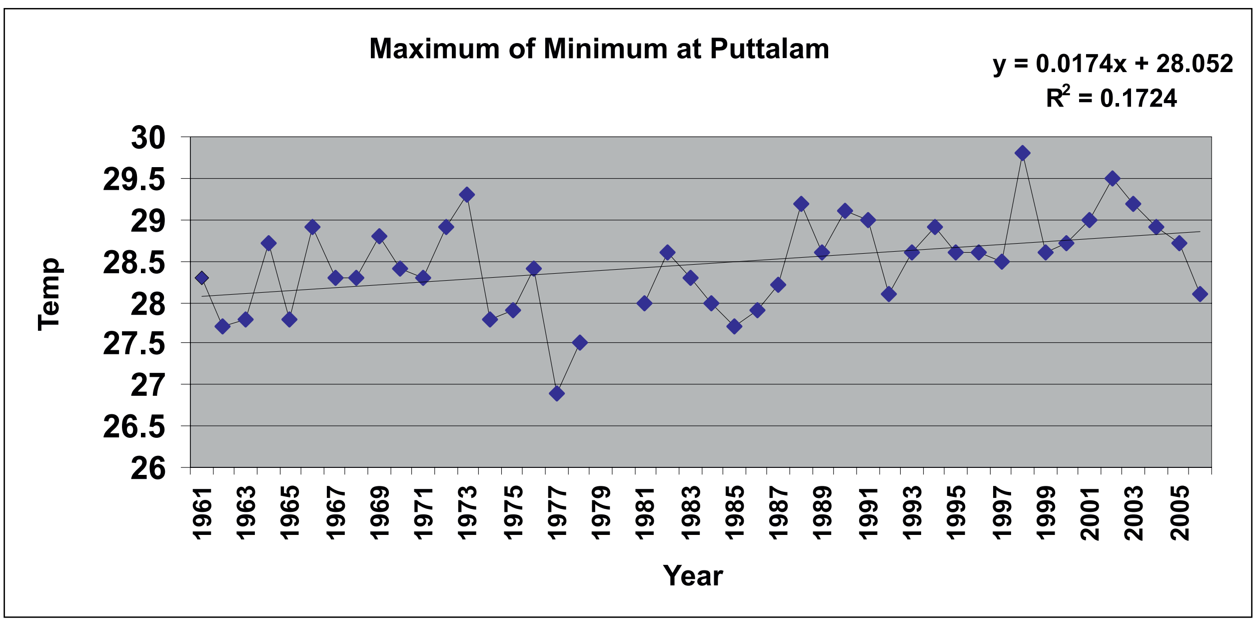


Figure 21. Maximum of minimum temperature at Puttalam.

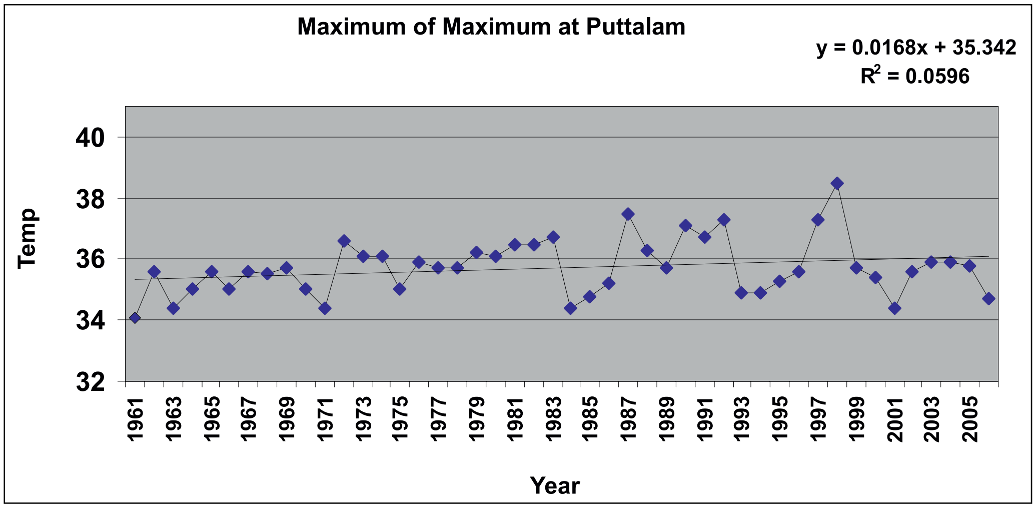


Figure 22. Maximum of maximum temperature at Puttalam.

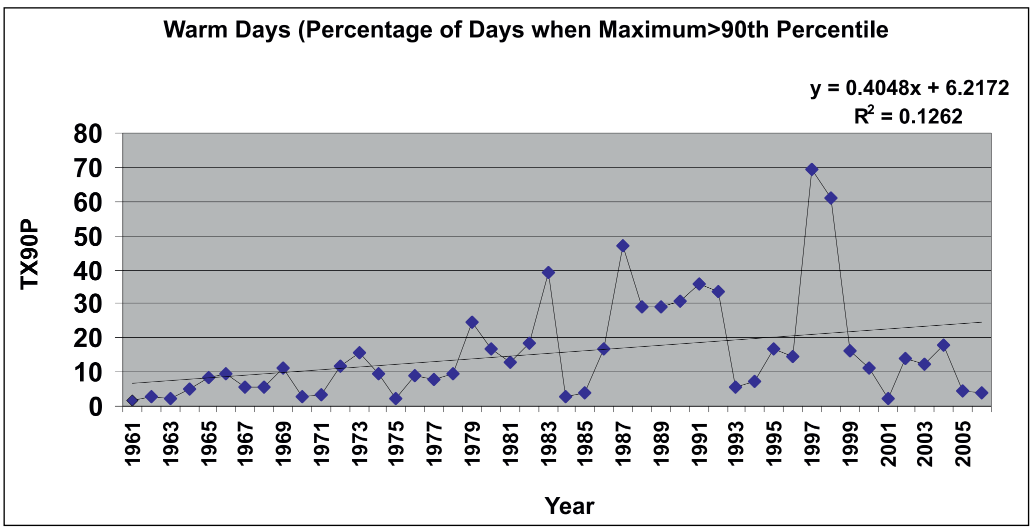


Figure 23. Number of warm days at Puttalam.

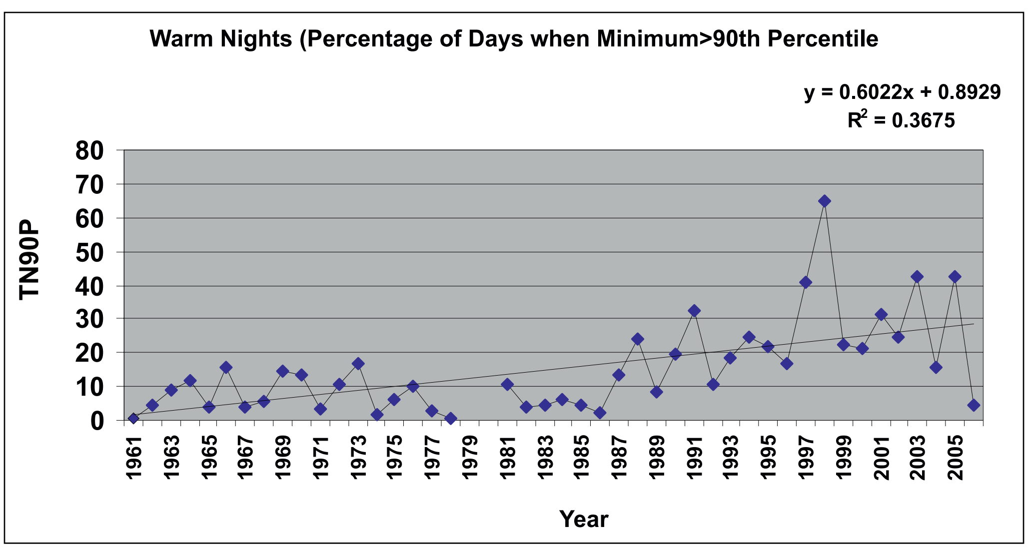


Figure 24. Number of warm nights at Puttalam

5.2.3 Agro-meteorological analysis in Puttalam District (1976–2008)

Annual rainfall distribution in Eluwankulama agro-meteorological station in Puttalam District (1976–2008)

Annual rainfall distribution in Eluwankulama agro-meteorological station in Puttalam District is depicted in Figure 25 for the period 1976–2008. Rainfall fluctuations observed in each year from 1976–2000 were relatively less compared to the fluctuations since 2000. Unpredictable rainfall variation was recorded during the recent past in Eluwankulama and crop damages were recorded as a result of this rainfall variation.

5.2.4 Mean monthly rainfall distribution in Eluwankulama agro-meteorological station in Puttalam District (1976–2008).

The Mean monthly rainfall distribution in Eluwankulama agro-meteorological station during 1976–2008 is predicted in Figure 26. At a glance, bi-modal rainfall pattern is visible in a year indicating two major rainfall seasons. Starting from the First Inter-Monsoon (March to April), mean monthly rainfall received in March was 63.3 mm and it increased up to 147.6 mm in April, indicating 17.6% rainfall in the First Inter-Monsoon. The Southwest Monsoon starts in May and ends in September indicating 73 mm mean monthly rainfall in May and gradual decline of rainfall indicating only 12.6 mm rainfall in August, which is the month for harvesting paddy in the Yala season. September is the last month of the Southwest Monsoon, getting a mean monthly rainfall of 56 mm. The time period from March to September is indicated as Yala season in Sri Lanka. During the Second Inter-Monsoon, from October to November, the highest mean rainfalls were recorded in a given year. Mean monthly rainfall in October is 238.9 mm and in November it is 297.7 mm; the highest amount of rainfall (45%) is received during these two months. Northeast Monsoon is the second monsoon season, which starts in December and ends in

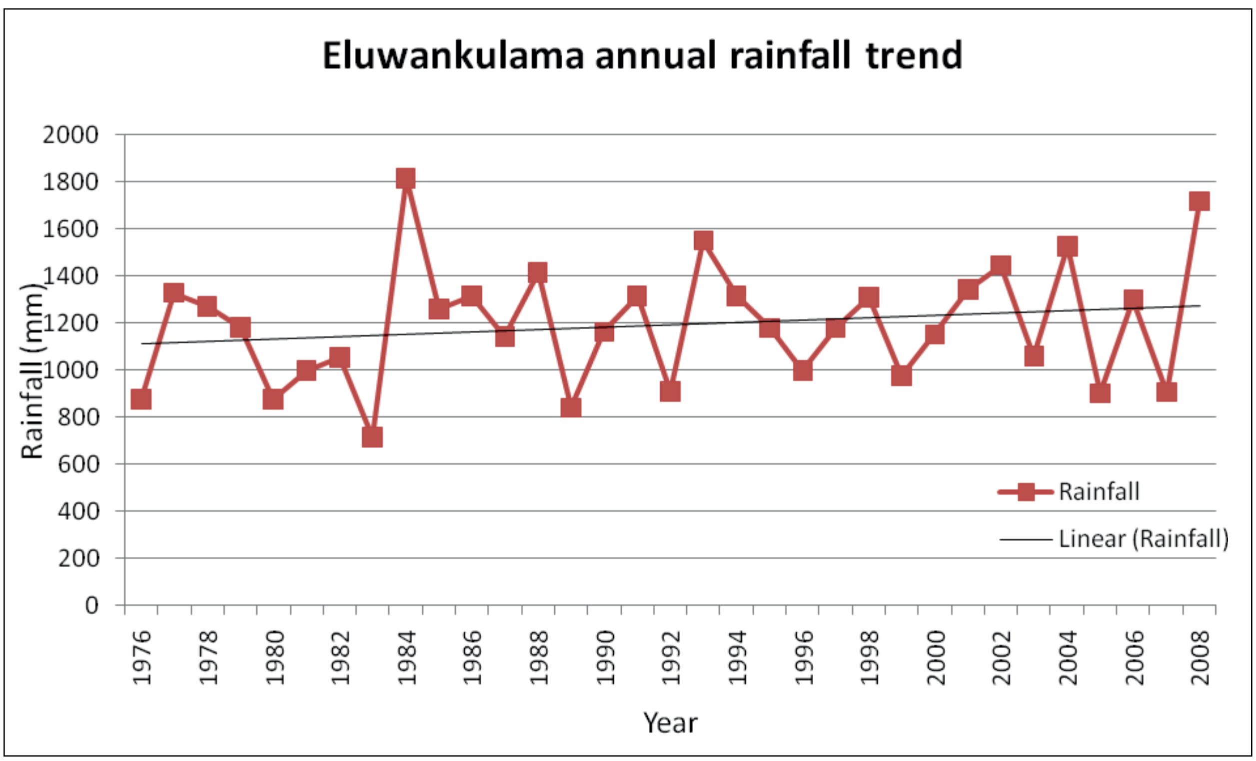
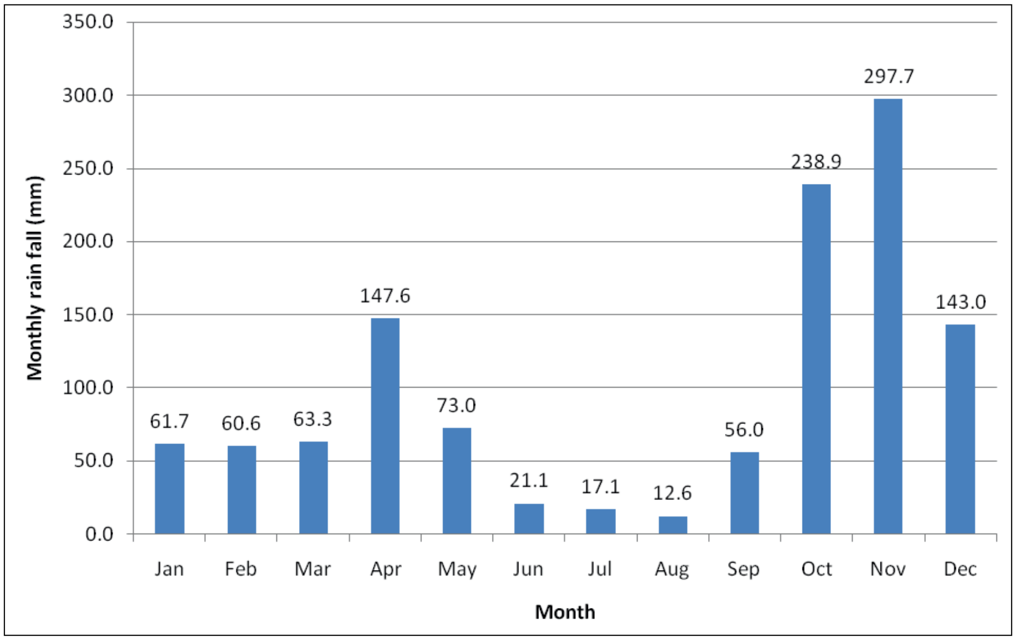


Figure 25. Annual rainfall distribution in Eluwankulama agro-meteorological station in Puttalam District (1976 -2008).

February. Mean monthly rainfall is gradually reduced in December (143 mm), January (61.7 mm), and February (60.6 mm). Maha is the main cultivation season in Sri Lanka, which starts in October and ends in February. Harvesting of Maha crops are undertaken in February. The total amount of rainfall received during the Northeast monsoon was relatively less (22.23%) compared to the 45% rainfall in the Second Inter-Monsoon (Figure 26). Mean rainfall was 802 mm during the Maha season. Percentage contribution of monthly rainfall in three decadal periods in Eluwankulama is shown in Figure 27.



Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AVG Rainfall	61.72	60.57	63.30	147.60	73.00	21.13	17.05	12.56	56.04	238.87	297.68	143.03
%Rainfall	5.15	5.11	5.30	12.34	6.14	1.78	1.42	1.04	4.71	20.01	25.04	11.97

Figure 26. Mean monthly rainfall distribution in Eluwankulama agro-met station in Puttalam District (1976 -2008).

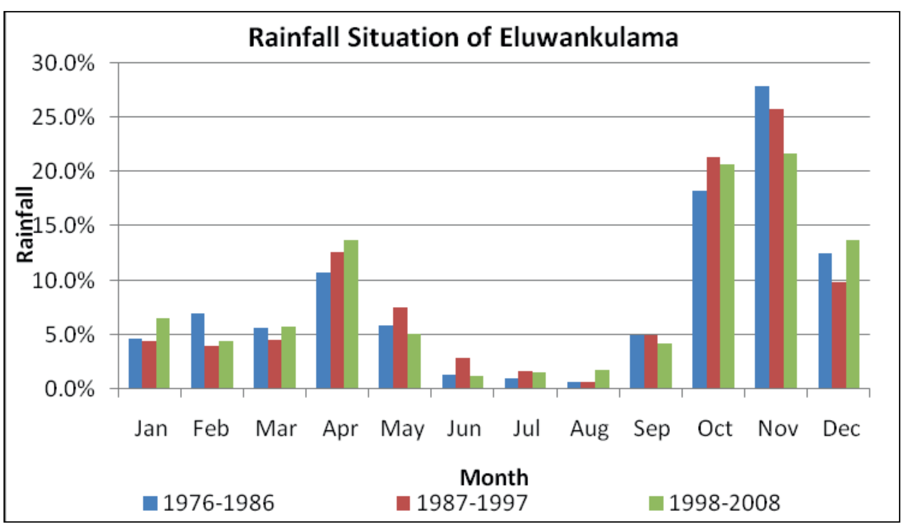


Figure 27. Percentage contribution of monthly rainfall in three decadal periods in Eluwankulama in Puttalam District.

5.2.5 Distribution of average annual number of rainy days in Eluwankulama

Annual average number of rainy days was studied from 1976 to 2008, indicating relatively higher variability up to the year 2000 and relatively less variability from 2000-2008. The lowest average annual number of rainy days of 40 was recorded in 1983. The highest value of about 90 days was recorded in 1984 (Figure 28).

5.2.6 Seasonal rainfall distribution at Eluwankulama in Puttalam District (1976-2008)

Rainfall characterization of Eluwankulama indicated that the distribution of annual rainfall is different in each rainfall season. The Eluwankulama region receives 17% rainfall during the First Inter-Monsoon, 15% during Southwest Monsoon, 45% during Second Inter-Monsoon and 23% during the Northeast Monsoon. The highest percentage of rainfall was received in the Second Inter-Monsoon and the lowest during the Southwest Monsoon (Table 4).

Table 4. Seasonal rainfall characterization in Puttalam District.

	Rainfall characterization in Puttalam District				
		Percentage of rainfall in different seasons			
S.No.	Puttalam District	First Inter-Monsoon (March-April)	Southwest Monsoon (May-September)	Second Inter-Monsoon (October-November)	Northeast Monsoon (December-February)
1	Eluwankulama Agro-Met Station	17	15	45	23

5.2.7 Rainfall distribution in Yala and Maha season

Rainfall distribution in Maha season in Eluwankulama agro-meteorology station in Puttalam District is depicted in Figure 29. Regarding the deviation of the rainfall from the mean, there was more number of negative deviations observed till the year 2000. But since 2000, a majority of these deviations were observed to be positive. Rainfall distributions and deviations in Yala and Maha seasons are depicted in Figure 29 and Figure 30.

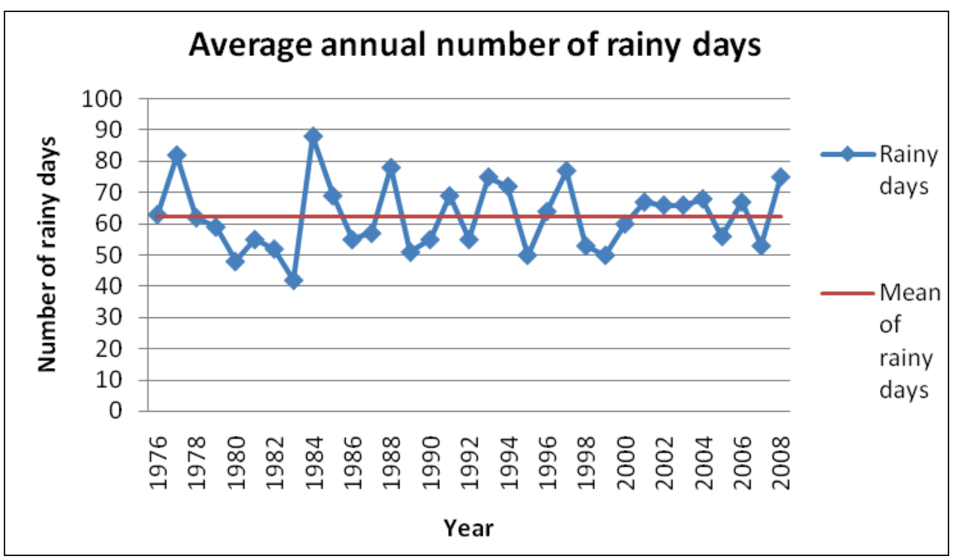


Figure 28. Distribution of average annual number of rainy days in Eluwankulama in Puttalam District 1976-2008.

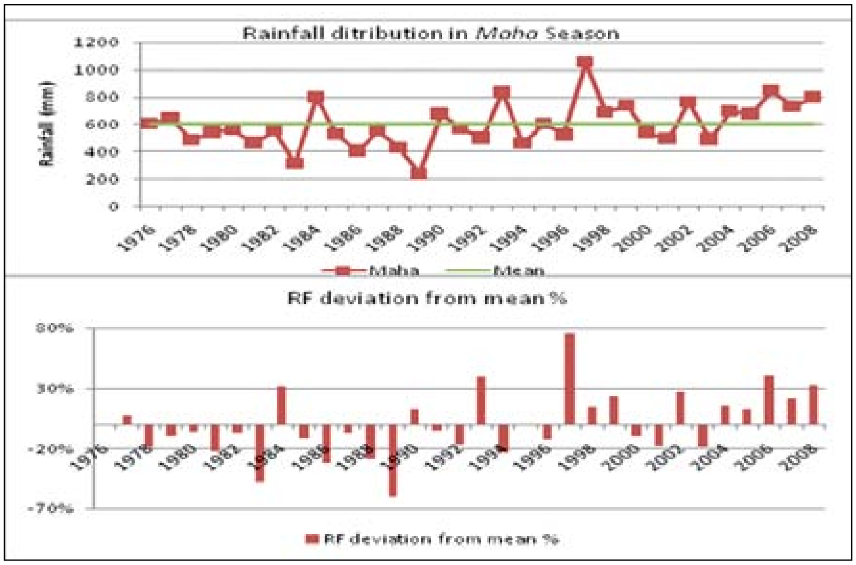


Figure 29. Rainfall distributions in Maha season in Eluwankulama.

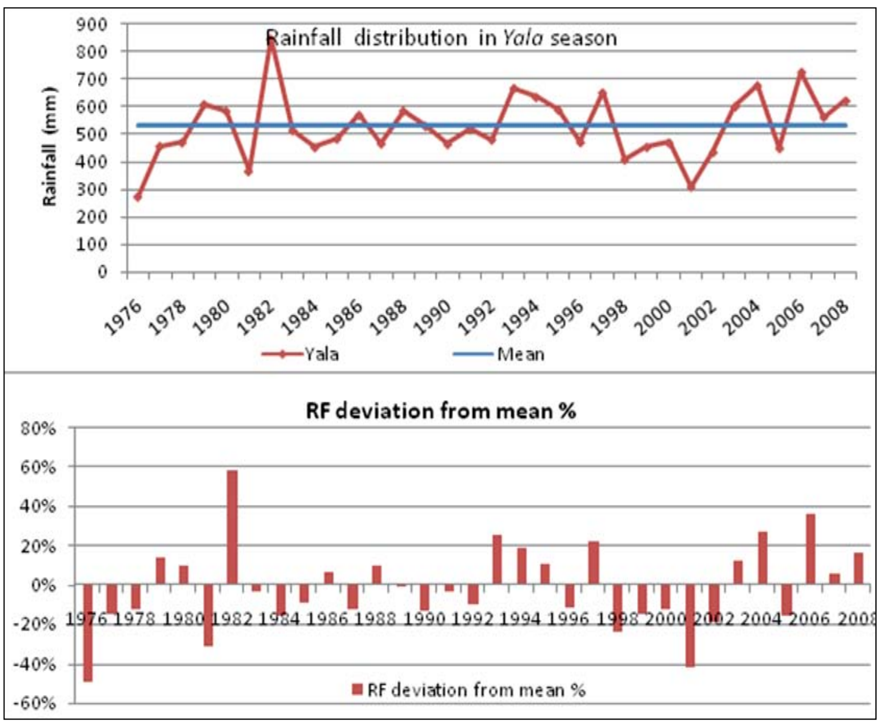


Figure 30. Rainfall distributions in Yala season in Eluwankulama.

5.2.8 Onset and withdrawal of Yala and Maha seasons

Three important parameters are described in a season for crop production, such as time of onset of rainfall, withdrawal of rains and the length of the rainy season. Several definitions were sited in literature depending upon the geographical location of the study and the time scale of the data. In order to decide the above three factors, two basic requirements have to be satisfied. First, rainfall sustained to represent the transition from dry season to wet season. Second, the rain that falls should percolate into the soil up to a reasonable depth and should build a moisture profile thereby preventing losses through evaporation.

After considering the above requirements in association with soil physical properties such as water holding capacity, expected evaporative conditions in the atmosphere, normal depth of seed placement of the major soil group of the DL1 region, Reddish Brown Earth (RBE) soils, onset of the season was defined in terms of rainfall. "A spell of at least 30 mm of rain per week in three consecutive weeks after a pre-specified week for the Maha (standard week 35) and Yala (standard week 9) seasons is defined as the beginning of rainy season. If a three week criterion was not satisfied, the condition was relaxed up to two consecutive weeks with rainfall equal to or greater than 30 mm. This relaxation was particularly important for the Yala season where the continuity of the rains is always uncertain. But under the dry zone's conditions where the rainfall is patchy and intermittent in nature, an evaluation of the continuity up to two to three weeks is necessary to avoid a false start of the seasons. Similarly, the first occurrence of a long dry spell (three consecutive weeks with less than 30 mm of rainfall after a pre-specified week (standard week 50 and 16 for Maha and Yala seasons, respectively) was used as the criterion for the end of a season. Length of the season was taken as the number of weeks between the end of the season and the onset of the season. Using these criteria, onset and withdrawal of the rainy season and the amount of the rainfall within each season were determined from the simulated data (Punyawardena 2002, p.15).

The weekly rainfall data for this study was generated using climate data analysis. Thirty three years (1976-2008) of weekly historical rainfall data of Eluwankulama was used to calculate the time of onset and withdrawal of rains, and length of the seasons. According to the Yala and Maha season, onset and withdrawal were determined for three periods as 1976-1986, 1987-1997 and 1998-2008. According to these criteria, onset and withdrawal of the season were determined from the historical weekly rainfall data of Eluwankulama. According to the weekly rainfall data of years 1976-2008, 13^{th} week and 41^{st} week was taken as onset of Yala and Maha, respectively. Also withdrawal of Yala and Maha was taken at 23^{rd} week and 4^{th} week in the following year, respectively (Table 5).

Table 5. Normal dates of onset and withdrawal of Yala and Maha seasons of Eluwankulama.

	Eluwankulama			
	Onset		Withdrawal	
Period	Yala	Maha	Yala	Maha
1976-2008	13^{th} week	41^{st} week	23^{rd} week	4^{th} week
1976-1986	13^{th} week	42^{nd} week	23^{rd} week	3^{rd} week
1987-1997	14^{th} week	42^{nd} week	23^{rd} week	4^{th} week
1998-2008	13^{th} week	42^{nd} week	20^{th} week	4^{th} week

5.2.9 Maximum and minimum temperature distribution in Eluwankulama

Mean annual maximum temperature distribution in Eluwankulama from 1976 to 1986 showed deviations from the mean indicating that maximum temperature has relatively reduced during that period. Upward deviation from the mean was shown in the period of 1987-97 indicating an increase of temperature, and this upward trend continued up to 2008 indicating that the maximum temperature has continued to be on the high side (Figure 31). Mean annual minimum temperature in Eluwankulama indicated an upward trend during the period of 1976-86, downward trend in 1987-97 periods and finally an upward trend in 1998-2008 indicating that the minimum temperature has gone up (Figure 32).

5.2.10 Drought analysis of Eluwankulama

Drought analysis was divided into agricultural drought and meteorological droughts. Agricultural impacts caused due to short term precipitation storages, temperature anomalies and soil water deficits. Agricultural drought is defined as a period of four consecutive weeks (severe meteorological drought) with a rainfall deficiency of more than 50% of the long term average (LTA) or with a weekly rain fall of 5 mm or less. Meteorological drought is defined as a period of prolonged dry weather condition lower

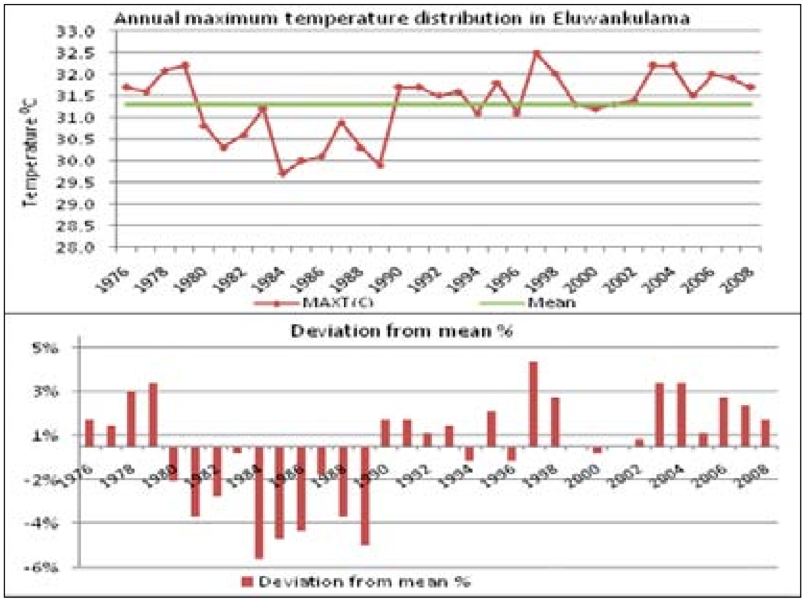


Figure 31. Mean annual maximum temperature distribution in Eluwankulama

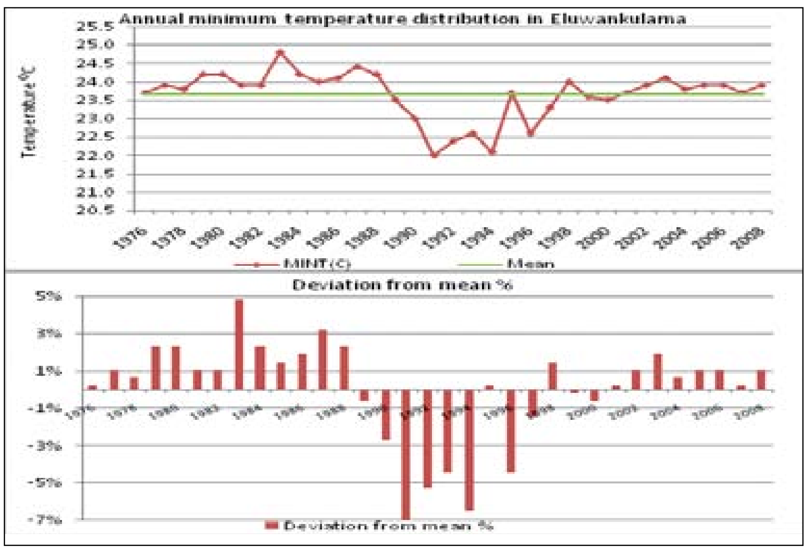


Figure 32. Mean annual minimum temperature distribution in Eluwankulama.

than normal rainfall. There are 3 types of drought conditions that are based on rainfall deficit from normal, named as mild drought (0-25%), moderate drought (26-50%) and severe drought (>50%).

Agricultural drought

Agricultural droughts were examined for the last 33 years from 1976-2008. Of this 33-year period, agricultural droughts were recorded in 19 years (57.6 %) in the period of June to September. In these years, the agricultural drought was generally spread from 36th to 42nd week (3 September to 21 October). Whereas in the period of October to February (Maha season), only one agricultural drought (3%) was experienced in the year 1995, which spread from 46th to 51st week (12 November to 23 December) (Table 6).

Table 6. Agricultural drought in Eluwankulama (1976-2008).

Condition/Season	Number of years indicating the droughts	%
Yala	19	57.6
Maha	1	3.0
No Drought	13	39.0

Meteorological drought

Meteorological droughts were analyzed for the period of 33 years starting from 1976-2008. It was revealed that the droughts were not recorded during 21 years (64%), while during 10 years (30%) mild droughts were recorded. Moderate droughts were recorded only during 2 years. Severe drought was not recorded for the whole 33-year period (Table 7).

Table 7. Meteorological drought in Eluwankulama (1976-2008).

Condition/Season	Number of years indicating the droughts	%
No drought	21	64.0
Mild drought	10	30.0
Moderate drought	2	6.0
Severe drought	0	0.0

5.2.11 Water balance and Length of Growing Period (LGP) analysis

Availability of water in the right quantity at the right time is essential for crop growth and development. To assess water availability to crops, soil moisture is to be taken into account and the net water balance through soil moisture can be analyzed using the water balance technique. The concepts of Potential Evapotranspiration (PET) and water balance have been extensively applied for studies such as climatic classification, aridity, humidity and drought. At the start of the rainy season, seed germination and initial crop growth depend on the amount and distribution of rainfall. The beginning and end of growing period are determined by the Index for Moisture Adequacy (IMA) Values. The length of growing period is an important parameter, which helps to assess climatic suitability for crop production.

Length of growing period (LGP) of Eluwankulama in Puttalam District

The beginning and end of growing period is identified based on Index for Moisture Adequacy (IMA) values. The growing season begins when the IMA is above 50% consecutively for at least three weeks. The end of season is identified when the IMA falls below 25% for four consecutive weeks. Generally, it can be concluded that over the past 33-year period (1976-2008), year-round growing season can be seen. This included Yala and Maha seasons in Sri Lanka. During most of the years, the growing season begins in the 20th week (7 April) and it ends in the following year 16th week (14 April). Accordingly, length of the growing period (LGP) is about 48-50 weeks indicating year–round cultivation (Figure 33).

5.2.12 Classification of climates according to the moisture index- Eluwankulama

Moisture Adequacy Index provides (MAI) a good indication of the moisture status of the soil in relation to the water needs and high values of the index signifying good moisture availability. Aridity index (Ia), humidity index (Ih), moisture index (Im) and MAI are the outputs of water balance analysis. Moisture Index (%) is the index used to classify climate of places and this method is put forth by Thornthwaite and Mather in 1955. In that, there were nine categories for climate types (Table 8). Based on this categorization, agro-meteorological stations and area around Eluwankulama was classified. An average yearly value of Im for the period 1976 to 2008 was -23.3% for Eluwankulama. Therefore, it is taken under the Dry sub-humid (C1) climatic type (Figure 34). In addition to that, from yearly values of Im, it is easy to understand how climatic type of a particular place is changing from year to year (Table 9).

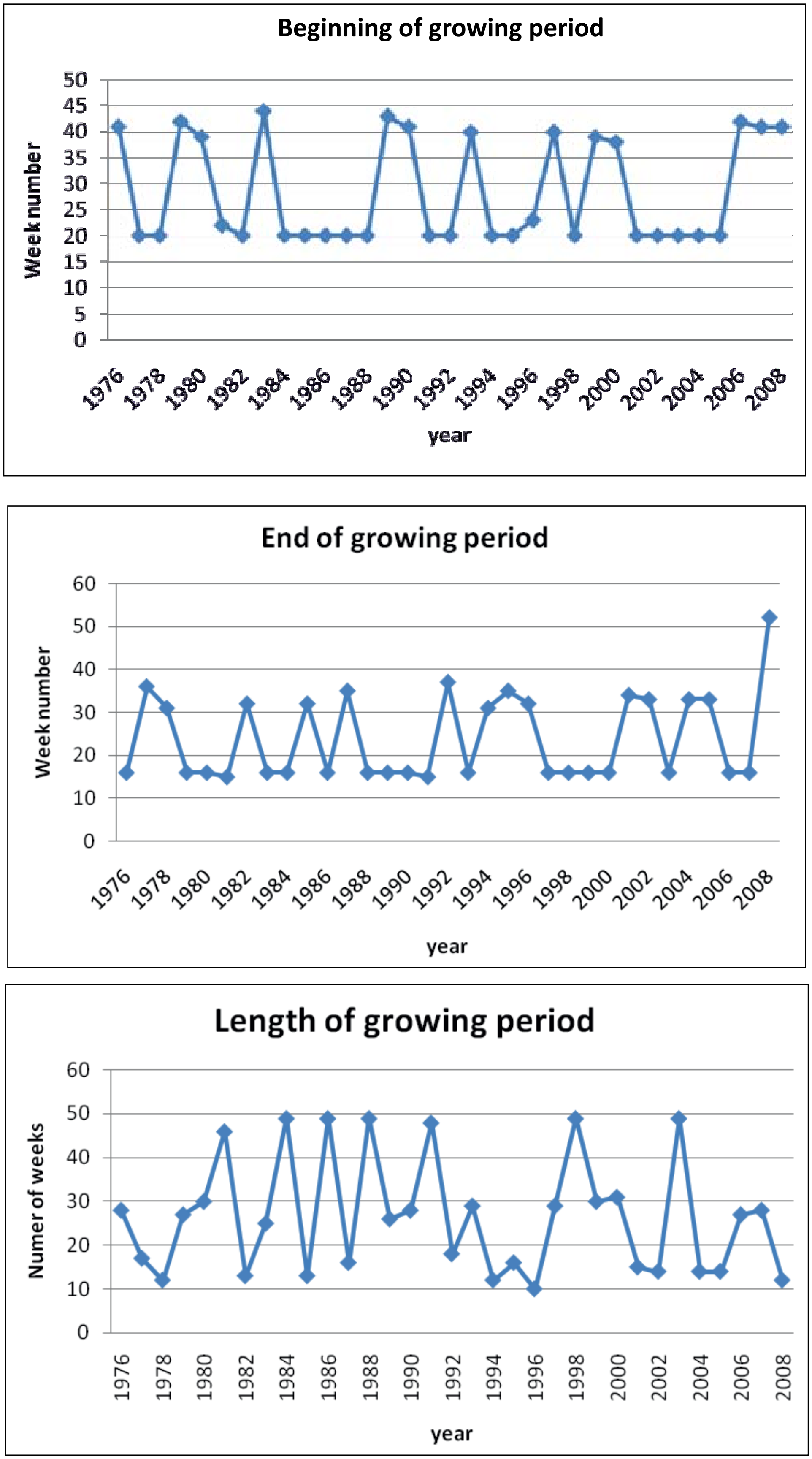


Figure 33. Graphical illustration of growing period in Eluwankulama (1976-2008).

Table 8. Classification of climates according to the Moisture Index.

Moisture Index Im (%)	Climate type (Symbol)
Above 100	Per-humid (A)
100-80	Humid (B4)
80-60	Humid (B3)
60-40	Humid (B2)
40-20	Humid (B1)
0-20	Moisture Sub-humid (C2)
0 to –33.3	Dry sub-humid (C1)
-33.3 to 66.7	Semi-arid (D)
Less than –66.7	Arid (E)

Source: Thornthwaite and Mather (1955).

Table 9. Distribution of Moisture Index (%) from 1976 to 2008.

Eluwankulama		
1976 - 1986	1987 – 1997	1998 - 2008
-24.6	-23.9	-21.5
Dry sub-humid (C1)	Dry sub-humid (C1)	Dry sub-humid (C1)

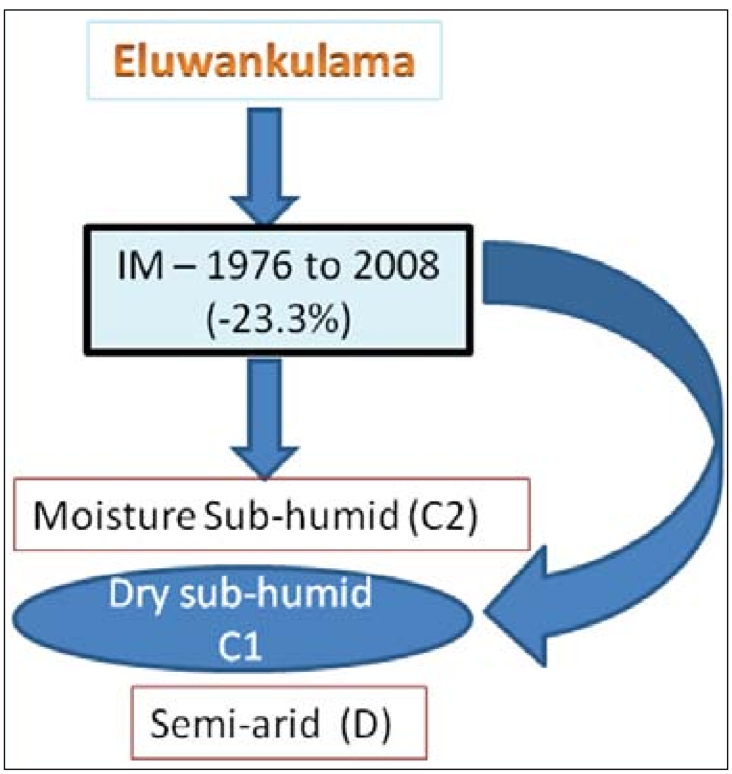


Figure 34. Classification of climate in an around Eluwankulama according to the moisture index.

5.2.13 Water balance analysis

Availability of water in the right quantity and at the right time and its management with suitable agronomic practices are essential for good crop growth, development and yield. To assess water availability to the crop, soil moisture is to be taken into account; the net water balance through soil moisture can be estimated using the water balance technique. Information on Potential Evapotranspiration for a location has great importance in agricultural water management. Many empirical methods are available, such as Thornthwaite (1948), Blaney and Criddle (1950), Hargreaves and Christiansen (1973) and others. The FAO Penman-Monteith method is selected as the method by which the evapotranspiration of the reference surface (ET0) can be unambiguously determined; this method provides consistent ET0 values in all regions and climates. Water surplus (WS) and water deficit (WD) occurs in different seasons at most places and both are significant in water balance studies. The information about when the period of water surplus and water deficit occurs in a season or year is useful to find out the ideal period for starting of crop season and stages that may fall in a deficit period.

This output file gives weekly values of PET, rainfall, soil moisture storage, Actual Evapo-transpiration (AET), water deficit, water surplus, IMA and SMI for every year. Writing interpretations based on weekly data may vary every week, consequently, the results may not give a good picture for crop growth period. Hence, we need the overall situation over a crop season. Average water deficit, water surplus, index of moisture adequacy and soil moisture index were analyzed for Yala and Maha seasons for three decadal periods. The results revealed that the average water deficit had slightly reduced from the first decade (1976-1986) to the last decade (1998-2008) both in Yala and Maha seasons. Water surplus had slightly reduced over the same period in Yala season and slightly increased in the Maha season. Average index of moisture adequacy had slightly increased in both seasons during the first and the last seasons. Soil moisture index (SMI) had slightly increased over the three periods both in Yala and Maha seasons (Table 10, 11, 12, 13).[1]

Table 10. Average water deficit (mm) in Eluwankulama (1976-2008).

Period	Yala (March-September) (week 10-39)	Maha (October-Feb) (week 40-9)
1976-1986	13.16	13.08
1987-1997	12.62	12.09
1998-2008	12.34	12.14

Table 11. Average water surplus (mm) in Eluwankulama (1976-2008).

Period	Yala (March-September) (week 10-39)	Maha (October-February) (week 40-9)
1976-1986	5.37	5.53
1987-1997	4.73	5.57
1998-2008	4.79	5.56

1. Key words

Potential evapotranspiration (PET): It is defined as the maximum quantity of water that is transpired and evaporated by a uniform cover of short dense grass (Reference crop) when water surplus is not limited.

Reference crop: A hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s/m and an albedo of 0.23.

Water balance: It refers to the climatic balance obtained by comparing the rainfall as income with evapotranspiration as loss or expenditure, soil being a medium for strong water during period of excess rainfall and utilizing or releasing moisture during period of deficit precipitation.

Water surplus: It is the excess amount of water remaining after the evaporation needs of the soil have been met (ie, when actual evapotranspiration equals potential evapotranspiration) and soil storage has been returned to the water holding capacity level.

Water deficit: It is the amount by which the available moisture fails to meet demand for water and is computed by subtracting the potential evapotranspiration from the actual evapotranspiration for the period of interest.

Actual evapotranspiration: It is the actual amount of water lost to the atmosphere by evaporation and transpiration under existing conditions of moisture availability.

Table 12. Average Index of Moisture Adequacy (IMA) in Eluwankulama (1976-2008).

Period	Yala (March-September) (week 10-39)	Maha (October-February) (week 40-9)
1976-1986	46.73	46.79
1987-1997	48.58	51.47
1998-2008	52.09	53.04

Table 13. Average Soil Moisture Index (SMI) in Eluwankulama (1976- 2008).

Period	Yala (March-September) (week 10-39)	Maha (October-February) (week 40-9)
1976-1986	59.35	59.39
1987-1997	61.22	63.32
1998-2008	63.49	64.23

5.3 Climatic analysis for Hambantota District

Climatological behavior (1961-1990) of Maximum, Minimum temperatures, rainfall and Diurnal Temperature Range is shown in Figure 35. In Hambantota, the highest maximum ranfall was reported during the period March to June. Behavior of minimum temperature is also similar to that of the maximum. The rainfall pattern represents a Bi-model pattern as in Anuradhapura, but the amount is less. The total average annual rainfall at Hambantota is 1049 mm. The maximum amounts of rainfall were reported in April (First Inter-Monsoon) and October (Second Inter-Monsoon). After receiving high rainfall during the Second Inter-Monsoon, the rainy condition prevails until the early part of the Northeast Monsoon. Diurnal Temperature Range (DTR) indicates higher values during January, February and March. The value of DTR at Hambantota is much lower than the DTR at Anuradhapura. Even though the climatological behavior at Hambantota is indicated above, following are the changes and variabilities identified by long term analysis.

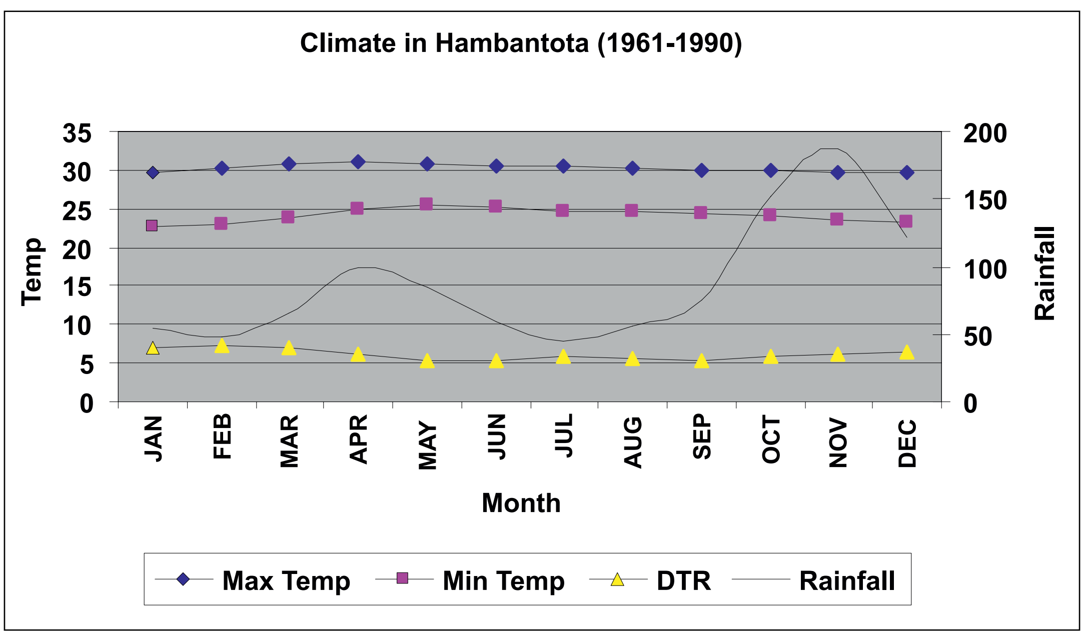


Figure 35. Averages of rainfall, maximum temperature, minimum temperature and Diurnal Temperature Range.

5.3.1 Change of minimum temperature at Hambantota

Figures 36 (a), (b) and (c) show the annual average minimum temperature anomalies during different periods. Accordingly, analysis during the periods 1961–1990 and 1990–2007 does not show any significant trend. However, the minimum temperature shows a slight decreasing trend during the past decade. Long term behavior of minimum temperature shows a significant increasing trend.

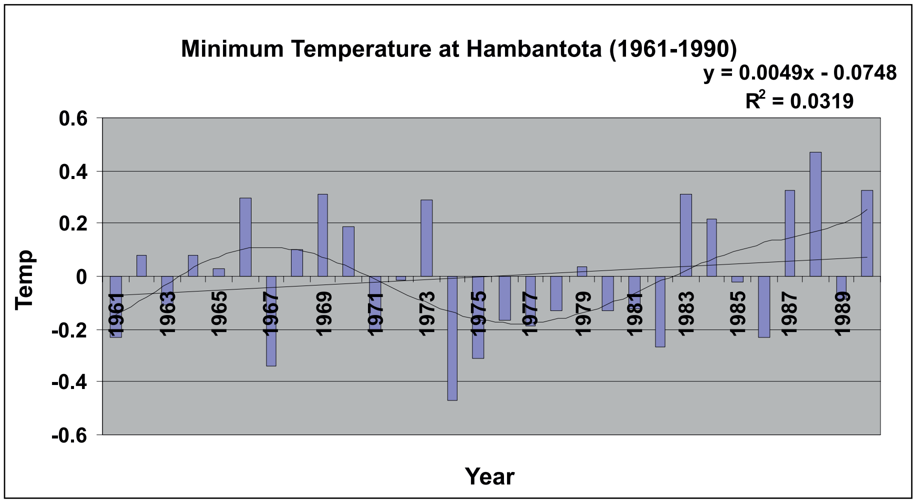


Figure 36(a). Minimum temperature anomaly trend for 1961-1990 (Base period 1961-1990).

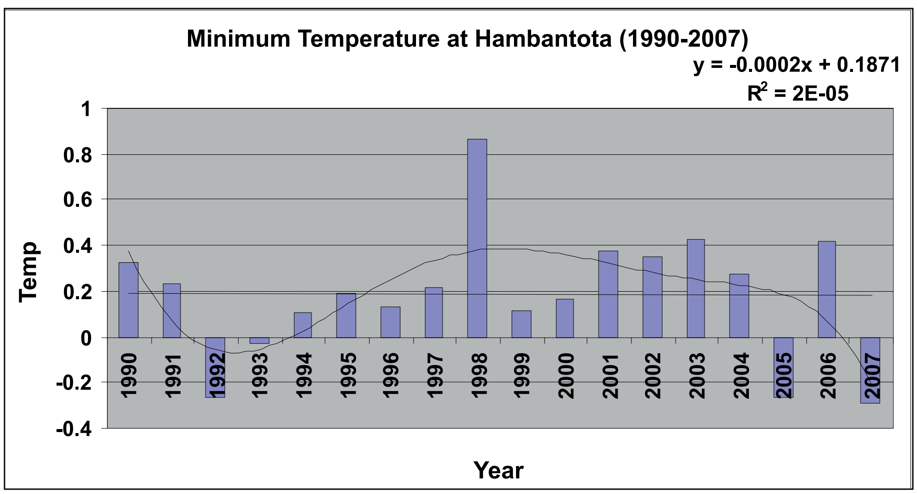


Figure 36(b). Minimum temperature anomaly trend for 1990-2007 (Base period 1961-1990).

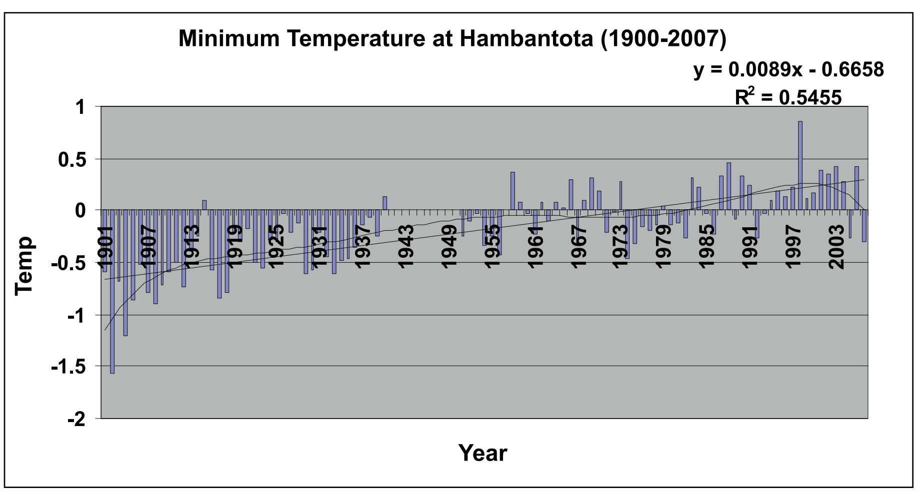


Figure 36(c). Minimum temperature anomaly trend for 1900-2007 (Base Period 1961-1990).

5.3.2 Change of maximum temperature in Hambantota

Figures 37(a) and (b) show the annual average maximum temperatures during different periods. The maximum temperature has been increased by about 0.0272 degrees Celsius per year during the period 1961-1990. But it does not show any significant trend during the recent two decades (1990-2007). The long term behavior of maximum temperature was rather different from other districts. It shows a decreasing trend during the early 5 decades (1900-1940), but after 1950, the temperature has been increasing (Figures 38 (a), (b) and (c)).

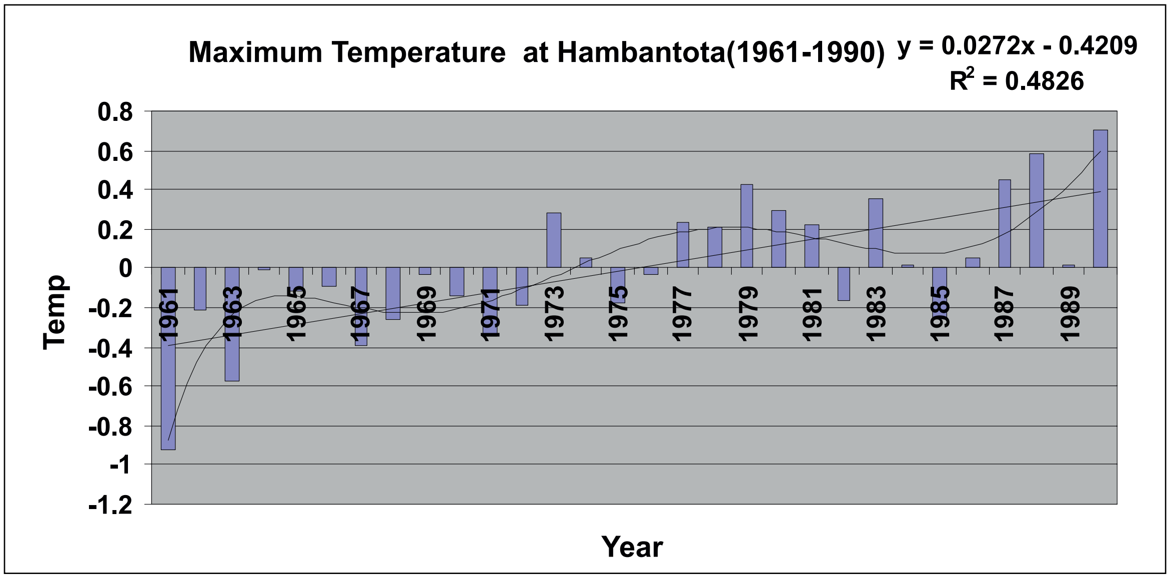


Figure 37(a). Maximum temperature anomaly trend for 1961-1990 (Base period 1961-1990).

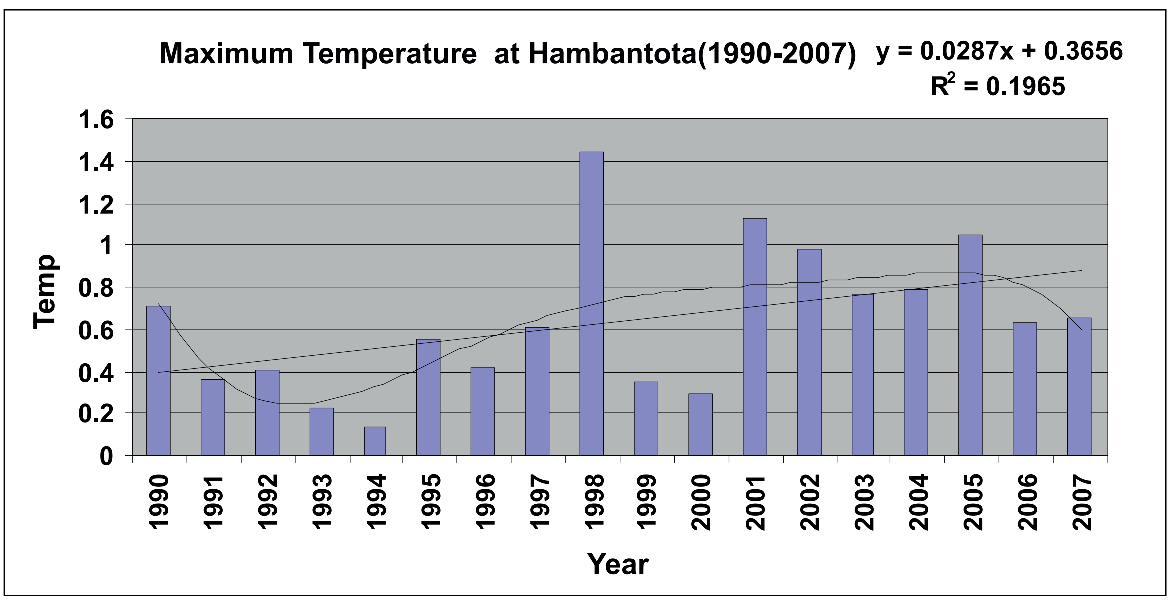


Figure 37(b). Maximum temperature anomaly trend for 1990-2007 (Base period 1961-1990).

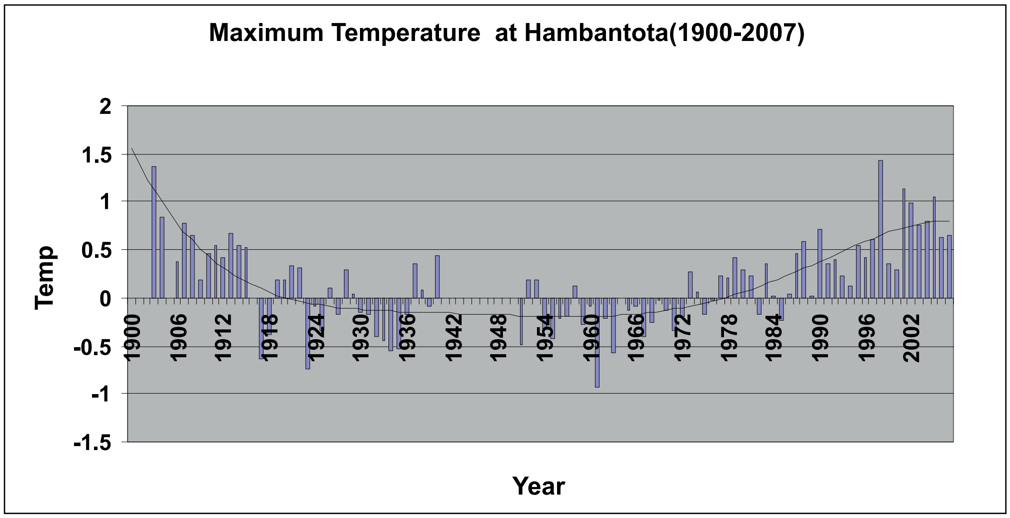


Figure 38(a). Maximum temperature anomaly trend for 1900-2007 (Base Period 1961-1990).

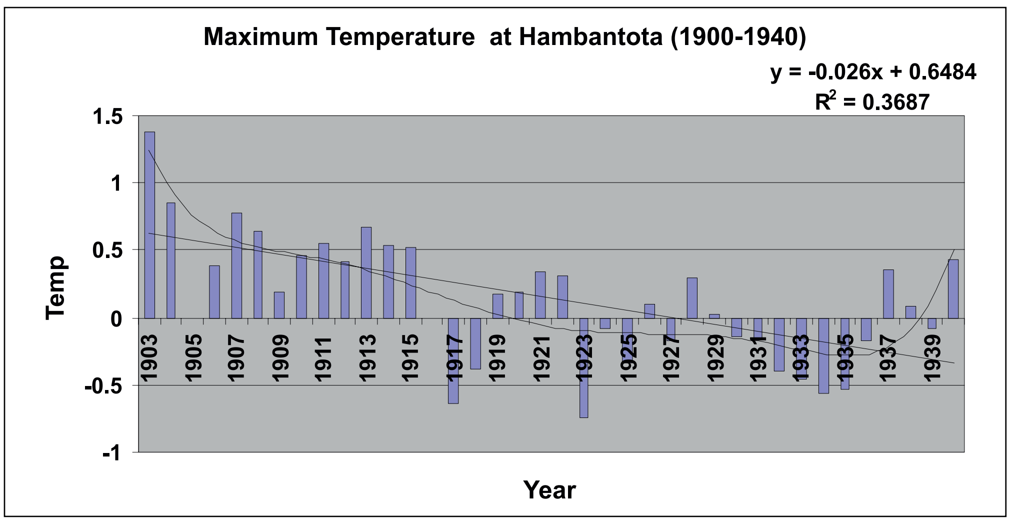


Figure 38(a). Maximum temperature anomaly trend for 1900-1940 (Base period 1961-1990).

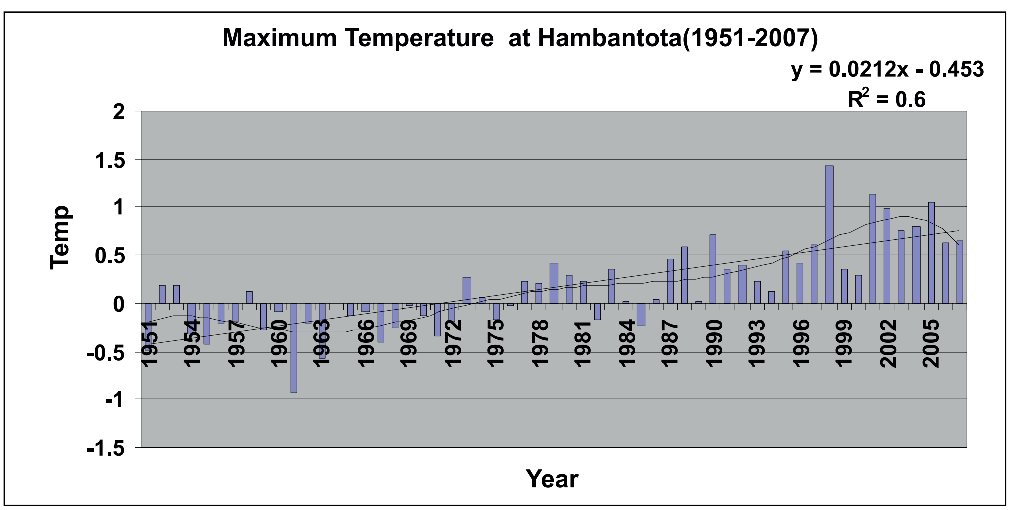


Figure 38(a). Maximum temperature anomaly trend for 1951-2007 (Base period 1961-1990).

5.3.3 Change of rainfall pattern at Hambantota

Total annual rainfall distribution in Hambantota Meteorological station during 1961-2009 is shown in Figure 39(a). It indicated a slight decreasing linear trend. But the polynomial trend shows a slight increasing trend after 1994 (Figure 39(b)). Even though in the long term it shows a decreasing trend, the short period trend does not show a similar behavior.

The long term rainfall analysis shows a chaotic behavior. It shows a decreasing trend after 1950s and an increasing trend after 1980s (Figure 39(c)). A similar behavior is shown in the periods 1961-1990 and 1990-2007.

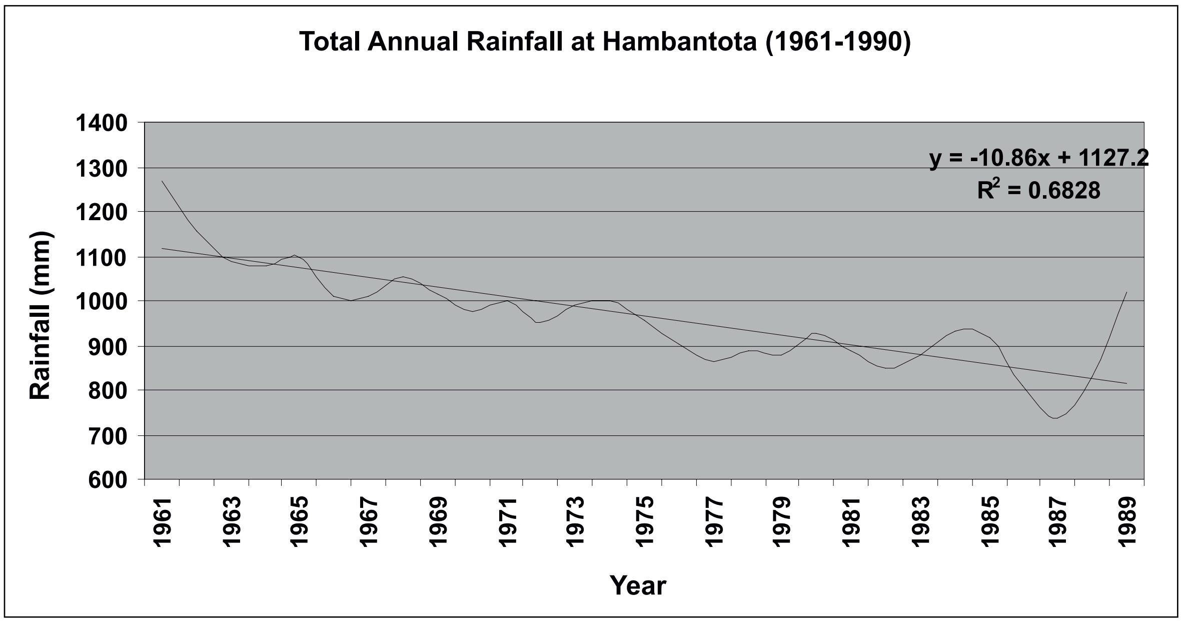


Figure 39(a). Total annual rainfall at Hambantota (1961-1990).

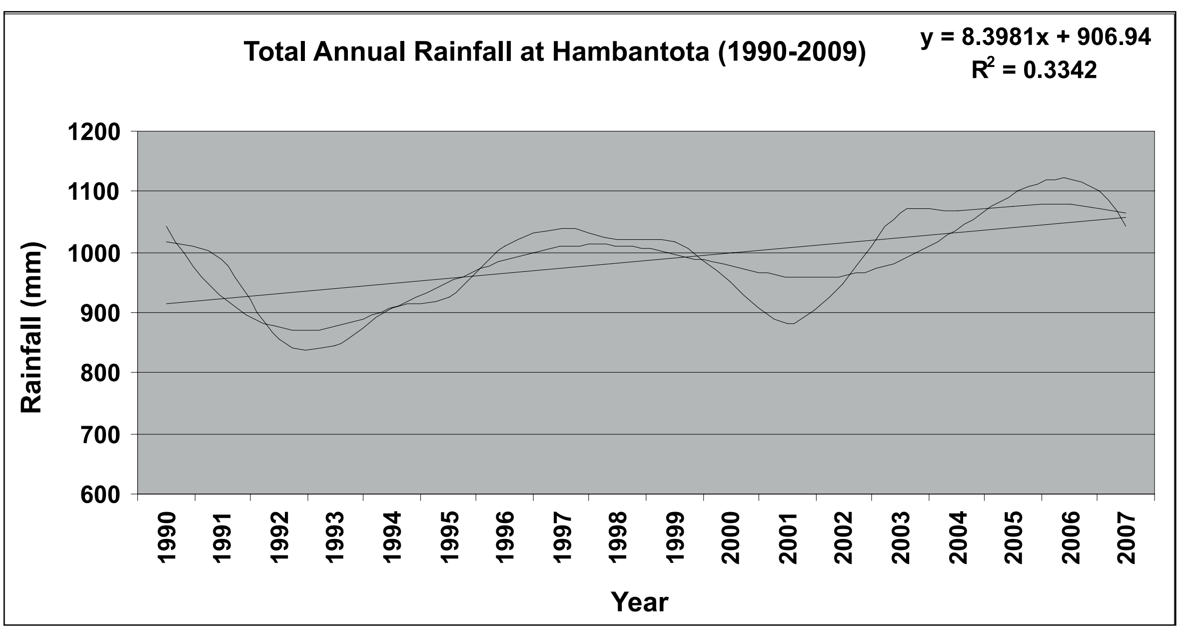


Figure 39(b). Total annual rainfall at Hambantota (1990-2009).

Change of Diurnal Temperature Range (DTR) is shown in Figure 40. It indicates an increasing trend in the Hambantota area.

Extreme climatic indices established in Hambantota area are as follows.

- Maximum of minimum temperature has been increased (Figure 41)
- Maximum of maximum temperature has been increased (Figure 42)
- Warm days (Percentage of days when Maximum (TX) >90th percentile) have been increased (Figure 43)
- Warm nights (Percentage of days when Minimum (TX) >90th percentile) have been increased (Figure 44).

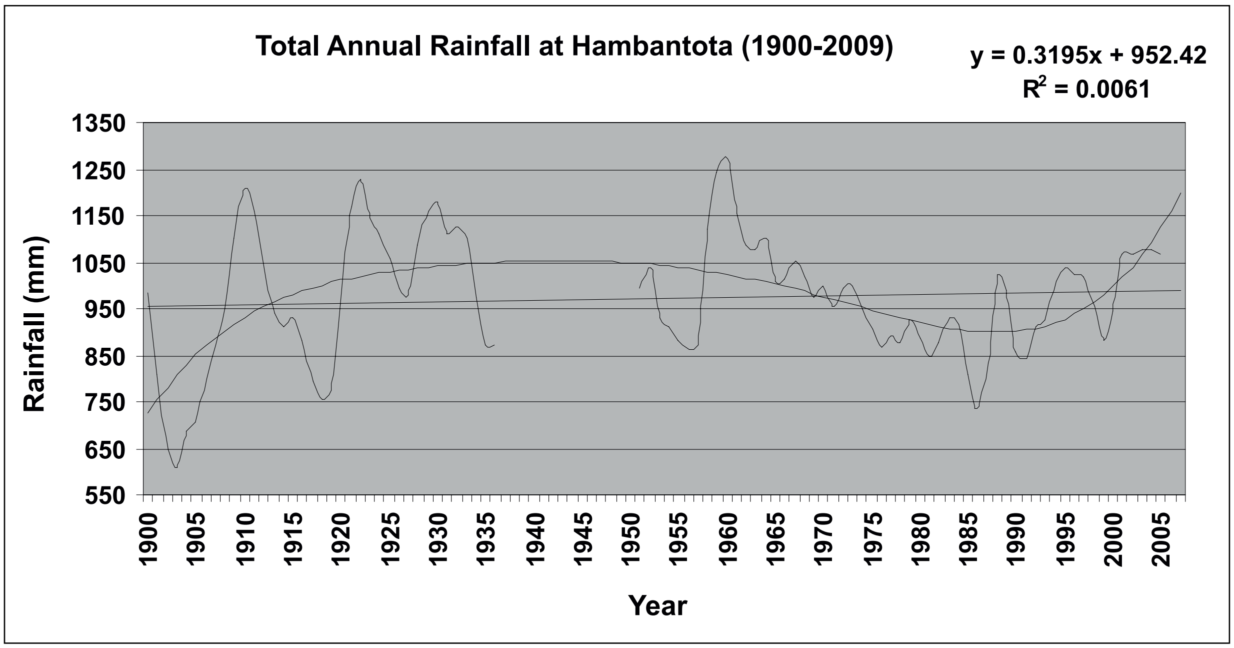


Figure 39(c). Annual total rainfall at Hambantota.

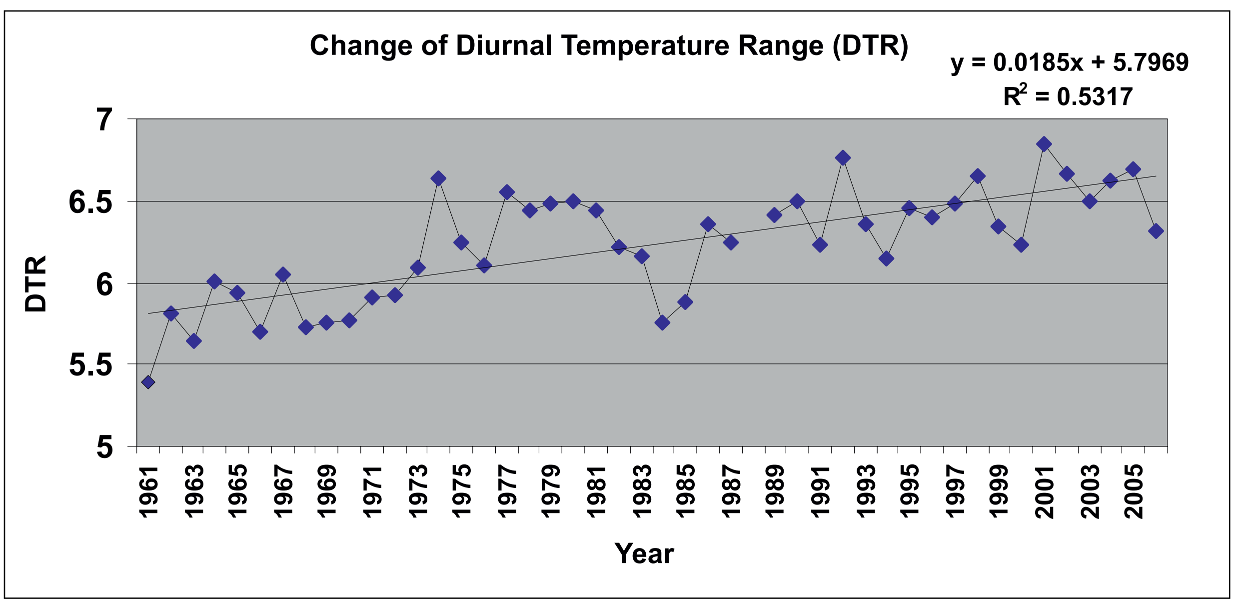


Figure 40. Diurnal Temperature Range (DTR) at Hambantota.

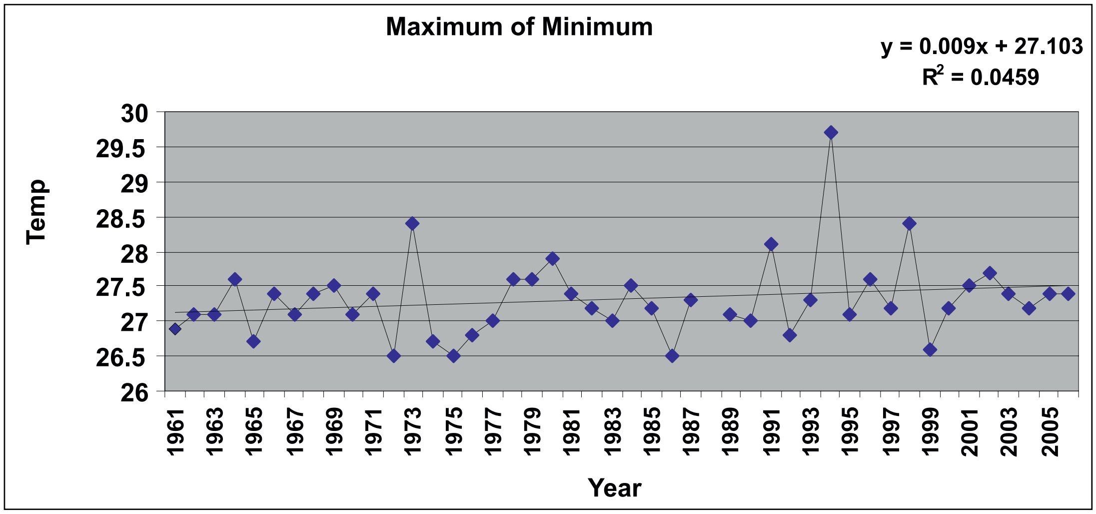


Figure 41. Maximum of minimum temperature in Hambantota

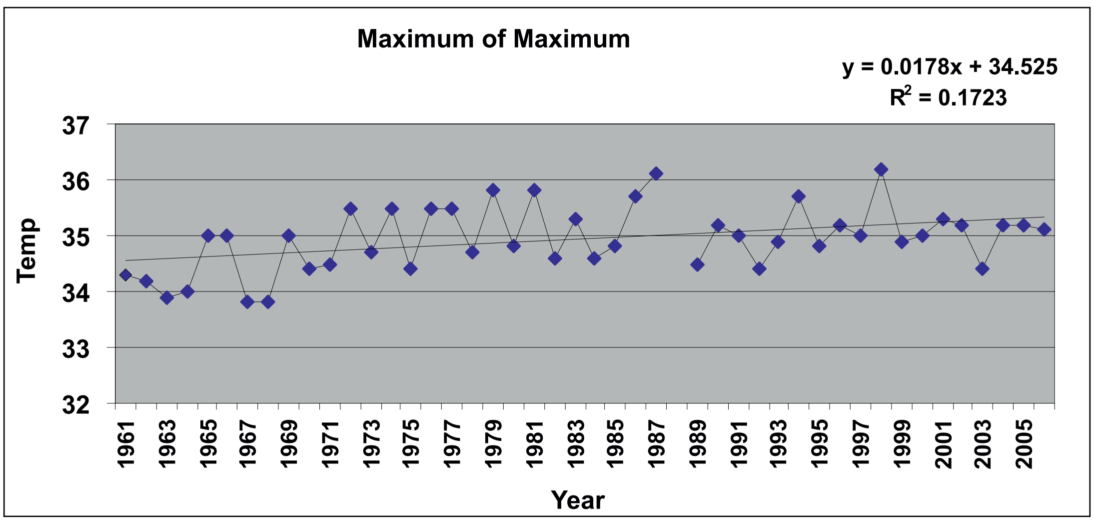


Figure 42. Maximum of maximum temperature in Hambantota.

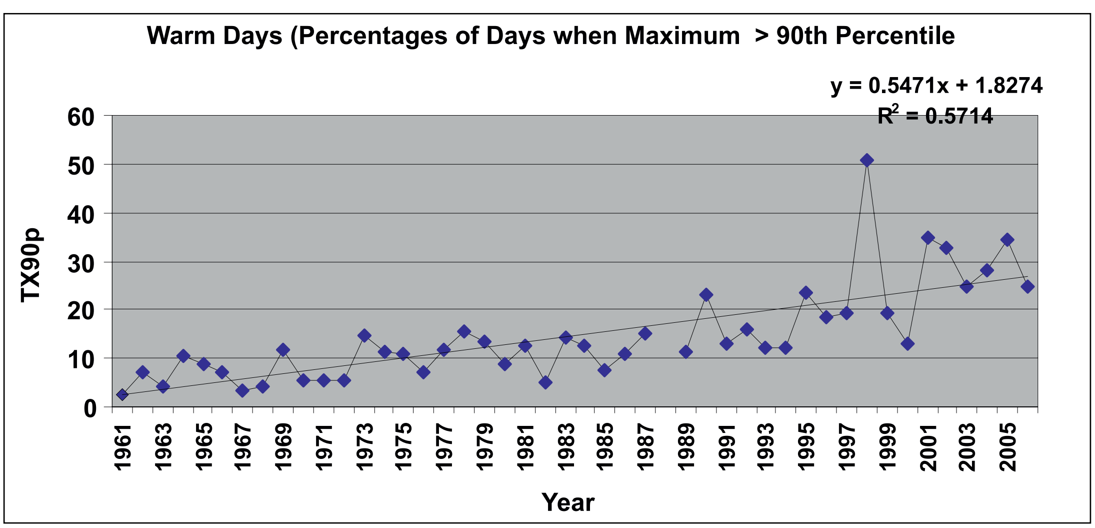


Figure 43. Number of warm days in Hambantota.

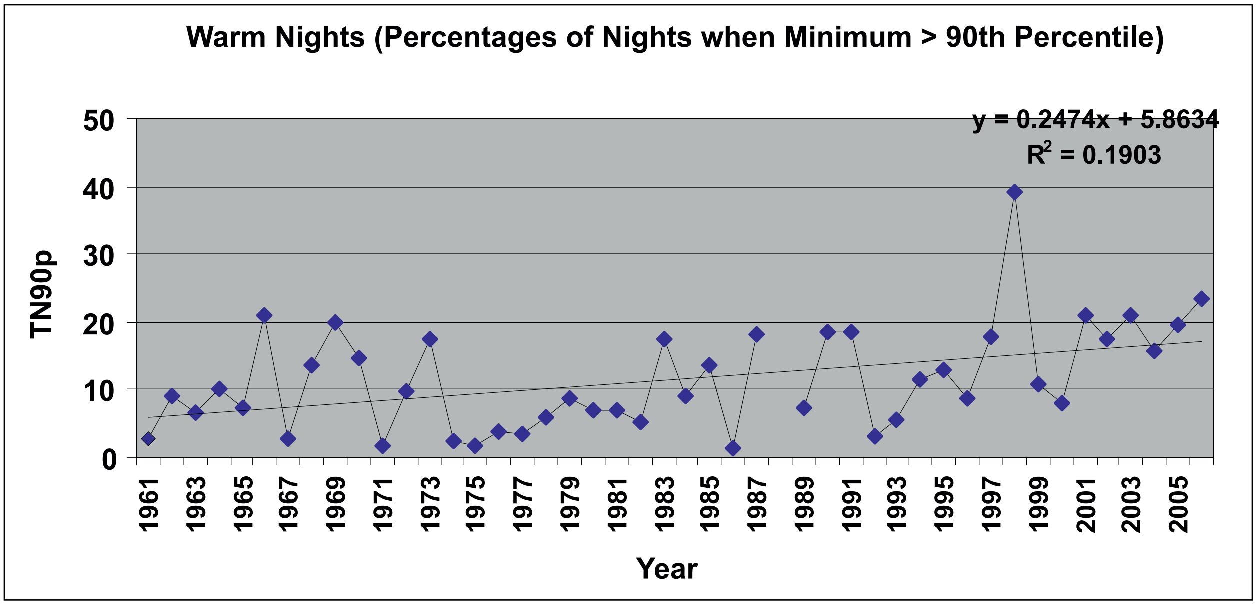


Figure 44. Number of warm nights in Hambantota.

5.3.4 Agro-climatic analysis for Angunakolapellessa agro-meteorological station in Hambantota District

Annual rainfall distribution in Angunakolapellessa agro-meteorological station in Hambantota District is depicted in Figure 45 for the period 1977–2008. Rainfall fluctuations observed during the period 1977–2000 were relatively less compared to the fluctuations since 2000. Unpredictable rainfall variations were observed during the recent past in Angunakolapellessa and crop damages were recorded as a result of these rainfall variations.

5.3.5 Mean monthly rainfall distribution in Angunakolapellessa agro-meteorological station in Hambantota District (1977 -2008)

The mean monthly rainfall distribution in Angunakolapellessa agro-meteorological station during 1977–2008 is depicted in Figure 46. As in the previous case in Eluwankulama, bi-modal rainfall pattern is visible in a year indicating two major rainfall seasons. Starting from the First Inter-Monsoon, mean monthly rainfall received in March was 67.9 mm and it increased up to 107.15 mm in April, indicating 15.4% rainfall in the First Inter-Monsoon (March-April). The Southwest Monsoon starts in May and ends in September; there was 98.2 mm mean monthly rainfall in May and a gradual decline of rainfall thereafter, with only 53.2 mm rainfall recorded in August, which is the month for harvesting paddy in the Yala season. September is the last month of the Southwest Monsoon, getting a mean monthly rainfall of 94.7 mm. The Second Inter-Monsoon starts between October and November, where the highest mean rainfall is recorded in a given year. Mean monthly rainfall in October is 150.9 mm and in November, it is 222.10 mm; the highest amount of rainfall (32.9%) is received during these two months. The Northeast Monsoon is the last monsoon, which starts in December and ends in February. The mean monthly rainfall is gradually reduced over the period – in December (109.2 mm), January (63.7 mm) and February (55.9 mm). Harvesting of Maha crops are undertaken in February. The total amount of rainfall received during the Northeast Monsoon was relatively less (20%) compared to 32.9% rainfall in the Second Inter-Monsoon (Figure 46). The mean rainfall was 80.2 mm during the Maha season. The percentage contribution of monthly rainfall in three decadal periods in Angunakolapellessa is shown in Figure 47.

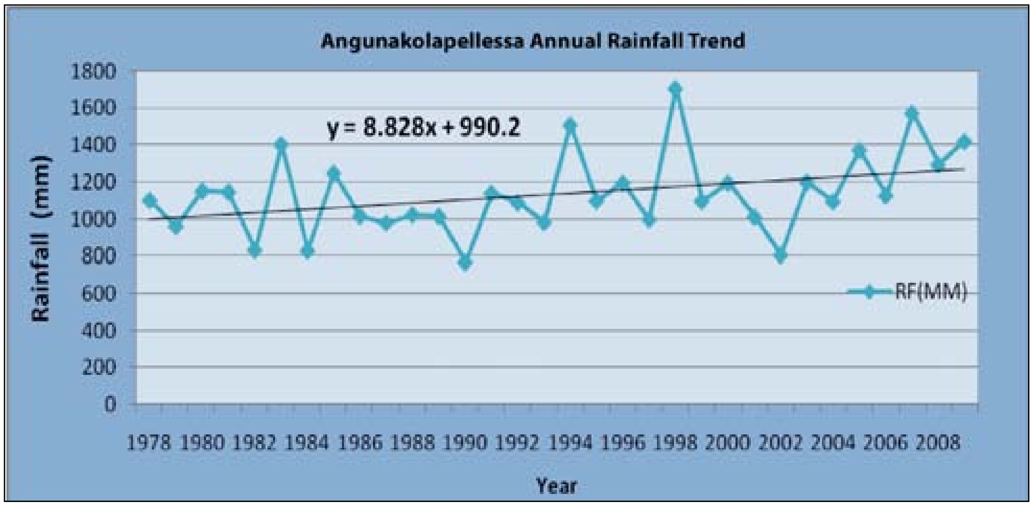


Figure 45. Annual rainfall distribution in Angunakolapellessa agro- meteorological station in Hambantota District, 1977 -2008.

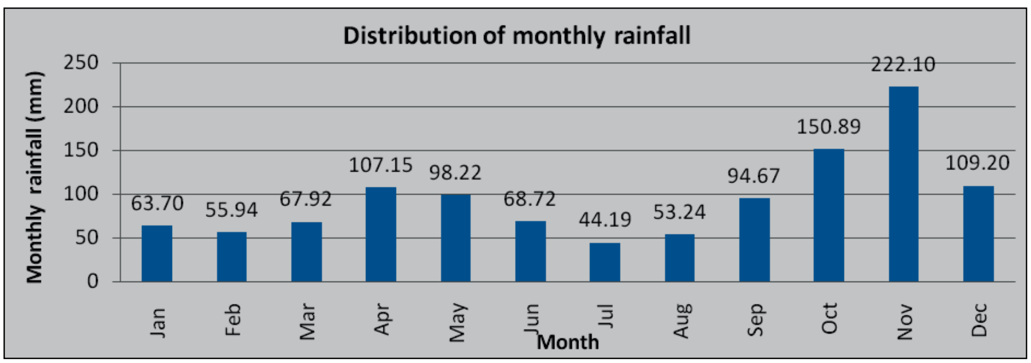


Figure 46. Mean monthly rainfall distribution in Angunakolapellessa agro-meteorological station in Hambantota District, 1977 -2008.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AVG Rainfall	63.7	55.9	67.9	107.1	98.2	68.7	44.2	53.2	94.7	150.9	222.1	109.2
% Rainfall	5.6%	4.9%	6.0%	9.4%	8.6%	6.0%	3.9%	4.7%	8.3%	13.3%	19.6%	9.6%

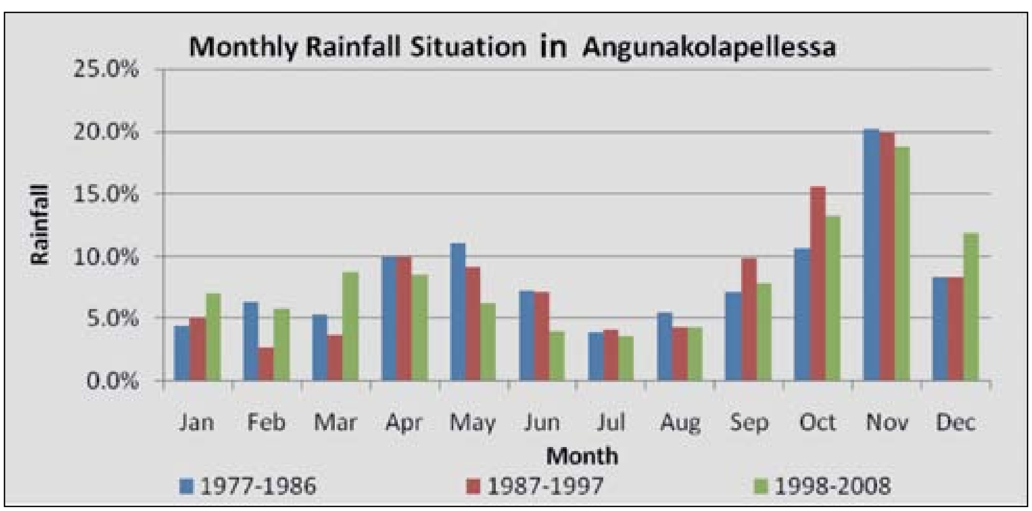


Figure 47. Percentage contribution of monthly rainfall in each decade in Angunakolapellessa agro-meteorological station in Hambantota District, 1976 -2008.

5.3.6 Distribution of average annual number of rainy days in Angunakolapellessa

The average annual number of rainy days was studied from 1977 to 2008; relatively higher variability was observed up to the year 1993 and since then, the variability is relatively less. The lowest average annual number of rainy days of 58 was recorded in 1992. The highest value of about 100 days was recorded in 2006 (Figure 48).

5.3.7 Seasonal rainfall distribution of Angunakolapellessa in Hambantota District, 1977–2008.

The Angunakolapellessa region receives 15.4% rainfall during the First Inter-Monsoon, 31.5% during the Southwest Monsoon, 32.9% during the Second Inter-Monsoon and 20% during the Northeast Monsoon. The highest percentage of rainfall was received during the Second Inter-Monsoon and the lowest during the First Inter-Monsoon (Table 14).

Table 14. Seasonal rainfall characterization in Hambantota District.

	Rainfall characterization in Hambantota district				
		Percentage of rainfall in different seasons			
S.No.	Area	First Inter-Monsoon (March-April)	Southwest Monsoon (May-September)	Second Inter-Monsoon (October-November)	Northeast Monsoon (December-February)
1	Angunakolapellessa Agro meteorological station	15.4	31.5	32.9	20.1

5.3.8 Rainfall distribution in Yala and Maha season

The rainfall distribution in Maha season in agro-meteorology station Angunakolapellessa in Hambantota District is depicted in Figure 49. When the deviation of the rainfall from the mean is considered, there were more number of negative deviations observed till the year 1997. But since 2008, a majority of these deviations were observed as positive. Rainfall distributions and deviations in Yala and Maha seasons are depicted in Figure 49 and Figure 50.

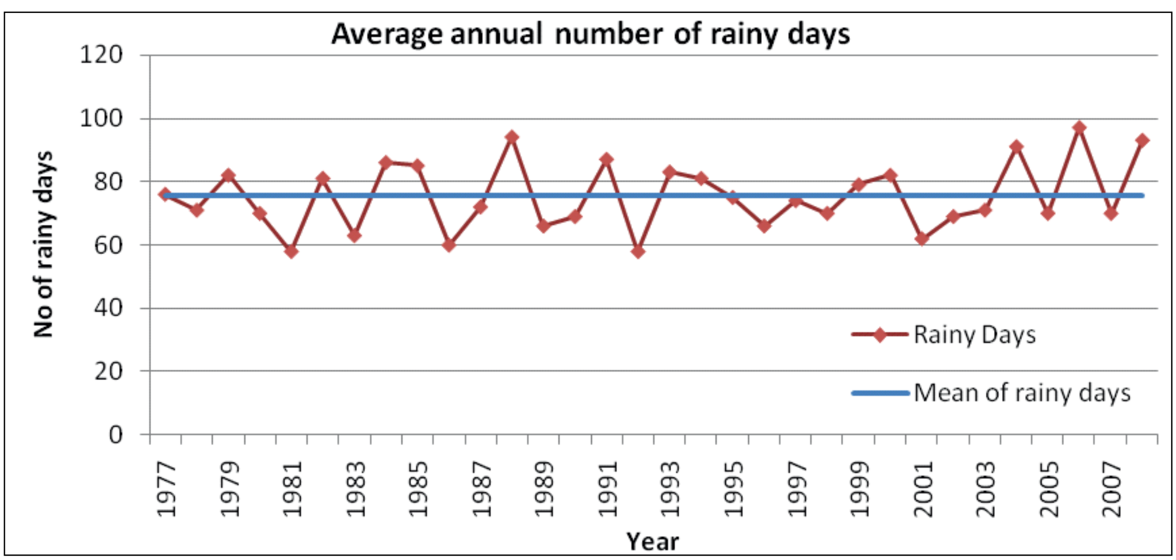


Figure 48. Distribution of average annual number of rainy days in Angunakolapellessa agro-meteorological station in Hambantota District, 1976 -2008.

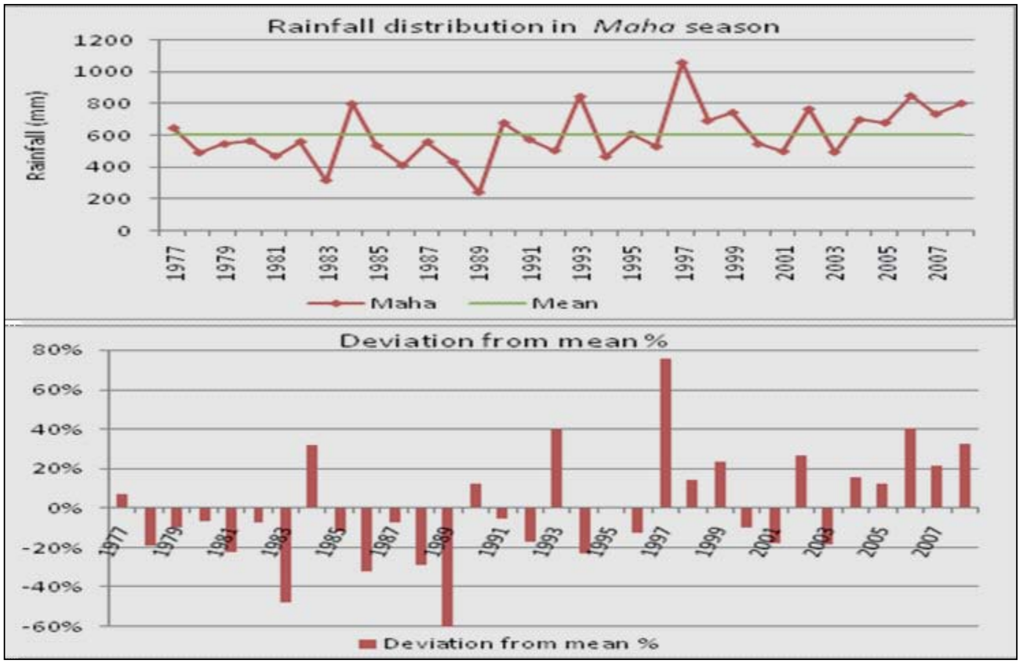


Figure 49. Rainfall distributions in maha season in Angunakolapellessa.

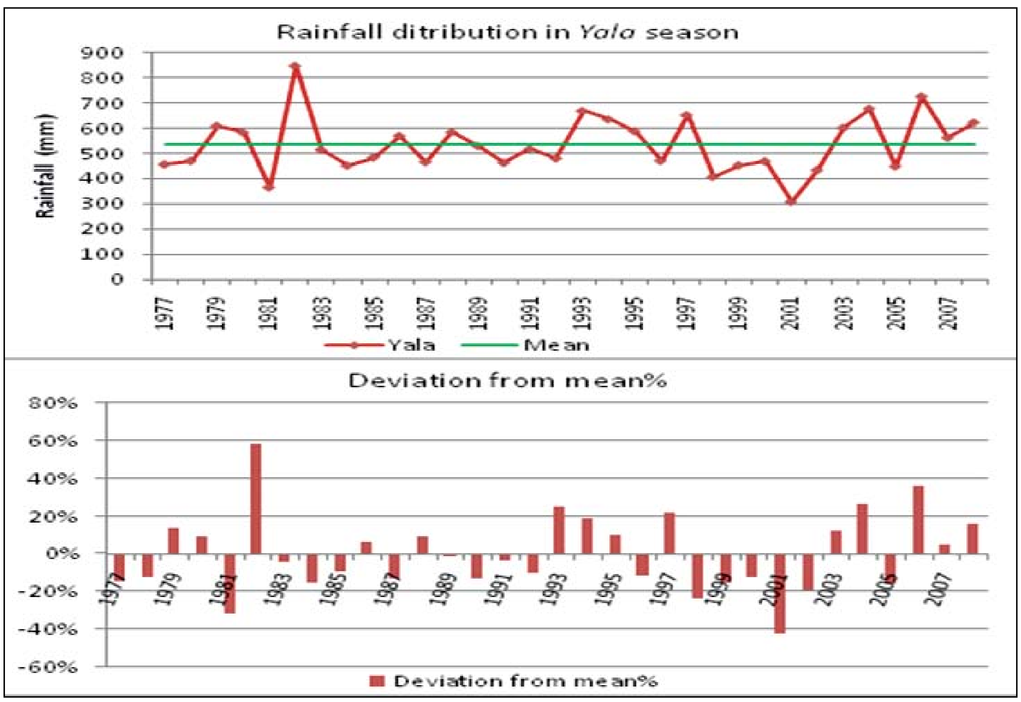


Figure 50. Rainfall distributions in yala season in Angunakolapellessa.

5.3.9 Onset and withdrawal of *Yala* and *Maha* seasons

Three important parameters described in a season for crop production are time of onset of rainfall, withdrawal of rains and the length of the rainy season. Several definitions were sited in literature depending upon the geographical location of the study and the time scale of the data. In order to decide the above three factors, two basic requirements have to be satisfied. First, sustained rainfall to represent the transition from dry season to wet season. Second, the rain that falls should percolate into the soil up to a reasonable depth and should build a moisture profile therein after losses through evaporation.

After considering the above requirements in association with soil physical properties such as water holding capacity, expected evaporative conditions in the atmosphere, normal depth of seed placement of the major soil group of the DL1 region, Reddish Brown Earth (RBE) soils, onset of the season was defined in terms of rainfall. "A spell of at least 30 mm of rain per week in three consecutive weeks after a pre-specified week for the Maha (standard week 35) and Yala (standard week 9) seasons is defined as beginning of rainy season. If a three week criterion was not satisfied, the condition was relaxed up to two consecutive weeks with rainfall equal to or higher than 30 mm. This relaxation was particularly important for the Yala season where the continuity of the rains is always uncertain. But under the dry zone's conditions where the rainfall is patchy and intermittent in nature, an evaluation of the continuity up to two to three weeks is necessary to avoid a false start of the seasons. Similarly, the first occurrence of a long dry spell (three consecutive weeks with less than 30 mm of rainfall after a pre-specified week (standard week 50 and 16 for Maha and Yala seasons, respectively) was used as the criterion for the end of a season. Length of the season was taken as the number of weeks between the end of the season and the onset of the season. Using these criteria, onset and withdrawal of the rainy season and the amount of rainfall within each of the seasons were determined from the simulated data (Punyawardena 2002, p.15).

The weekly rainfall data for this study was generated using climate data analysis. Thirty three years (1976-2008) of weekly historical rainfall data of Angunakolapellessa was used to calculate the time of onset and withdrawal of rains, and length of the seasons. According to the Yala and Maha seasons, onset and withdrawal were determined for three periods as 1976-1986, 1987-1997 and 1998-2008. Onset of the seasons in terms of rainfall was defined as a spell of at least 30 mm of rain per week in three consecutive weeks after a pre-specified week, for the Yala and Maha seasons. Similarly, the first occurrence of a long dry spell (three consecutive weeks with less than 30 mm of rainfall after a pre-specified week, – week 50 and 16 – for Maha and Yala seasons, respectively, was used as a criterion for the end of a season. Also length of the season was taken as the number of weeks between the end of the season and onset of the season. According to these criteria, onset and withdrawal of the season were determined from the historical weekly rainfall data of Angunakolapellessa. According to the weekly rainfall data of years 1977-2008, 13th week and 42nd week were taken as the onset of Yala and Maha, respectively. Also, withdrawal of Yala and Maha were taken at 23rd week and 5th week (in the following year), respectively (Table 15).

Table 15. Normal dates of onset and withdrawal of Yala and Maha seasons in Angunakolapellessa.

	Angunakolapellessa			
	Onset		Withdrawal	
Period	Yala	Maha	Yala	Maha
1977-2008	13th week	42nd week	23rd week	5th week
1977-1986	14th week	42nd week	23rd week	3rd week
1987-1997	14th week	42nd week	23rd week	4th week
1998-2008	10th week	42nd week	23rd week	3rd week

5.3.10 Maximum and minimum temperature distribution in Angunakolapellessa

Mean annual maximum temperature distribution in Angunakolapellessa from 1977 to 1997 showed mostly in downward temperature deviations from the mean. Upward deviations from the mean were shown in the period of 1998-2008 of mean annual maximum temperature (Figure 51). Mean annual minimum temperature in Angunakolapellessa indicated a downward trend during the period 1977-1994, and an upward trend during the period 1995-2008 (Figure 52).

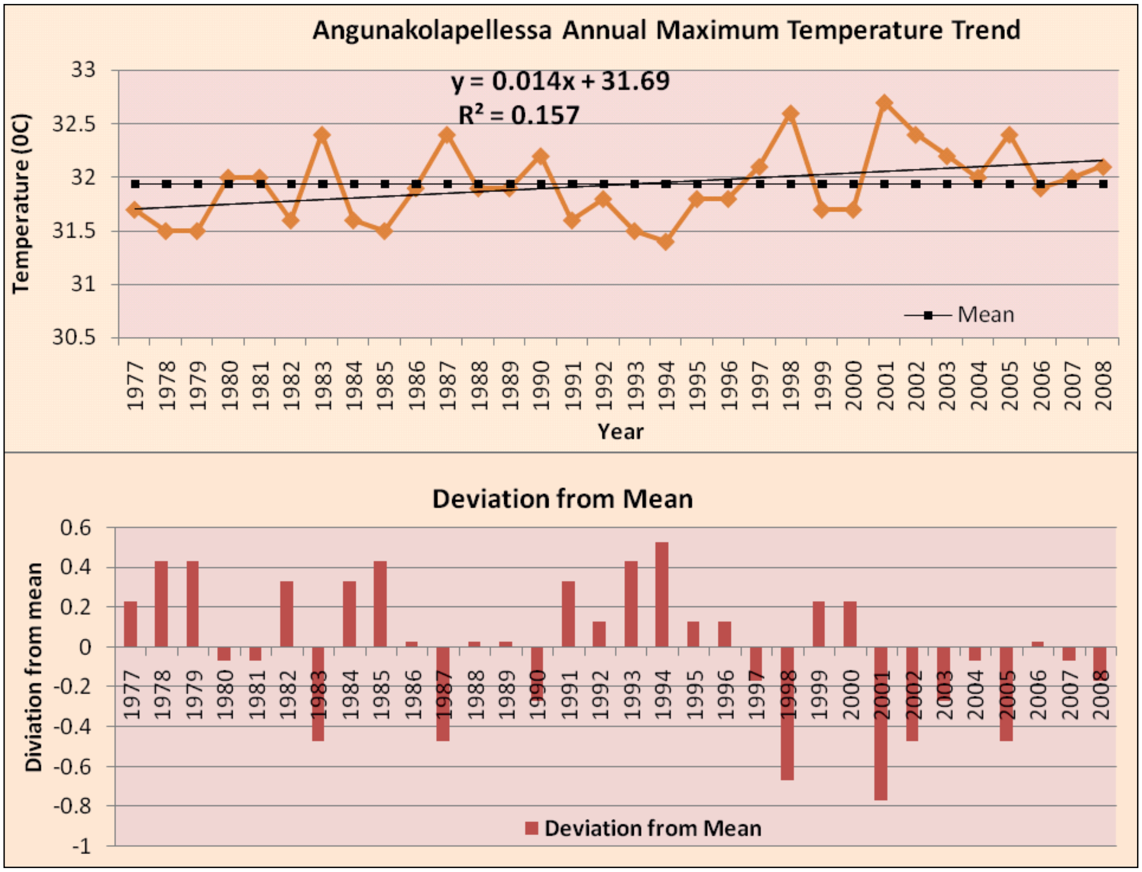


Figure 51. Mean annual maximum temperature distribution in Angunakolapellessa.

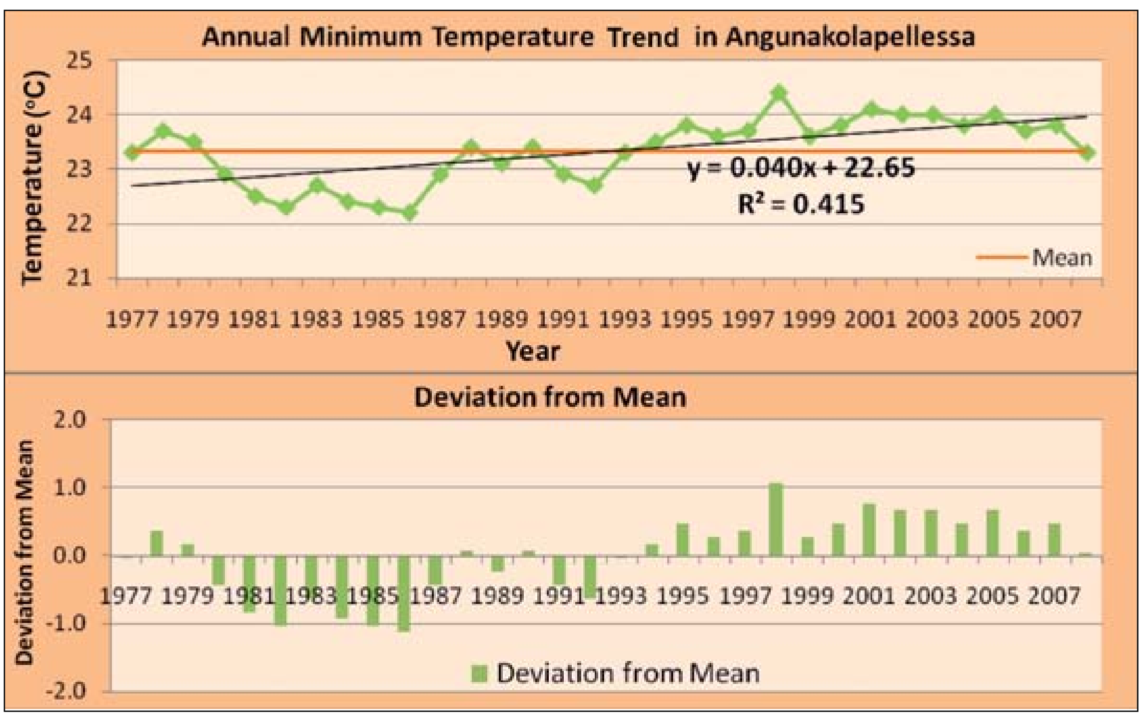


Figure 52. Mean annual minimum temperature distribution in Angunakolapellessa.

5.3.11 Climatic trends and variability

The annual mean, Standard Deviation (SD) and Coefficient of variation (CV) of maximum temperature, minimum temperature and annual rainfall in Angunakolapellessa from 1977 to 2008 are shown in Table 7. The annual mean of rainfall, maximum temperature and minimum temperature in Angunakolapellessa are calculated as 1135.9 mm, 31.9°C, 23.3°C, respectively. These figures for Eluwankulama are in Appendix Table 13.

Results of the detailed analysis of initial and conditional probabilities of rainfall, probabilities of dry and wet spells of consecutive weeks, drought analysis (meteorological and agricultural droughts), climatic trend analysis and consolidated dates of heavy rainfall pertaining to Angunakolapellessa and Eluwankulama are indicated in Appendixes 1 and 2.

5.3.12 Drought analysis of Angunakolapellessa

Drought analysis was divided into agricultural drought and meteorological drought. Agricultural drought is defined as a period of four consecutive weeks (severe meteorological drought) with a rainfall deficiency of more than 50% of the long term average (LTA) or with a weekly rainfall of 5 mm or less. Meteorological drought is defined as a period of prolonged dry weather condition due to below normal rainfall. There are three types of drought conditions that are based on rainfall deficit from normal, named as mild drought (0-25%), moderate drought (26-50%) and severe drought (>50%).

Agricultural drought

Agricultural droughts were examined for the last 32 years from 1977-2008. Of this 32-year period, agricultural droughts were recorded throughout 19 years (68.8%) in the period of March to September (Yala season). In these years, the drought was generally spread from the 36th to the 42nd week (3 September to 21 October). During the period from October to February (Maha season), only one agricultural drought (6%) was experienced, in 1995, which spread from the 46th to the 51st week (12 November to 23 December) (Table 16).

Table 16. Agricultural drought in Angunakolapellessa (1977-2008).

Condition/Season	Number of years indicating the droughts	%
Yala	1	68.8
Maha	2	6.0
No drought	11	25.2

Meteorological drought

Meteorological droughts were analyzed for 32 years starting from 1977-2008. Throughout most of the cases of drought in these 19 years (59%), meteorological droughts were not recorded, while during 11 years (34%) mild droughts and during two years (6%) moderate droughts were recorded. Severe drought was not recorded throughout the 32-year period (Table 17).

Table 17. Meteorological drought in Angunakolapellessa (1977-2008).

Condition/Season	Number of years indicating the droughts	%
No drought	19	59.0
Mild drought	11	34.0
Moderate drought	2	6.0
Severe drought	0	0.0

5.3.13 Water balance and Length of Growing Period (LGP) analysis

Availability of water in the right quantity at the right time is essential for crop growth and development. To assess water availability for crops, soil moisture is to be taken into account and the net water balance through soil moisture can be analyzed using the water balance technique. The concepts of Potential Evapotranspiration (PET) and water balance have been extensively applied for studies such as climatic classification, aridity, humidity and drought. At the start of the rainy season, seed germination and initial crop growth depend on the amount and distribution of rainfall. The beginning and end of growing period are determined by the Index for Moisture Adequacy (IMA) values. The length of growing period is an important parameter, which helps in assessing climatic suitability for crop production.

5.3.14 Length of growing period (LGP) of Angunakolapellessa

The beginning and end of growing periods are identified based on Index for Moisture Adequacy (IMA) values. The growing season begins when the IMA is above 50% consecutively for at least three weeks. The end of season is identified when the IMA falls below 25% for four consecutive weeks. Generally, it can be concluded that over the past 32-year period (1977-2008), year-round growing season can be seen. This included Yala and Maha seasons in Sri Lanka. During most of the years, the growing season begins in the 20^{th} week (7 April) and ends in the 16^{th} week the following year (14 April). Accordingly, length of the growing period (LGP) is about 48-50 weeks, indicating that year-round cultivation can be done (Figure 53).

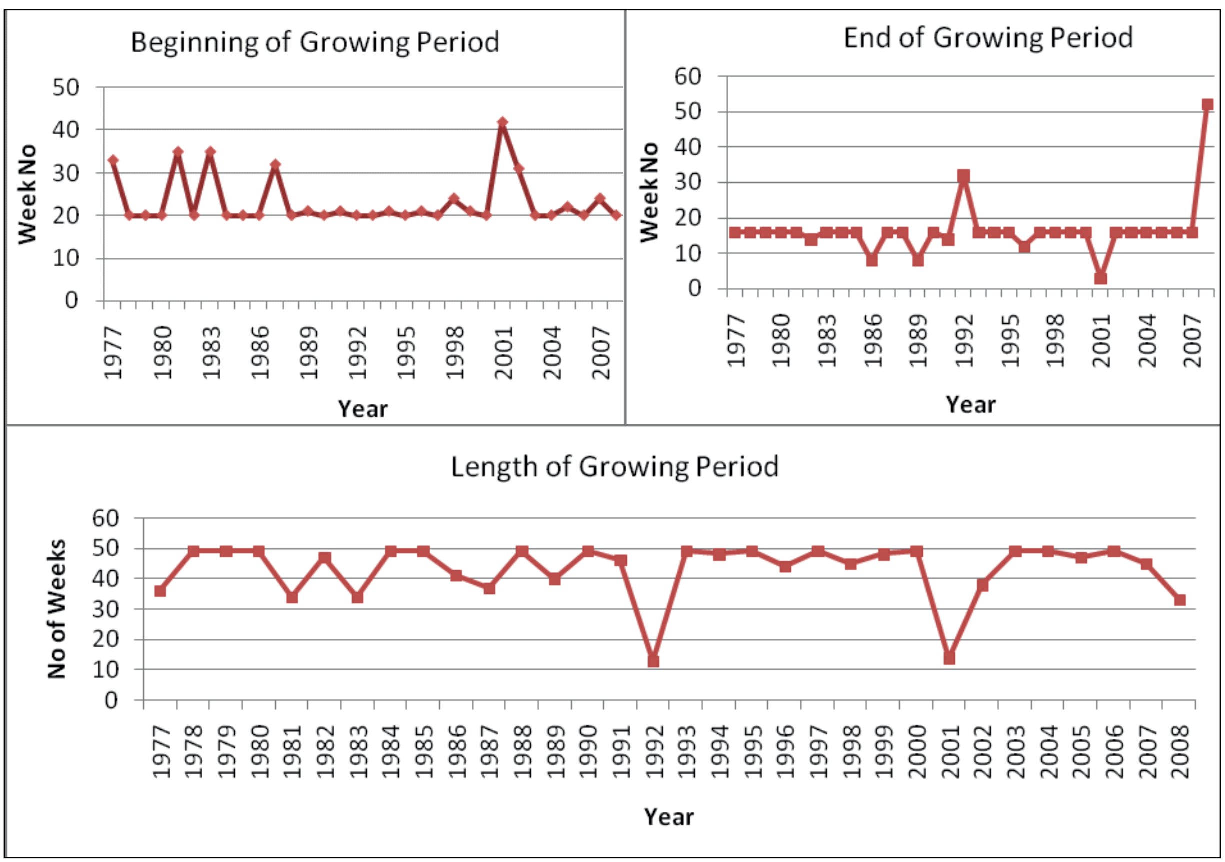


Figure 53. Graphical illustration of growing period in Angunakolapellessa in Hambantota District (1977-2008).

5.3.15 Classification of climates according to the moisture index – Angunakolapellessa

Agro-meteorological stations and area around Angunakolapellessa was classified based on the classification of climate types introduced by Thornthwaite and Mather in 1955. An average yearly value of Im for the period of 1977 to 2008 was -28.4% for Angunakolapellessa. Therefore, it is taken under the Dry sub-humid (C1) climatic type (Figure 54). In addition to that, from yearly values of Im, it is easy to understand how climatic type of a particular place is changing from year to year (Table 18).

Table 18. Distribution of Index of moisture (%) in three decadal periods in Angunakolapellessa.

	Angunakolapellessa	
1977–1986	1987–1997	1998–2008
-31.8	-29.0	-24.3
Dry sub-humid (C1)	Dry sub-humid (C1)	Dry sub-humid (C1)

5.3.16 Water balance analysis

The results of average water deficit, average water surplus, average index of moisture adequacy and average soil moisture index in Angunakolapellesa during 1977-2008 is given below (Tables 19, 20, 21, 22).

Table 19. Average water deficit (mm) in Angunakolapellessa (1977-2008).

Period	Yala (Mar-Sep) (week 10-39)	Maha (Oct-Feb) (week 40-9)
1977-1986	13.19	7.44
1987-1997	13.82	7.55
1998-2008	12.69	5.52

Table 20. Average water surplus (mm) in Angunakolapellessa (1977-2008).

Period	Yala (Mar-Sep) (week 10-39)	Maha (Oct-Feb) (week 40-9)
1977-1986	0.31	1.85
1987-1997	0.03	5.40
1998-2008	0.19	5.00

Table 21. Average Index of Moisture Adequacy (IMA) in Angunakolapellessa (1977-2008).

Period	Yala (Mar-Sep) (week 10-39)	Maha (Oct-Feb) (week 40-9)
1977-1986	61.33	75.87
1987-1997	59.60	76.04
1998-2008	62.17	81.43

Table 22. Average Soil Moisture Index (SMI) in Angunakolapellessa (1977-2008).

Period	Yala (Mar-Sep) (week 10-39)	Maha (Oct-Feb) (week 40-9)
1977-1986	38.14	55.27
1987-1997	34.49	60.55
1998-2008	40.82	65.24

5.4 Climatology at Anuradhapura District

Climatological behavior (1961-1990) of Maximum, Minimum temperatures, rainfall and Diurnal Temperature Range (DTR) is shown in Figure 55. Generally, behavior of maximum temperature is higher during March and April due to the higher incoming solar radiation. Behavior of minimum temperature is slightly different. Rainfall pattern is Bi-model and maximum rainfall was reported in April (First Inter-Monsoon) and October (Second Inter-Monsoon). Total average annual rainfall at Anuradhapura is 1284 mm. After receiving higher rainfall during the Second Inter-Monsoon, the rainy condition continues to prevail until the early part of Northeast Monsoon. Diurnal Temperature Range (DTR) indicates that, higher values prevail during February, March and April. Even though the climatological behavior at Anuradhapura is indicated above, following are the changes and variabilities identified by long term analysis.

5.4.1 Change of minimum temperature for different periods

Figures 56 (a), (b) and (c) show the annual average minimum temperatures during different seasons. The baseline was chosen as 1961-1990 to calculate the temperature anomalies. The minimum temperature has been significantly increased by about 0.0243 degrees Celsius per year during the period 1961-1990. But it can be seen that the present trend (1990–2009) of increasing minimum temperature is 0.039 degree Celsius per year. It indicated that the increasing trend is higher during the recent past. From Figure 56 (b) it is obvious that the minimum temperature has slightly decreased with the increasing linear trend. The analysis of a long period shows a positive temperature anomaly before the year 1990, but the minimum temperatures show a sudden drop after 1990 and thereafter it has been gradually increasing. It can be seen that minimum temperature was high before 1900, according to the base period 1961-1990. After 1900 the temperature has gradually increased (Figures 57 (a), (b) and (c)).

5.4.2 Change of maximum temperature for different periods

Figures 57 (a) and (b) show the annual average maximum temperatures during different periods. Maximum temperature has been increased by about 0.042 degrees Celsius per year during the period 1961-1990. However, there is no trend that can be observed from the analysis of the data during 1990-2007.

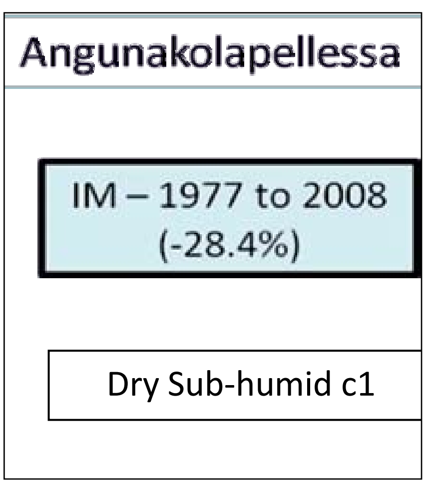


Figure 54. Classification of climate in an around Angunakolapellessa according to the moisture index.

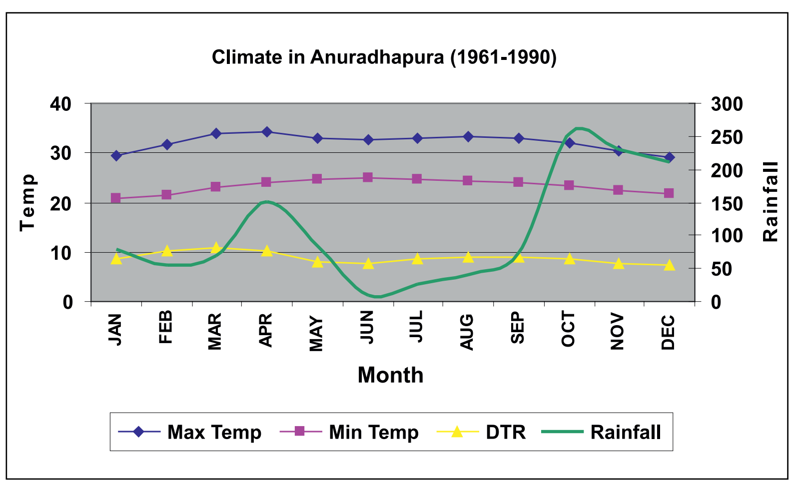


Figure 55. Averages of rainfall, maximum temperature, minimum temperature and diurnal temperature range.

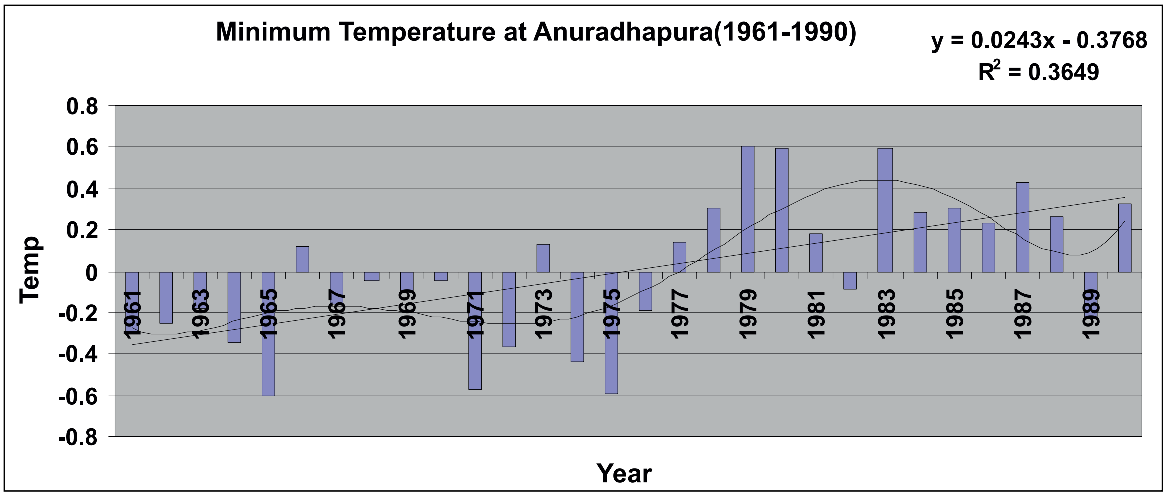


Figure 56(a). Minimum temperature anomaly trend for 1961-1990 (Base period 1961-1990).

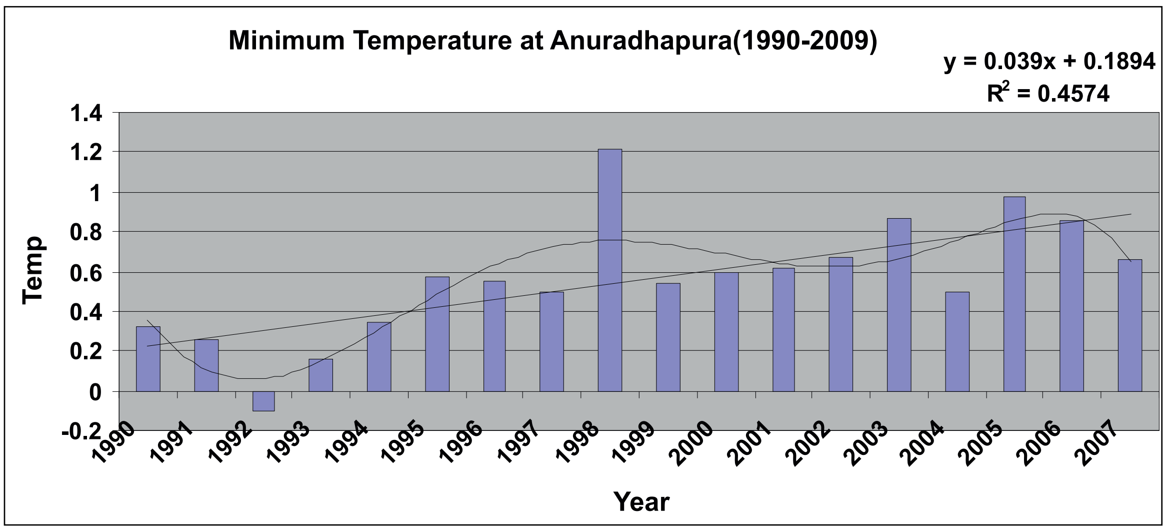


Figure 56(b). Minimum temperature anomaly trend for 1990-2009 (Base period 1961-1990).

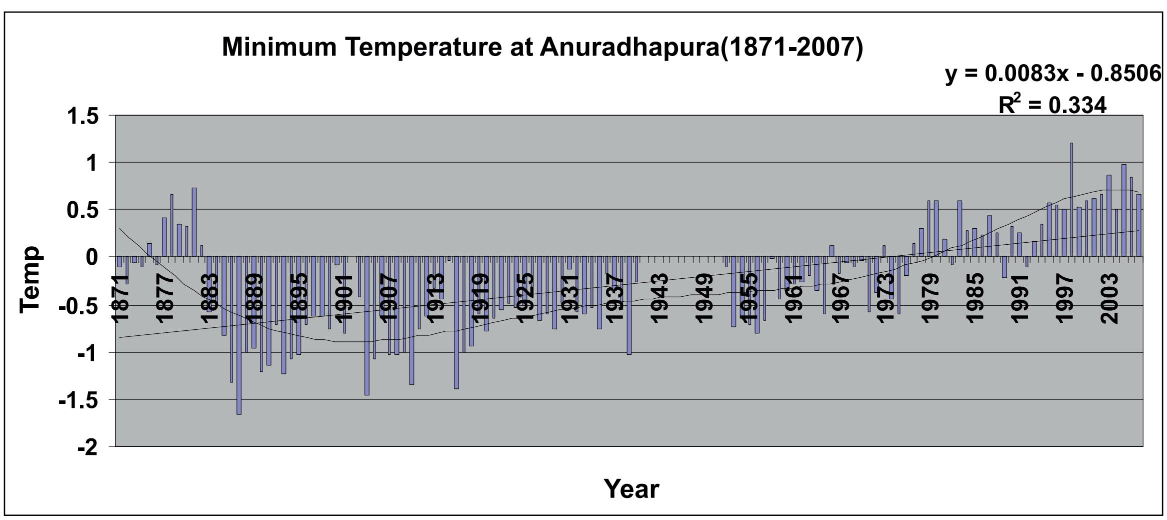


Figure 56(c). Minimum temperature anomaly trend for 1871-2007 (Base Period 1961-1990).

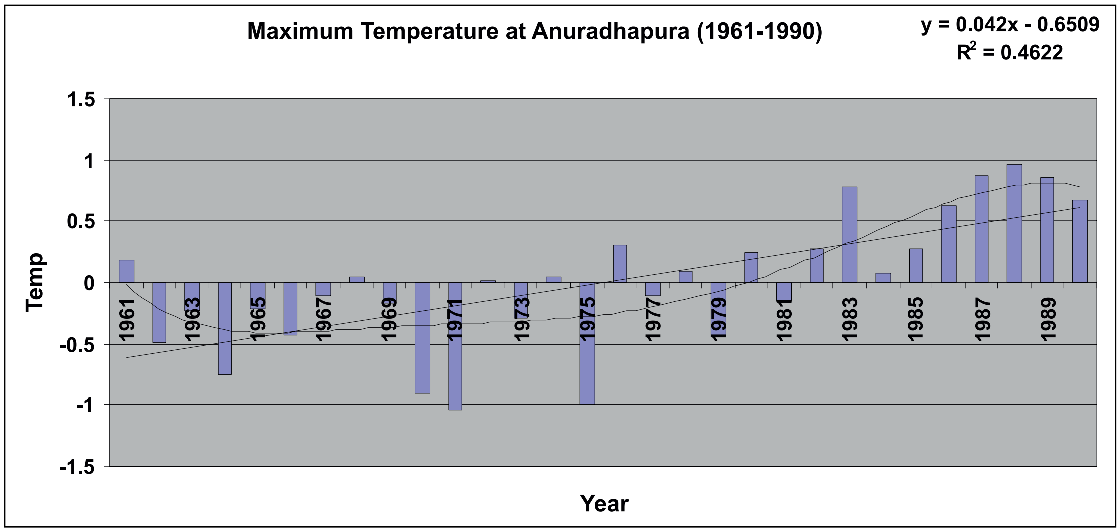


Figure 57(a). Maximum temperature anomaly trend for 1961-1990 (Base period 1961-1990.

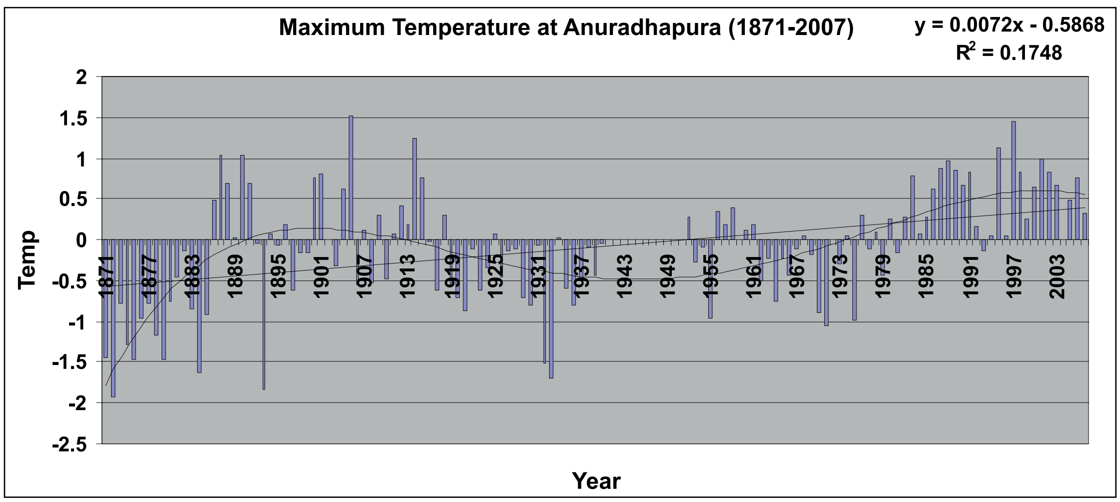


Figure 57(b). Maximum temperature anomaly trend for 1990-2007 (Base period 1961-1990).

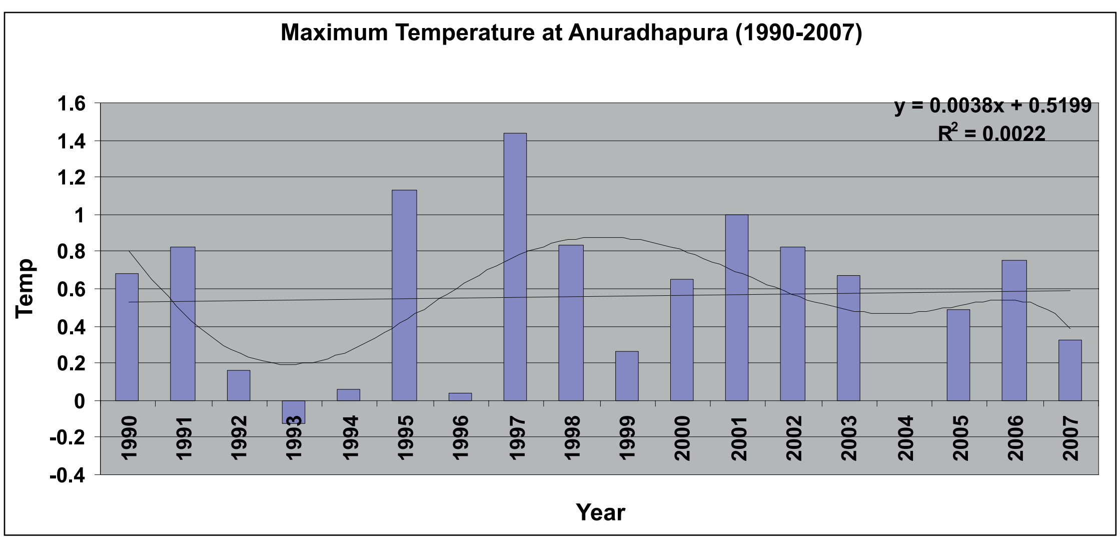


Figure 57(c). Maximum temperature anomaly trend for 1990-2007 (Base Period 1961-1990).

5.4.3 Change of rainfall pattern in Anuradhapura District

Analysis has been done using the 5-year smoothing technique using the following equation (Samui 1994)

$$Y = (X_{i-2} + 4X_{i-1} + 6X_i + 4X_{i+1} + X_{i+2})/16$$

where, X_i is the rainfall at i^{th} Year.

Generally, the rainfall pattern shows a decreasing trend after 1950s. Before that it does not show any change. After 2000, the decreasing trend is higher than before in Anuradhapura area (Figures 58 (a), (b) and (c)).

Change of Diurnal Temperature Range (DTR) is shown in Figure 59. It indicated an increasing trend in Anuradhapura area.

Linear trend of DTR at Anuradhapura shows a slight increasing trend, but it can be seen that there is a slight decreasing trend after 1998. Extreme climatic Indices established in Anuradhapura area are as follows.

- Maximum of minimum temperature has been increased (Figure 60)
- Maximum of maximum temperature has been increased, but it shows a decreasing trend during the recent past (Figure 61)
- Warm days (Percentage of days when Maximum (TX)>90th percentile) have been increased (Figure 62)
- Warm nights (Percentage of days when TX>90th percentile) have been increased (Figure 63).

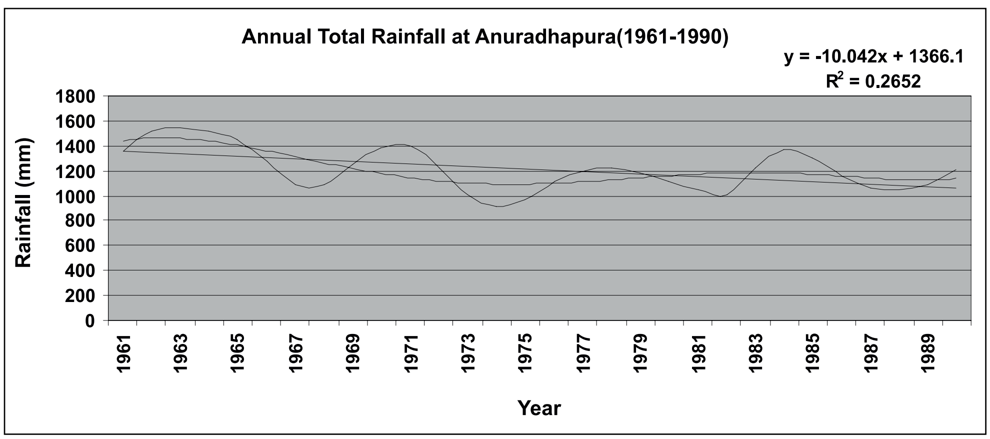


Figure 58(a). Rainfall trend for 1961-1999.

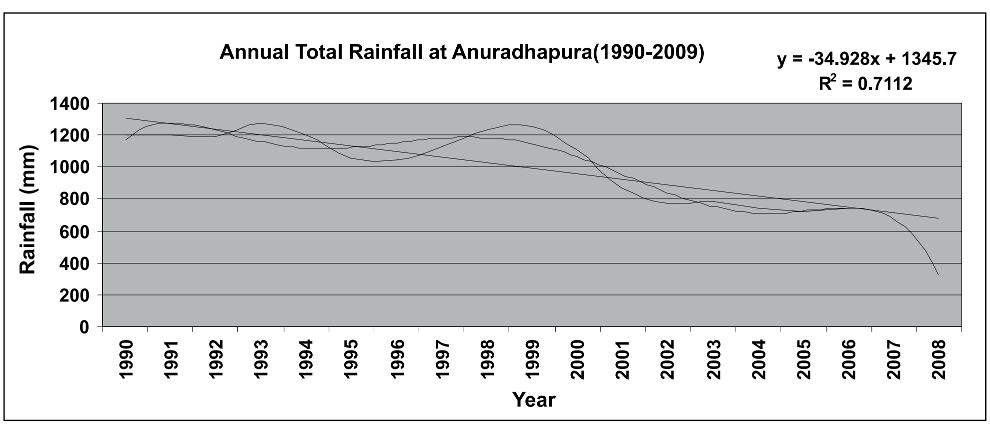


Figure 58(b). Rainfall trend for 1991-2009.

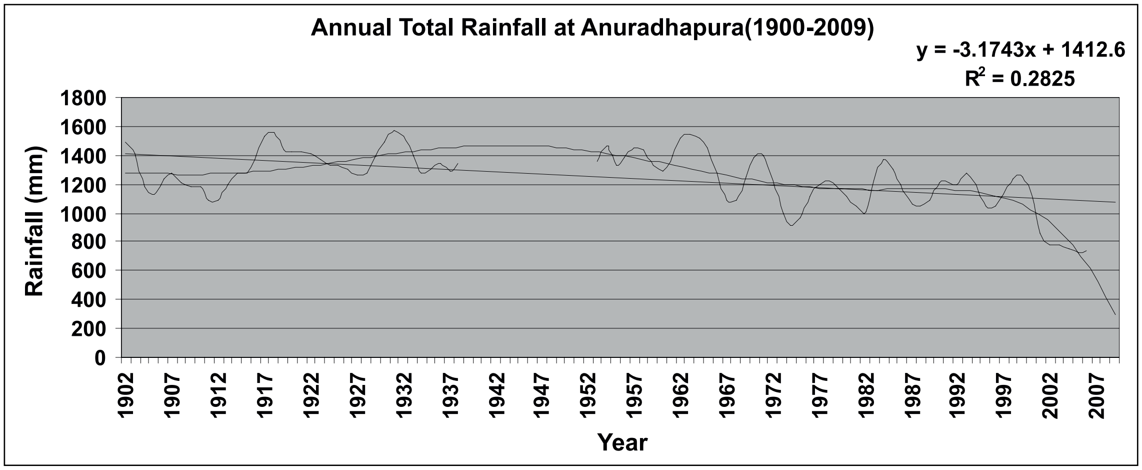


Figure 58(c). Rainfall trend for 1900-2009.

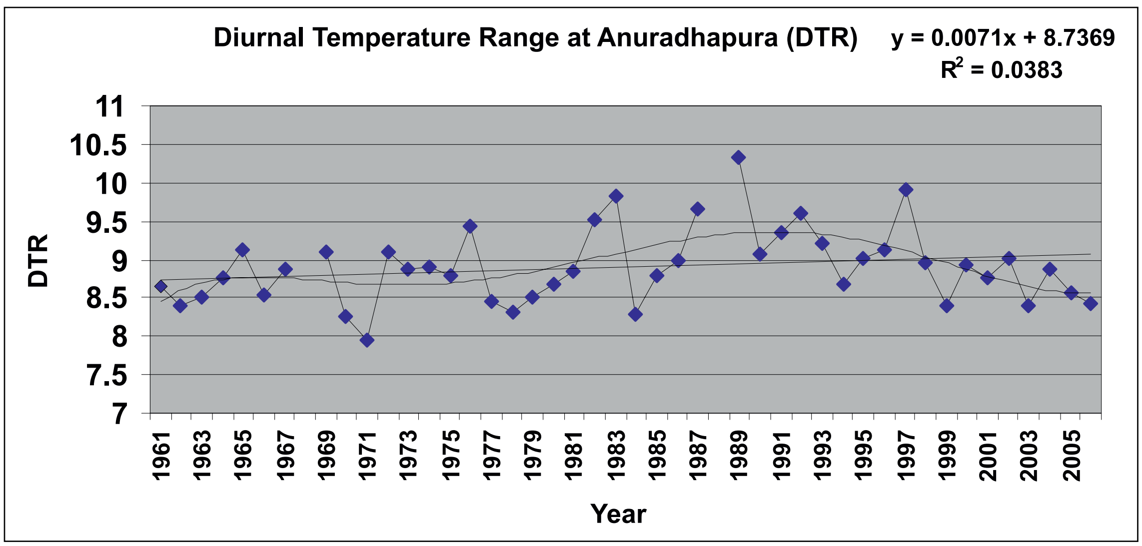


Figure 59. Diurnal Temperature Range (DTR) at Anuradhapura District.

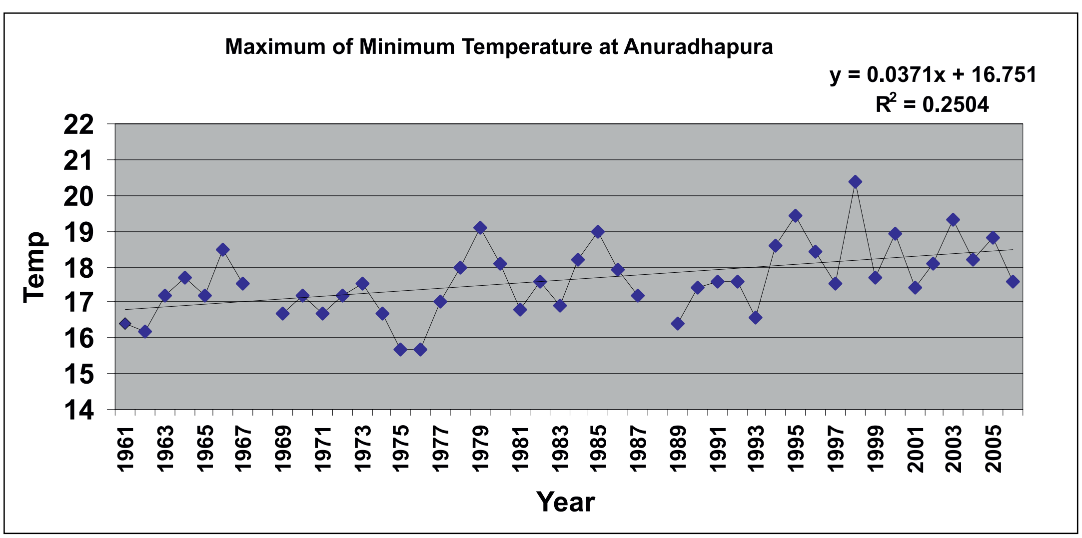


Figure 60. Maximum of minimum temperature in Anuradhapura District.

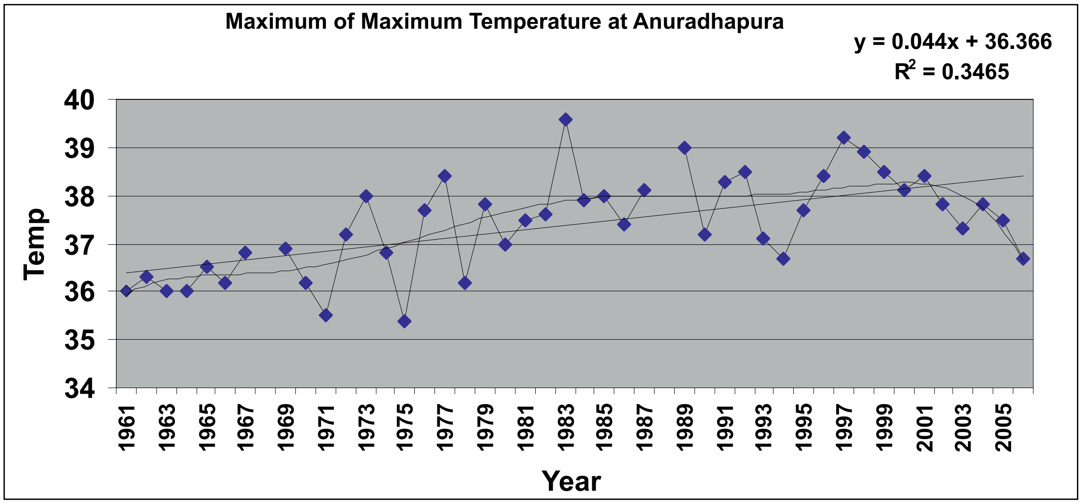


Figure 61. Maximum of maximum temperature in Anuradhapura District.

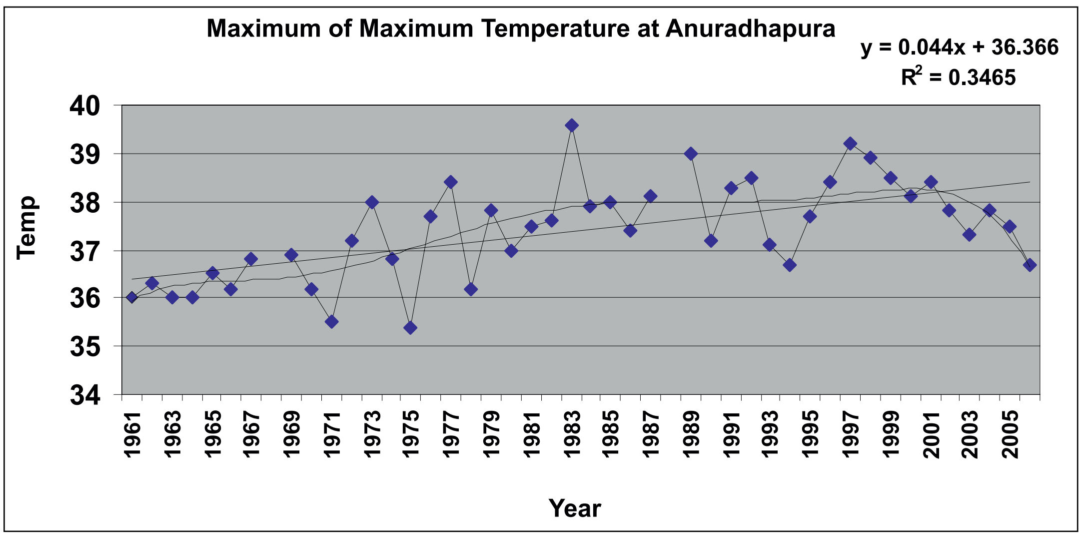


Figure 62. Number of warm days in Anuradhapura District.

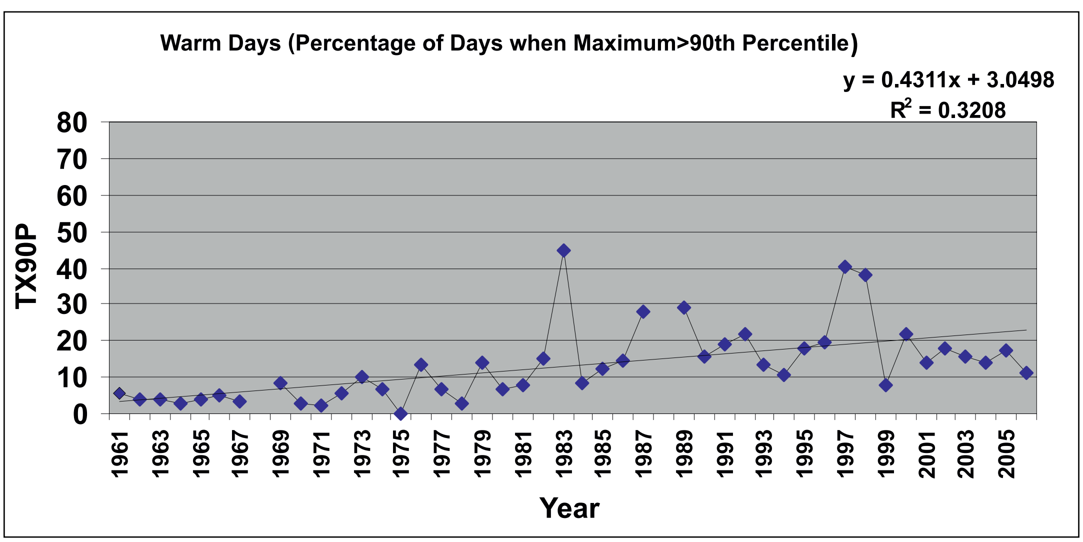


Figure 63. Number of warm nights in Anuradhapura District.

6. Conclusion

Analysis found that both the Maximum and Minimum temperatures have been increased over the years. Extreme temperatures (No. of days with reported higher temperature) also increased with the increase of temperature. Therefore, crop damage and yield reduction may occur if the atmospheric temperature exceeds the optimum temperature of different crops. Detailed temperature analyses have to be done to identify the above mentioned impacts.

Behavior of rainfall pattern is erratic. Even though Decadal Variability has decreased for some climatic seasons, inter seasonal variability may be high. It may cause undesirable impact upon rain-fed agriculture practices. But, rainwater harvesting and soil water storage capacity methods can be introduced to avoid the impacts from rainfall variability. In addition indigenous technology, rainwater harvesting also possible as adaptation methods.

During 1977 to 2008, the onset and withdrawal of Yala and Maha seasons was delayed by 3 to 4 weeks. Agricultural drought occurred 19 times in the Yala season as well as 2 times in the Maha season during the same period. Meteorological drought was not experienced during the period under study. Length of growing period was also calculated for the region and it was found that year round cultivation is possible in these regions. Supplementary irrigation requirement has increased, more significantly in the Yala season for growth and mid stage of the crops in both stations over the period 1976–2008.

In Sri Lanka, the knowledge about weather, climate and climate change of farmers is very poor. Therefore, proper mechanism has to be introduced to enhance the knowledge of farmers about weather and climate and grassroot level applications are recommended to attend to this issue.

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Appendixes

Appendix 1. Agro-climatic Data Analysis at Angunakolapellessa

Initial and Conditional Probabilities of Rainfall
(Markov chain probability)

Station: Angunakolapellessa

Period: 1977-2008 Limit: 10

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.3548	0.6452		0.3333	0.6667	0.6250	0.3750
2	0.4063	0.5938		0.5455	0.4545	0.6667	0.3333
3	0.3438	0.6563		0.3846	0.6154	0.6842	0.3158
4	0.1875	0.8125		0.2727	0.7273	0.8571	0.1429
5	0.3438	0.6563		0.3333	0.6667	0.6538	0.3462
6	0.2500	0.7500		0.3636	0.6364	0.8095	0.1905
7	0.4063	0.5938		0.6250	0.3750	0.6667	0.3333
8	0.2813	0.7188		0.4615	0.5385	0.8421	0.1579
9	0.3750	0.6250		0.4444	0.5556	0.6522	0.3478
10	0.4063	0.5938		0.4167	0.5833	0.6000	0.4000
11	0.4375	0.5625		0.6154	0.3846	0.6842	0.3158
12	0.3438	0.6563		0.4286	0.5714	0.7222	0.2778
13	0.5000	0.5000		0.6364	0.3636	0.5714	0.4286
14	0.6875	0.3125		0.7500	0.2500	0.3750	0.6250
15	0.6563	0.3438		0.6818	0.3182	0.4000	0.6000
16	0.5625	0.4375		0.6190	0.3810	0.5455	0.4545
17	0.5625	0.4375		0.5000	0.5000	0.3571	0.6429
18	0.5000	0.5000		0.5000	0.5000	0.5000	0.5000
19	0.3438	0.6563		0.5625	0.4375	0.8750	0.1250
20	0.5000	0.5000		0.8182	0.1818	0.6667	0.3333
21	0.4375	0.5625		0.3750	0.6250	0.5000	0.5000
22	0.6250	0.3750		0.7857	0.2143	0.5000	0.5000
23	0.5000	0.5000		0.5500	0.4500	0.5833	0.4167
24	0.4375	0.5625		0.4375	0.5625	0.5625	0.4375
25	0.4063	0.5938		0.4286	0.5714	0.6111	0.3889
26	0.5000	0.5000		0.5385	0.4615	0.5263	0.4737
27	0.3125	0.6875		0.3750	0.6250	0.7500	0.2500
28	0.4688	0.5313		0.6000	0.4000	0.5909	0.4091
29	0.1250	0.8750		0.1333	0.8667	0.8824	0.1176
30	0.3125	0.6875		0.7500	0.2500	0.7500	0.2500
31	0.2188	0.7813		0.3000	0.7000	0.8182	0.1818

Continued

continued

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
32	0.4063	0.5938		0.4286	0.5714	0.6000	0.4000
33	0.3438	0.6563		0.4615	0.5385	0.7368	0.2632
34	0.2813	0.7188		0.2727	0.7273	0.7143	0.2857
35	0.4375	0.5625		0.3333	0.6667	0.5217	0.4783
36	0.3750	0.6250		0.5714	0.4286	0.7778	0.2222
37	0.4688	0.5313		0.5833	0.4167	0.6000	0.4000
38	0.5000	0.5000		0.4000	0.6000	0.4118	0.5882
39	0.7188	0.2813		0.6875	0.3125	0.2500	0.7500
40	0.5938	0.4063		0.6087	0.3913	0.4444	0.5556
41	0.5625	0.4375		0.6842	0.3158	0.6154	0.3846
42	0.7188	0.2813		0.7778	0.2222	0.3571	0.6429
43	0.7500	0.2500		0.6957	0.3043	0.1111	0.8889
44	0.7188	0.2813		0.7500	0.2500	0.3750	0.6250
45	0.9063	0.0938		0.9565	0.0435	0.2222	0.7778
46	0.9063	0.0938		0.8966	0.1034	0.0000	1.0000
47	0.8438	0.1563		0.8276	0.1724	0.0000	1.0000
48	0.7500	0.2500		0.7037	0.2963	0.0000	1.0000
49	0.5938	0.4063		0.6667	0.3333	0.6250	0.3750
50	0.6875	0.3125		0.6842	0.3158	0.3077	0.6923
51	0.5000	0.5000		0.5000	0.5000	0.5000	0.5000
52	0.5000	0.5000		0.5000	0.5000	0.5000	0.5000

Initial and Conditional Probabilities of Rainfall
(Markov chain probability)

Station: Angunakolapellessa

Period: 1977-2008 **Limit:** 20

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.2581	0.7419		0.2222	0.7778	0.7273	0.2727
2	0.2813	0.7188		0.2500	0.7500	0.7083	0.2917
3	0.2188	0.7813		0.3333	0.6667	0.8261	0.1739
4	0.1250	0.8750		0.2857	0.7143	0.9200	0.0800
5	0.2188	0.7813		0.0000	1.0000	0.7500	0.2500
6	0.1563	0.8438		0.1429	0.8571	0.8400	0.1600
7	0.2500	0.7500		0.4000	0.6000	0.7778	0.2222
8	0.2500	0.7500		0.2500	0.7500	0.7500	0.2500
9	0.2188	0.7813		0.2500	0.7500	0.7917	0.2083
10	0.2813	0.7188		0.2857	0.7143	0.7200	0.2800
11	0.3125	0.6875		0.5556	0.4444	0.7826	0.2174
12	0.2500	0.7500		0.3000	0.7000	0.7727	0.2273
13	0.2813	0.7188		0.2500	0.7500	0.7083	0.2917
14	0.5313	0.4688		0.4444	0.5556	0.4348	0.5652
15	0.4688	0.5313		0.4118	0.5882	0.4667	0.5333
16	0.3750	0.6250		0.3333	0.6667	0.5882	0.4118
17	0.4063	0.5938		0.2500	0.7500	0.5000	0.5000
18	0.4375	0.5625		0.5385	0.4615	0.6316	0.3684
19	0.3125	0.6875		0.5000	0.5000	0.8333	0.1667
20	0.4375	0.5625		0.8000	0.2000	0.7273	0.2727
21	0.2188	0.7813		0.3571	0.6429	0.8889	0.1111
22	0.3438	0.6563		0.5714	0.4286	0.7200	0.2800
23	0.2813	0.7188		0.2727	0.7273	0.7143	0.2857
24	0.1563	0.8438		0.2222	0.7778	0.8696	0.1304
25	0.2813	0.7188		0.0000	1.0000	0.6667	0.3333
26	0.2813	0.7188		0.3333	0.6667	0.7391	0.2609
27	0.1250	0.8750		0.0000	1.0000	0.8261	0.1739
28	0.3125	0.6875		0.7500	0.2500	0.7500	0.2500
29	0.1250	0.8750		0.2000	0.8000	0.9091	0.0909
30	0.1563	0.8438		0.2500	0.7500	0.8571	0.1429
31	0.1875	0.8125		0.2000	0.8000	0.8148	0.1852
32	0.2813	0.7188		0.3333	0.6667	0.7308	0.2692
33	0.2188	0.7813		0.2222	0.7778	0.7826	0.2174

Continued

continued

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
34	0.1250	0.8750		0.2857	0.7143	0.9200	0.0800
35	0.2500	0.7500		0.2500	0.7500	0.7500	0.2500
36	0.2500	0.7500		0.1250	0.8750	0.7083	0.2917
37	0.3125	0.6875		0.3750	0.6250	0.7083	0.2917
38	0.3125	0.6875		0.5000	0.5000	0.7727	0.2273
39	0.5625	0.4375		0.5000	0.5000	0.4091	0.5909
40	0.4688	0.5313		0.3889	0.6111	0.4286	0.5714
41	0.4688	0.5313		0.6000	0.4000	0.6471	0.3529
42	0.5938	0.4063		0.6667	0.3333	0.4706	0.5294
43	0.6563	0.3438		0.6316	0.3684	0.3077	0.6923
44	0.6875	0.3125		0.7143	0.2857	0.3636	0.6364
45	0.8438	0.1563		0.9091	0.0909	0.3000	0.7000
46	0.6875	0.3125		0.7037	0.2963	0.4000	0.6000
47	0.7500	0.2500		0.7273	0.2727	0.2000	0.8000
48	0.6563	0.3438		0.6667	0.3333	0.3750	0.6250
49	0.4688	0.5313		0.6190	0.3810	0.8182	0.1818
50	0.5625	0.4375		0.6667	0.3333	0.5294	0.4706
51	0.3750	0.6250		0.4444	0.5556	0.7143	0.2857
52	0.3125	0.6875		0.2500	0.7500	0.6500	0.3500

Initial and Conditional Probabilities of Rainfall
(Markov chain probability)

Station: Angunakolapellessa

Period: 1977-2008 Limit: 30

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.1613	0.8387		0.0000	1.0000	0.8148	0.1852
2	0.2500	0.7500		0.4000	0.6000	0.7778	0.2222
3	0.1875	0.8125		0.2500	0.7500	0.8333	0.1667
4	0.0313	0.9688		0.0000	1.0000	0.9615	0.0385
5	0.1250	0.8750		0.0000	1.0000	0.8710	0.1290
6	0.1563	0.8438		0.0000	1.0000	0.8214	0.1786
7	0.2188	0.7813		0.4000	0.6000	0.8148	0.1852
8	0.2500	0.7500		0.2857	0.7143	0.7600	0.2400
9	0.1563	0.8438		0.2500	0.7500	0.8750	0.1250
10	0.1875	0.8125		0.2000	0.8000	0.8148	0.1852
11	0.1563	0.8438		0.1667	0.8333	0.8462	0.1538
12	0.1875	0.8125		0.2000	0.8000	0.8148	0.1852
13	0.2188	0.7813		0.0000	1.0000	0.7308	0.2692
14	0.3750	0.6250		0.4286	0.5714	0.6400	0.3600
15	0.3750	0.6250		0.3333	0.6667	0.6000	0.4000
16	0.3125	0.6875		0.2500	0.7500	0.6500	0.3500
17	0.2188	0.7813		0.1000	0.9000	0.7273	0.2727
18	0.3125	0.6875		0.4286	0.5714	0.7200	0.2800
19	0.2500	0.7500		0.4000	0.6000	0.8182	0.1818
20	0.3125	0.6875		0.7500	0.2500	0.8333	0.1667
21	0.1563	0.8438		0.1000	0.9000	0.8182	0.1818
22	0.2500	0.7500		0.8000	0.2000	0.8519	0.1481
23	0.2188	0.7813		0.3750	0.6250	0.8333	0.1667
24	0.0938	0.9063		0.2857	0.7143	0.9600	0.0400
25	0.1250	0.8750		0.0000	1.0000	0.8621	0.1379
26	0.1875	0.8125		0.5000	0.5000	0.8571	0.1429
27	0.0313	0.9688		0.0000	1.0000	0.9615	0.0385
28	0.1875	0.8125		0.0000	1.0000	0.8065	0.1935
29	0.0938	0.9063		0.1667	0.8333	0.9231	0.0769
30	0.0938	0.9063		0.0000	1.0000	0.8966	0.1034
31	0.1250	0.8750		0.0000	1.0000	0.8621	0.1379
32	0.2188	0.7813		0.2500	0.7500	0.7857	0.2143
33	0.1250	0.8750		0.1429	0.8571	0.8800	0.1200
34	0.0625	0.9375		0.0000	1.0000	0.9286	0.0714

Continued

continued

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
35	0.0938	0.9063		0.0000	1.0000	0.9000	0.1000
36	0.1875	0.8125		0.3333	0.6667	0.8276	0.1724
37	0.1875	0.8125		0.3333	0.6667	0.8462	0.1538
38	0.1875	0.8125		0.1667	0.8333	0.8077	0.1923
39	0.5000	0.5000		0.5000	0.5000	0.5000	0.5000
40	0.4063	0.5938		0.3750	0.6250	0.5625	0.4375
41	0.3125	0.6875		0.4615	0.5385	0.7895	0.2105
42	0.5313	0.4688		0.6000	0.4000	0.5000	0.5000
43	0.5000	0.5000		0.5294	0.4706	0.5333	0.4667
44	0.6563	0.3438		0.7500	0.2500	0.4375	0.5625
45	0.6250	0.3750		0.6190	0.3810	0.3636	0.6364
46	0.5000	0.5000		0.5500	0.4500	0.5833	0.4167
47	0.7188	0.2813		0.6875	0.3125	0.2500	0.7500
48	0.5313	0.4688		0.5652	0.4348	0.5556	0.4444
49	0.3438	0.6563		0.4706	0.5294	0.8000	0.2000
50	0.4063	0.5938		0.6364	0.3636	0.7143	0.2857
51	0.2813	0.7188		0.2308	0.7692	0.6842	0.3158
52	0.1563	0.8438		0.1111	0.8889	0.8261	0.1739

Probabilities of Dry and Wet Spells of Consecutive Weeks
(Markov chain probability)

Station: Angunakolapellessa

Period: 1977-2008 Limit: 10

Week	Consecutive Dry Probabilities				Consecutive Wet Probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
1	0.4301	0.2943	0.2522		0.1935	0.0744	0.0203
2	0.4063	0.3482	0.2277		0.1563	0.0426	0.0142
3	0.5625	0.3678	0.2977		0.0938	0.0313	0.0114
4	0.5313	0.4301	0.2867		0.0625	0.0227	0.0142
5	0.5313	0.3542	0.2982		0.1250	0.0781	0.0361
6	0.5000	0.4211	0.2746		0.1563	0.0721	0.0321
7	0.5000	0.3261	0.1957		0.1875	0.0833	0.0347
8	0.4688	0.2813	0.1924		0.1250	0.0521	0.0321
9	0.3750	0.2566	0.1853		0.1563	0.0962	0.0412
10	0.4063	0.2934	0.1677		0.2500	0.1071	0.0682
11	0.4063	0.2321	0.0871		0.1875	0.1193	0.0895
12	0.3750	0.1406	0.0563		0.2188	0.1641	0.1119
13	0.1875	0.0750	0.0409		0.3750	0.2557	0.1583
14	0.1250	0.0682	0.0244		0.4688	0.2902	0.1451
15	0.1875	0.0670	0.0335		0.4063	0.2031	0.1016
16	0.1563	0.0781	0.0684		0.2813	0.1406	0.0791
17	0.2188	0.1914	0.1276		0.2813	0.1582	0.1294
18	0.4375	0.2917	0.1458		0.2813	0.2301	0.0863
19	0.4375	0.2188	0.1094		0.2813	0.1055	0.0829
20	0.2500	0.1250	0.0729		0.1875	0.1473	0.0810
21	0.2813	0.1641	0.0923		0.3438	0.1891	0.0827
22	0.2188	0.1230	0.0752		0.3438	0.1504	0.0645
23	0.2813	0.1719	0.0905		0.2188	0.0938	0.0505
24	0.3438	0.1809	0.1357		0.1875	0.1010	0.0379
25	0.3125	0.2344	0.1385		0.2188	0.0820	0.0492
26	0.3750	0.2216	0.1955		0.1875	0.1125	0.0150
27	0.4063	0.3585	0.2688		0.1875	0.0250	0.0188
28	0.4688	0.3516	0.2876		0.0625	0.0469	0.0141
29	0.6563	0.5369	0.3222		0.0938	0.0281	0.0121
30	0.5625	0.3375	0.2487		0.0938	0.0402	0.0185
31	0.4688	0.3454	0.2467		0.0938	0.0433	0.0118
32	0.4375	0.3125	0.1630		0.1875	0.0511	0.0170
33	0.4688	0.2446	0.1902		0.0938	0.0313	0.0179
34	0.3750	0.2917	0.1750		0.0938	0.0536	0.0313

Continued

continued

Week	Consecutive Dry Probabilities				Consecutive Wet Probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
35	0.4375	0.2625	0.1081		0.2500	0.1458	0.0583
36	0.3750	0.1544	0.0386		0.2188	0.0875	0.0602
37	0.2188	0.0547	0.0243		0.1875	0.1289	0.0785
38	0.1250	0.0556	0.0342		0.3438	0.2092	0.1432
39	0.1250	0.0769	0.0275		0.4375	0.2993	0.2328
40	0.2500	0.0893	0.0099		0.4063	0.3160	0.2198
41	0.1563	0.0174	0.0065		0.4375	0.3043	0.2283
42	0.0313	0.0117	0.0026		0.5000	0.3750	0.3587
43	0.0938	0.0208	0.0000		0.5625	0.5380	0.4824
44	0.0625	0.0000	0.0000		0.6875	0.6164	0.5101
45	0.0000	0.0000	0.0000		0.8125	0.6724	0.4732
46	0.0000	0.0000	0.0000		0.7500	0.5278	0.3519
47	0.0000	0.0000	0.0000		0.5938	0.3958	0.2708
48	0.1563	0.0481	0.0240		0.5000	0.3421	0.1711
49	0.1250	0.0625	0.0313		0.4063	0.2031	0.1016
50	0.1563	0.0781	0.0000		0.3438	0.1719	0.0000
51	0.2500	0.0000	0.0000		0.2500	0.0000	0.0000

Probabilities of Dry and Wet Spells of Consecutive Weeks
(Markov chain probability)

Station: Angunakolapellessa

Period: 1977-2008 Limit: 20

Week	Consecutive Dry Probabilities				Consecutive Wet Probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
1	0.5255	0.4341	0.3994		0.0645	0.0215	0.0061
2	0.5938	0.5463	0.4097		0.0938	0.0268	0.0000
3	0.7188	0.5391	0.4528		0.0625	0.0000	0.0000
4	0.6563	0.5513	0.4288		0.0000	0.0000	0.0000
5	0.6563	0.5104	0.3828		0.0313	0.0125	0.0031
6	0.6563	0.4922	0.3896		0.0625	0.0156	0.0039
7	0.5625	0.4453	0.3206		0.0625	0.0156	0.0045
8	0.5938	0.4275	0.3346		0.0625	0.0179	0.0099
9	0.5625	0.4402	0.3402		0.0625	0.0347	0.0104
10	0.5625	0.4347	0.3079		0.1563	0.0469	0.0117
11	0.5313	0.3763	0.1636		0.0938	0.0234	0.0104
12	0.5313	0.2310	0.1078		0.0625	0.0278	0.0114
13	0.3125	0.1458	0.0858		0.1250	0.0515	0.0172
14	0.2188	0.1287	0.0643		0.2188	0.0729	0.0182
15	0.3125	0.1563	0.0987		0.1563	0.0391	0.0210
16	0.3125	0.1974	0.1645		0.0938	0.0505	0.0252
17	0.3750	0.3125	0.2273		0.2188	0.1094	0.0875
18	0.4688	0.3409	0.3030		0.2188	0.1750	0.0625
19	0.5000	0.4444	0.3200		0.2500	0.0893	0.0510
20	0.5000	0.3600	0.2571		0.1563	0.0893	0.0244
21	0.5625	0.4018	0.3494		0.1250	0.0341	0.0076
22	0.4688	0.4076	0.2717		0.0938	0.0208	0.0000
23	0.6250	0.4167	0.3080		0.0625	0.0000	0.0000
24	0.5625	0.4158	0.3435		0.0000	0.0000	0.0000
25	0.5313	0.4389	0.3291		0.0938	0.0000	0.0000
26	0.5938	0.4453	0.4048		0.0000	0.0000	0.0000
27	0.6563	0.5966	0.5114		0.0938	0.0188	0.0047
28	0.6250	0.5357	0.4365		0.0625	0.0156	0.0031
29	0.7500	0.6111	0.4466		0.0313	0.0063	0.0021
30	0.6875	0.5024	0.3932		0.0313	0.0104	0.0023
31	0.5938	0.4647	0.4275		0.0625	0.0139	0.0040
32	0.5625	0.5175	0.3881		0.0625	0.0179	0.0045
33	0.7188	0.5391	0.3818		0.0625	0.0156	0.0020
34	0.6563	0.4648	0.3293		0.0313	0.0039	0.0015

Continued

continued

Week	Consecutive Dry Probabilities				Consecutive Wet Probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
35	0.5313	0.3763	0.2908		0.0313	0.0117	0.0059
36	0.5313	0.4105	0.1679		0.0938	0.0469	0.0234
37	0.5313	0.2173	0.0931		0.1563	0.0781	0.0304
38	0.2813	0.1205	0.0780		0.1563	0.0608	0.0365
39	0.1875	0.1213	0.0571		0.2188	0.1313	0.0875
40	0.3438	0.1618	0.0498		0.2813	0.1875	0.1184
41	0.2500	0.0769	0.0280		0.3125	0.1974	0.1410
42	0.1250	0.0455	0.0136		0.3750	0.2679	0.2435
43	0.1250	0.0375	0.0150		0.4688	0.4261	0.2999
44	0.0938	0.0375	0.0075		0.6250	0.4398	0.3199
45	0.0625	0.0125	0.0047		0.5938	0.4318	0.2879
46	0.0625	0.0234	0.0192		0.5000	0.3333	0.2063
47	0.0938	0.0767	0.0406		0.5000	0.3095	0.2063
48	0.2813	0.1489	0.1064		0.4063	0.2708	0.1204
49	0.2813	0.2009	0.1306		0.3125	0.1389	0.0347
50	0.3125	0.2031	0.0000		0.2500	0.0625	0.0000
51	0.4063	0.0000	0.0000		0.0938	0.0000	0.0000

Probabilities of Dry and Wet Spells of Consecutive Weeks
(Markov chain probability)

Station: Angunakolapellessa

Period: 1977-2008 Limit: 30

Week	Consecutive Dry Probabilities				Consecutive Wet Probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
1	0.6523	0.5436	0.5227		0.0645	0.0161	0.0000
2	0.6250	0.6010	0.5234		0.0625	0.0000	0.0000
3	0.7813	0.6804	0.5589		0.0000	0.0000	0.0000
4	0.8438	0.6931	0.5647		0.0000	0.0000	0.0000
5	0.7188	0.5856	0.4451		0.0000	0.0000	0.0000
6	0.6875	0.5225	0.4572		0.0625	0.0179	0.0045
7	0.5938	0.5195	0.4233		0.0625	0.0156	0.0031
8	0.6563	0.5347	0.4525		0.0625	0.0125	0.0021
9	0.6875	0.5817	0.4740		0.0313	0.0052	0.0010
10	0.6875	0.5602	0.4094		0.0313	0.0063	0.0000
11	0.6875	0.5024	0.3215		0.0313	0.0000	0.0000
12	0.5938	0.3800	0.2280		0.0000	0.0000	0.0000
13	0.5000	0.3000	0.1950		0.0938	0.0313	0.0078
14	0.3750	0.2438	0.1773		0.1250	0.0313	0.0031
15	0.4063	0.2955	0.2127		0.0938	0.0094	0.0040
16	0.5000	0.3600	0.2945		0.0313	0.0134	0.0054
17	0.5625	0.4602	0.3835		0.0938	0.0375	0.0281
18	0.5625	0.4688	0.3835		0.1250	0.0938	0.0094
19	0.6250	0.5114	0.4356		0.1875	0.0188	0.0150
20	0.5625	0.4792	0.3993		0.0313	0.0250	0.0094
21	0.7188	0.5990	0.5750		0.1250	0.0469	0.0134
22	0.6250	0.6000	0.5172		0.0938	0.0268	0.0000
23	0.7500	0.6466	0.5542		0.0625	0.0000	0.0000
24	0.7813	0.6696	0.6439		0.0000	0.0000	0.0000
25	0.7500	0.7212	0.5816		0.0625	0.0000	0.0000
26	0.7813	0.6300	0.5816		0.0000	0.0000	0.0000
27	0.7813	0.7212	0.6466		0.0000	0.0000	0.0000
28	0.7500	0.6724	0.5797		0.0313	0.0000	0.0000
29	0.8125	0.7004	0.5503		0.0000	0.0000	0.0000
30	0.7813	0.6138	0.5402		0.0000	0.0000	0.0000
31	0.6875	0.6050	0.5618		0.0313	0.0045	0.0000
32	0.6875	0.6384	0.5746		0.0313	0.0000	0.0000
33	0.8125	0.7313	0.6052		0.0000	0.0000	0.0000
34	0.8438	0.6983	0.5908		0.0000	0.0000	0.0000

Continued

Continued

Week	Consecutive Dry Probabilities				Consecutive Wet Probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
35	0.7500	0.6346	0.5126		0.0313	0.0104	0.0017
36	0.6875	0.5553	0.2776		0.0625	0.0104	0.0052
37	0.6563	0.3281	0.1846		0.0313	0.0156	0.0059
38	0.4063	0.2285	0.1804		0.0938	0.0352	0.0162
39	0.2813	0.2220	0.1110		0.1875	0.0865	0.0519
40	0.4688	0.2344	0.1250		0.1875	0.1125	0.0596
41	0.3438	0.1833	0.0802		0.1875	0.0993	0.0744
42	0.2500	0.1094	0.0398		0.2813	0.2109	0.1306
43	0.2188	0.0795	0.0464		0.3750	0.2321	0.1277
44	0.1250	0.0729	0.0182		0.4063	0.2234	0.1536
45	0.2188	0.0547	0.0304		0.3438	0.2363	0.1336
46	0.1250	0.0694	0.0556		0.3438	0.1943	0.0914
47	0.1563	0.1250	0.0893		0.4063	0.1912	0.1217
48	0.3750	0.2679	0.1833		0.2500	0.1591	0.0367
49	0.4688	0.3207	0.2649		0.2188	0.0505	0.0056
50	0.4063	0.3356	0.0000		0.0938	0.0104	0.0000
51	0.5938	0.0000	0.0000		0.0313	0.0000	0.0000

Angunakolapellessa

Table 1. Consolidated data of heavy rainfall								
Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
1977	0	0	0	0	0	0	0	0
1977	2	76	0	0	0	0	0	0
1977	2	65	0	0	0	0	0	0
1977	5	165	1	61.7	1	76.8	0	0
1977	9	306	1	61.7	1	76.8	0	0
1978	1	30.2	0	0	0	0	0	0
1978	4	129.5	0	0	1	98.8	0	0
1978	0	0	0	0	0	0	0	0
1978	2	52.8	2	102.9	1	86.6	0	0
1978	7	212.5	2	102.9	2	185.4	0	0
1979	2	66.2	0	0	0	0	0	0
1979	4	127.9	0	0	1	86	0	0
1979	2	81.9	0	0	0	0	0	0
1979	6	189.6	0	0	0	0	0	0
1979	14	465.6	0	0	1	86	0	0
1980	0	0	0	0	0	0	0	0
1980	3	109.4	0	0	1	79	0	0
1980	2	93.5	0	0	0	0	0	0
1980	5	149.8	3	185.6	0	0	0	0
1980	10	352.7	3	185.6	1	79	0	0
1981	1	31.4	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0
1981	1	26.8	0	0	0	0	0	0
1981	3	89.8	1	64.5	0	0	1	152.9
1981	5	148	1	64.5	0	0	1	152.9
1982	0	0	0	0	0	0	0	0
1982	2	69.9	2	114.3	0	0	0	0
1982	3	77.8	2	126.4	1	92.2	0	0
1982	4	122	0	0	1	78.1	0	0
1982	9	269.7	4	240.7	2	170.3	0	0
1983	0	0	0	0	0	0	0	0
1983	2	74.9	1	55.7	0	0	0	0
1983	2	70.7	0	0	0	0	0	0
1983	2	57.9	1	51	0	0	0	0
1983	6	203.5	2	106.7	0	0	0	0

Continued

continued

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
1984	4	146.8	2	112.6	0	0	0	0
1984	2	75.9	0	0	0	0	0	0
1984	2	52.6	0	0	0	0	0	0
1984	2	61.6	0	0	0	0	1	105.3
1984	10	336.9	2	112.6	0	0	1	105.3
1985	1	39.4	0	0	0	0	0	0
1985	1	31.3	0	0	0	0	0	0
1985	3	96.6	0	0	0	0	0	0
1985	3	85.3	0	0	0	0	0	0
1985	8	252.6	0	0	0	0	0	0
1986	3	105.3	0	0	1	83.5	0	0
1986	1	33	1	67.1	1	84.2	0	0
1986	2	53.4	1	55.4	0	0	0	0
1986	0	0	0	0	0	0	0	0
1986	6	191.7	2	122.5	2	167.7	0	0
1987	0	0	0	0	0	0	0	0
1987	2	63	0	0	0	0	0	0
1987	1	29.1	2	118.8	0	0	0	0
1987	3	93.8	1	56.5	0	0	1	112.5
1987	6	185.9	3	175.3	0	0	1	112.5
1988	1	26.7	0	0	0	0	0	0
1988	3	102.3	0	0	1	76.6	0	0
1988	1	29.8	1	54.8	0	0	0	0
1988	0	0	0	0	0	0	0	0
1988	5	158.8	1	54.8	1	76.6	0	0
1989	0	0	1	66.6	0	0	0	0
1989	2	71.6	0	0	0	0	0	0
1989	2	69.1	0	0	0	0	0	0
1989	1	39.2	0	0	0	0	0	0
1989	5	179.9	1	66.6	0	0	0	0
1990	1	38.1	0	0	0	0	0	0
1990	4	124	0	0	0	0	0	0
1990	1	29.4	0	0	0	0	0	0
1990	3	105.4	1	74.5	1	81.8	0	0
1990	9	296.9	1	74.5	1	81.8	0	0
1991	0	0	0	0	0	0	1	122
1991	0	0	1	66.2	0	0	0	0
1991	2	56.4	0	0	0	0	0	0

continued

continued

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
1991	5	171.6	0	0	0	0	0	0
1991	7	228	1	66.2	0	0	1	122
1992	0	0	0	0	0	0	0	0
1992	3	89.9	0	0	0	0	0	0
1992	2	69.4	0	0	1	98.3	0	0
1992	1	31.9	4	252.2	0	0	0	0
1992	6	191.2	4	252.2	1	98.3	0	0
1993	0	0	0	0	0	0	0	0
1993	4	154.4	2	114.8	0	0	0	0
1993	2	66.1	0	0	1	84	0	0
1993	8	272.7	2	139	0	0	1	103
1993	14	493.2	4	253.8	1	84	1	103
1994	0	0	1	57	0	0	0	0
1994	1	27	1	55	0	0	0	0
1994	5	150.7	1	66.2	0	0	0	0
1994	4	127.3	0	0	0	0	0	0
1994	10	305	3	178.2	0	0	0	0
1995	2	53.3	0	0	0	0	0	0
1995	1	32.5	2	128.4	0	0	0	0
1995	2	60.8	0	0	0	0	0	0
1995	3	110.2	3	173.6	0	0	0	0
1995	8	256.8	5	302	0	0	0	0
1996	1	27.9	1	67.4	0	0	0	0
1996	2	73.7	0	0	0	0	0	0
1996	1	34	1	56.8	0	0	0	0
1996	2	57.5	2	118.1	0	0	0	0
1996	6	193.1	4	242.3	0	0	0	0
1997	0	0	0	0	0	0	0	0
1997	3	127	0	0	0	0	0	0
1997	3	88.4	0	0	1	87.5	0	0
1997	7	239.1	4	234.5	2	160.8	2	256
1997	13	454.5	4	234.5	3	248.3	2	256
1998	1	48.7	0	0	0	0	0	0
1998	1	48.5	0	0	0	0	0	0
1998	1	34.5	0	0	0	0	0	0
1998	6	202.6	1	52.2	0	0	0	0

continued

continued

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
1998	9	334.3	1	52.2	0	0	0	0
1999	1	41.5	1	55.3	0	0	0	0
1999	1	39.6	0	0	0	0	0	0
1999	1	36	0	0	0	0	0	0
1999	4	138.3	1	65.7	1	91.7	0	0
1999	7	255.4	2	121	1	91.7	0	0
2000	2	73.4	0	0	0	0	0	0
2000	3	108.7	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2000	2	64.1	1	61.6	0	0	0	0
2000	7	246.2	1	61.6	0	0	0	0
2001	1	25.2	1	50.1	0	0	1	106.8
2001	1	37.6	1	55.9	0	0	0	0
2001	0	0	0	0	0	0	0	0
2001	1	36.5	0	0	0	0	0	0
2001	3	99.3	2	106	0	0	1	106.8
2002	1	31.8	0	0	0	0	0	0
2002	2	55.7	1	62.8	0	0	0	0
2002	1	28.7	1	62.2	0	0	0	0
2002	7	223.5	3	172.9	0	0	0	0
2002	11	339.7	5	297.9	0	0	0	0
2003	1	42.1	0	0	0	0	0	0
2003	3	118.4	0	0	0	0	1	101.5
2003	1	39.7	1	58.3	0	0	0	0
2003	3	92.1	2	118.8	0	0	0	0
2003	8	292.3	3	177.1	0	0	1	101.5
2004	0	0	0	0	1	76.8	0	0
2004	6	202.8	0	0	1	76.5	0	0
2004	2	65.2	0	0	1	77.4	0	0
2004	7	216.3	0	0	0	0	0	0
2004	15	484.3	0	0	3	230.7	0	0
2005	1	36.4	0	0	0	0	0	0
2005	1	28.9	2	109.1	0	0	0	0
2005	0	0	0	0	0	0	0	0
2005	4	149.3	2	112.2	1	76.9	0	0
2005	6	214.6	4	221.3	1	76.9	0	0
2006	0	0	0	0	0	0	0	0
2006	2	66.9	2	120	0	0	0	0

continued

continued

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
2006	3	105.5	1	53	0	0	0	0
2006	4	132.4	4	240.9	1	76.2	0	0
2006	9	304.8	7	413.9	1	76.2	0	0
2007	1	36.6	0	0	0	0	1	160.5
2007	3	83.2	0	0	0	0	0	0
2007	4	124.3	0	0	0	0	0	0
2007	5	168.8	0	0	0	0	1	143.5
2007	13	412.9	0	0	0	0	2	304
2008	0	0	0	0	0	0	0	0
2008	4	168.8	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0
2008	9	318.1	1	63.3	1	79.5	0	0
2008	13	486.9	1	63.3	1	79.5	0	0

Statistical Test Value on Rainfall Trend in Angunakolapellessa

Test statistic	Critical values		a=0.05	a=0.01	
Mann-Kendall	2.059	1.645	1.96	2.576	S (0.05)
Spearman’s Rho	2.002	1.645	1.96	2.576	S (0.05)
Linear regression	2.218	1.697	2.042	2.75	S (0.05)
Cusum	5	6.901	7.693	9.221	NS
Cumulative deviation	1.227	1.122	1.244	1.468	S (0.1)
Worsley likelihood	2.665	2.868	3.198	3.864	NS
Rank Sum	-2.356	1.645	1.96	2.576	S (0.05)
Student’s t	-2.41	1.696	2.04	2.745	S (0.05)
Median Crossing	1.616	1.645	1.96	2.576	NS
Turning Point	2.158	1.645	1.96	2.576	S (0.05)
Rank Difference	1.179	1.645	1.96	2.576	NS
Auto Correlation	-0.552	1.645	1.96	2.576	NS

Statistical Test Value on Maximum Temperature Trend

Data file: Angunakolapellessa_MAXT.csv

Test statistic		a = 0.1	a = 0.05	a = 0.01	
Mann-Kendall	2.076	1.645	1.96	2.576	S (0.05)
Spearman's Rho	2.712	1.645	1.96	2.576	S (0.01)
Linear regression	2.367	1.697	2.042	2.75	S (0.05)
Cusum	10	6.901	7.693	9.221	S (0.01)
Cumulative deviation	1.363	1.122	1.244	1.468	S (0.05)
Worsley likelihood	3.143	2.868	3.198	3.864	S (0.1)
Rank Sum	-1.753	1.645	1.96	2.576	S (0.1)
Student's t	1.365	1.696	2.04	2.745	S (0.01)
Median Crossing	2.335	1.645	1.96	2.576	S (0.05)
Turning Point	-3.022	1.645	1.96	2.576	S (0.01)
Rank Difference	-1.919	1.645	1.96	2.576	S (0.1)
Auto Correlation	1.335	1.645	1.96	2.576	NS

Mean, SD and CV of Maximum Temperature, Minimum Temperature and Annual Rainfall in Angunakolapellessa, 1977-2008.			
Year	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
Mean	31.9	23.3	1135.9
SD	0.3	0.6	220.6
CV	1.1	2.5	19.4

Station : Angunakolapellessa	
Year	Drought Period
1989	44 -49
1994	47 -52
No of years : 32	

Agricultural Drought

Station: Angunakolapellessa	
Year	Drought Period
1977	36 -39
1978	35 -38
1980	29 -32
1981	25 -28
	39 -42
1982	33 -36
1984	31 -34
	35 -38
1985	27 -30
1986	25 -28
	33 -36
1987	25 -28
1988	39 -42
1990	31 -34
	35 -38
1991	35 -38
1992	30 -33
1993	30 -33
	34 -37
1994	23 -26
1996	29 -32
1999	25 -28
2001	33 -36
2003	30 -33
2004	29 -32
2005	31 -34
2008	37 -40

Drought Information	
Station : Angunakolapellessa	
Drought Condition	No. of years
No Drought	19 59%
Mild Drought	11 34%
Moderate Drought	2 6%
Severe Drought	0 0%
Total	32

Meteorological Drought

Station: Angunakolapellessa				
Sn.	Year	Annual RF (mm)	Deviation (%)	Drought condition
1.	1977	1100.32	0.8032	No Drought
2.	1978	958.33	-12.2049	Mild
3.	1979	1151.15	5.4599	No Drought
4.	1980	1145.14	4.9092	No Drought
5.	1981	831.51	-23.8232	Mild
6.	1982	1403.10	28.5416	No Drought
7.	1983	827.54	-24.1869	Mild
8.	1984	1247.46	14.2831	No Drought
9.	1985	1014.69	-7.0416	Mild
10.	1986	978.34	-10.3717	Mild
11.	1987	1022.17	-6.3563	Mild
12.	1988	1013.75	-7.1277	Mild
13.	1989	767.41	-29.6956	Moderate
14.	1990	1139.20	4.3651	No Drought
15.	1991	1087.38	-0.3823	Mild
16.	1992	980.70	-10.1555	Mild
17.	1993	1507.99	38.1509	No Drought
18.	1994	1097.22	0.5192	No Drought
19.	1995	1193.59	9.3479	No Drought
20.	1996	996.80	-8.6806	Mild
21.	1997	1705.80	56.2728	No Drought
22.	1998	1096.10	0.4166	No Drought
23.	1999	1193.90	9.3763	No Drought
24.	2000	1010.60	-7.4163	Mild
25.	2001	804.90	-26.2610	Moderate
26.	2002	1197.70	9.7244	No Drought
27.	2003	1093.20	0.1509	No Drought
28.	2004	1372.60	25.7475	No Drought
29.	2005	1126.10	3.1650	No Drought
30.	2006	1571.30	43.9509	No Drought
31.	2007	1293.70	18.5192	No Drought
32.	2008	1419.90	30.0807	No Drought

Appendix 2. Agro-climatic Data Analysis at Eluwankulama

Initial and Conditional Probabilities of Rainfall
(Markov chain probability)

Station: Eluwankulama
Period: 1976-2008 Limit: 10

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.4688	0.5313		0.4706	0.5294	0.5333	0.4667
2	0.4242	0.5758		0.5333	0.4667	0.6667	0.3333
3	0.2424	0.7576		0.3571	0.6429	0.8421	0.1579
4	0.2424	0.7576		0.3750	0.6250	0.8000	0.2000
5	0.3333	0.6667		0.3750	0.6250	0.6800	0.3200
6	0.3333	0.6667		0.6364	0.3636	0.8182	0.1818
7	0.2121	0.7879		0.2727	0.7273	0.8182	0.1818
8	0.2727	0.7273		0.4286	0.5714	0.7692	0.2308
9	0.3636	0.6364		0.5556	0.4444	0.7083	0.2917
10	0.2424	0.7576		0.3333	0.6667	0.8095	0.1905
11	0.2727	0.7273		0.1250	0.8750	0.6800	0.3200
12	0.2727	0.7273		0.4444	0.5556	0.7917	0.2083
13	0.3030	0.6970		0.2222	0.7778	0.6667	0.3333
14	0.5758	0.4242		0.7000	0.3000	0.4783	0.5217
15	0.5455	0.4545		0.5789	0.4211	0.5000	0.5000
16	0.5152	0.4848		0.5556	0.4444	0.5333	0.4667
17	0.5152	0.4848		0.5882	0.4118	0.5625	0.4375
18	0.3333	0.6667		0.3529	0.6471	0.6875	0.3125
19	0.3333	0.6667		0.7273	0.2727	0.8636	0.1364
20	0.3636	0.6364		0.5455	0.4545	0.7273	0.2727
21	0.2121	0.7879		0.1667	0.8333	0.7619	0.2381
22	0.3030	0.6970		0.0000	1.0000	0.6154	0.3846
23	0.1515	0.8485		0.4000	0.6000	0.9565	0.0435
24	0.1212	0.8788		0.4000	0.6000	0.9286	0.0714
25	0.1212	0.8788		0.2500	0.7500	0.8966	0.1034
26	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
27	0.0606	0.9394		0.0000	0.0000	0.9394	0.0606
28	0.1515	0.8485		0.0000	1.0000	0.8387	0.1613
29	0.1515	0.8485		0.0000	1.0000	0.8214	0.1786
30	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
31	0.0303	0.9697		0.0000	0.0000	0.9697	0.0303
32	0.0606	0.9394		0.0000	1.0000	0.9375	0.0625
33	0.0909	0.9091		0.0000	1.0000	0.9032	0.0968

Continued

continued

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
34	0.0303	0.9697		0.0000	1.0000	0.9667	0.0333
35	0.0909	0.9091		0.0000	1.0000	0.9063	0.0938
36	0.1818	0.8182		0.3333	0.6667	0.8333	0.1667
37	0.1818	0.8182		0.3333	0.6667	0.8519	0.1481
38	0.3333	0.6667		0.3333	0.6667	0.6667	0.3333
39	0.2424	0.7576		0.4545	0.5455	0.8636	0.1364
40	0.4545	0.5455		0.6250	0.3750	0.6000	0.4000
41	0.5152	0.4848		0.6667	0.3333	0.6111	0.3889
42	0.6061	0.3939		0.6471	0.3529	0.4375	0.5625
43	0.7879	0.2121		0.9000	0.1000	0.3846	0.6154
44	0.8485	0.1515		0.8846	0.1154	0.2857	0.7143
45	0.9697	0.0303		1.0000	0.0000	0.2000	0.8000
46	0.8182	0.1818		0.8125	0.1875	0.0000	1.0000
47	0.9091	0.0909		1.0000	0.0000	0.5000	0.5000
48	0.6970	0.3030		0.6667	0.3333	0.0000	1.0000
49	0.7576	0.2424		0.8261	0.1739	0.4000	0.6000
50	0.6061	0.3939		0.6400	0.3600	0.5000	0.5000
51	0.6667	0.3333		0.8000	0.2000	0.5385	0.4615
52	0.5152	0.4848		0.5000	0.5000	0.4545	0.5455

Initial and Conditional Probabilities of Rainfall
(Markov Chain Probability)

Station: Eluwankulama

Period: 1976-2008 Limit: 20

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.3438	0.6563		0.4167	0.5833	0.7000	0.3000
2	0.3030	0.6970		0.3636	0.6364	0.7273	0.2727
3	0.2121	0.7879		0.3000	0.7000	0.8261	0.1739
4	0.1515	0.8485		0.2857	0.7143	0.8846	0.1154
5	0.2424	0.7576		0.4000	0.6000	0.7857	0.2143
6	0.3030	0.6970		0.5000	0.5000	0.7600	0.2400
7	0.1818	0.8182		0.1000	0.9000	0.7826	0.2174
8	0.1515	0.8485		0.5000	0.5000	0.9259	0.0741
9	0.3333	0.6667		0.8000	0.2000	0.7500	0.2500
10	0.1818	0.8182		0.3636	0.6364	0.9091	0.0909
11	0.1818	0.8182		0.1667	0.8333	0.8148	0.1852
12	0.2121	0.7879		0.3333	0.6667	0.8148	0.1852
13	0.2727	0.7273		0.0000	1.0000	0.6538	0.3462
14	0.4848	0.5152		0.6667	0.3333	0.5833	0.4167
15	0.4848	0.5152		0.6250	0.3750	0.6471	0.3529
16	0.3939	0.6061		0.4375	0.5625	0.6471	0.3529
17	0.4242	0.5758		0.4615	0.5385	0.6000	0.4000
18	0.3333	0.6667		0.2857	0.7143	0.6316	0.3684
19	0.2727	0.7273		0.6364	0.3636	0.9091	0.0909
20	0.2727	0.7273		0.3333	0.6667	0.7500	0.2500
21	0.1515	0.8485		0.1111	0.8889	0.8333	0.1667
22	0.2424	0.7576		0.0000	1.0000	0.7143	0.2857
23	0.1212	0.8788		0.5000	0.5000	1.0000	0.0000
24	0.0606	0.9394		0.2500	0.7500	0.9655	0.0345
25	0.0606	0.9394		0.0000	1.0000	0.9355	0.0645
26	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
27	0.0606	0.9394		0.0000	0.0000	0.9394	0.0606
28	0.0606	0.9394		0.0000	1.0000	0.9355	0.0645
29	0.1212	0.8788		0.0000	1.0000	0.8710	0.1290
30	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
31	0.0303	0.9697		0.0000	0.0000	0.9697	0.0303
32	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
33	0.0909	0.9091		0.0000	0.0000	0.9091	0.0909
34	0.0303	0.9697		0.0000	1.0000	0.9667	0.0333
35	0.0303	0.9697		0.0000	1.0000	0.9688	0.0313

Continued

Agricultural Drought

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
36	0.1212	0.8788		0.0000	1.0000	0.8750	0.1250
37	0.1212	0.8788		0.5000	0.5000	0.9310	0.0690
38	0.2424	0.7576		0.2500	0.7500	0.7586	0.2414
39	0.2424	0.7576		0.5000	0.5000	0.8400	0.1600
40	0.3030	0.6970		0.5000	0.5000	0.7600	0.2400
41	0.4848	0.5152		0.6000	0.4000	0.5652	0.4348
42	0.5455	0.4545		0.6250	0.3750	0.5294	0.4706
43	0.6667	0.3333		0.8333	0.1667	0.5333	0.4667
44	0.7879	0.2121		0.8636	0.1364	0.3636	0.6364
45	0.9697	0.0303		1.0000	0.0000	0.1429	0.8571
46	0.7576	0.2424		0.7500	0.2500	0.0000	1.0000
47	0.8182	0.1818		0.8800	0.1200	0.3750	0.6250
48	0.5758	0.4242		0.5556	0.4444	0.3333	0.6667
49	0.4848	0.5152		0.5789	0.4211	0.6429	0.3571
50	0.4545	0.5455		0.5625	0.4375	0.6471	0.3529
51	0.5758	0.4242		0.6667	0.3333	0.5000	0.5000
52	0.3636	0.6364		0.3158	0.6842	0.5714	0.4286

Initial and Conditional Probabilities of Rainfall
(Markov Chain Probability)

Station: Eluwankulama
Period: 1976-2008 Limit: 30

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.2813	0.7188		0.4286	0.5714	0.7600	0.2400
2	0.1818	0.8182		0.3333	0.6667	0.8750	0.1250
3	0.1212	0.8788		0.1667	0.8333	0.8889	0.1111
4	0.0606	0.9394		0.0000	1.0000	0.9310	0.0690
5	0.1818	0.8182		0.5000	0.5000	0.8387	0.1613
6	0.2121	0.7879		0.3333	0.6667	0.8148	0.1852
7	0.1212	0.8788		0.1429	0.8571	0.8846	0.1154
8	0.0909	0.9091		0.7500	0.2500	1.0000	0.0000
9	0.2121	0.7879		0.3333	0.6667	0.8000	0.2000
10	0.1515	0.8485		0.4286	0.5714	0.9231	0.0769
11	0.1818	0.8182		0.2000	0.8000	0.8214	0.1786
12	0.1212	0.8788		0.3333	0.6667	0.9259	0.0741
13	0.2424	0.7576		0.0000	1.0000	0.7241	0.2759
14	0.3636	0.6364		0.5000	0.5000	0.6800	0.3200
15	0.4545	0.5455		0.5000	0.5000	0.5714	0.4286
16	0.3333	0.6667		0.4000	0.6000	0.7222	0.2778
17	0.3333	0.6667		0.2727	0.7273	0.6364	0.3636
18	0.2727	0.7273		0.1818	0.8182	0.6818	0.3182
19	0.2121	0.7879		0.3333	0.6667	0.8333	0.1667
20	0.1515	0.8485		0.2857	0.7143	0.8846	0.1154
21	0.0909	0.9091		0.0000	1.0000	0.8929	0.1071
22	0.1515	0.8485		0.0000	1.0000	0.8333	0.1667
23	0.0909	0.9091		0.6000	0.4000	1.0000	0.0000
24	0.0606	0.9394		0.3333	0.6667	0.9667	0.0333
25	0.0303	0.9697		0.0000	1.0000	0.9677	0.0323
26	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
27	0.0606	0.9394		0.0000	0.0000	0.9394	0.0606
28	0.0303	0.9697		0.0000	1.0000	0.9677	0.0323
29	0.0606	0.9394		0.0000	1.0000	0.9375	0.0625
30	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
31	0.0303	0.9697		0.0000	0.0000	0.9697	0.0303
32	0.0000	1.0000		0.0000	1.0000	1.0000	0.0000
33	0.0606	0.9394		0.0000	0.0000	0.9394	0.0606
34	0.0303	0.9697		0.0000	1.0000	0.9677	0.0323

Continued

continued

Week	Initial Probabilities			Conditional Probabilities			
	P(W)	P(D)		P(W/W)	P(D/W)	P(D/D)	P(W/D)
35	0.0303	0.9697		0.0000	1.0000	0.9688	0.0313
36	0.1212	0.8788		0.0000	1.0000	0.8750	0.1250
37	0.0909	0.9091		0.5000	0.5000	0.9655	0.0345
38	0.1212	0.8788		0.0000	1.0000	0.8667	0.1333
39	0.2121	0.7879		0.5000	0.5000	0.8276	0.1724
40	0.2424	0.7576		0.4286	0.5714	0.8077	0.1923
41	0.4242	0.5758		0.5000	0.5000	0.6000	0.4000
42	0.4848	0.5152		0.6429	0.3571	0.6316	0.3684
43	0.6667	0.3333		0.8125	0.1875	0.4706	0.5294
44	0.7576	0.2424		0.8182	0.1818	0.3636	0.6364
45	0.8182	0.1818		0.8800	0.1200	0.3750	0.6250
46	0.6364	0.3636		0.6667	0.3333	0.5000	0.5000
47	0.6667	0.3333		0.7619	0.2381	0.5000	0.5000
48	0.4545	0.5455		0.4545	0.5455	0.5455	0.4545
49	0.3636	0.6364		0.4667	0.5333	0.7222	0.2778
50	0.4242	0.5758		0.5000	0.5000	0.6190	0.3810
51	0.3939	0.6061		0.5000	0.5000	0.6842	0.3158
52	0.2121	0.7879		0.2308	0.7692	0.8000	0.2000

Probabilities of Dry and Wet Spells of Consecutive Weeks (Markov chain probability)

Station: Eluwankulama
Period: 1976-2008 **Limit:** 10

Week	Consecutive dry probabilities				Consecutive wet probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
1	0.3542	0.2982	0.2386		0.2500	0.0893	0.0335
2	0.4848	0.3879	0.2638		0.1515	0.0568	0.0213
3	0.6061	0.4121	0.3372		0.0909	0.0341	0.0217
4	0.5152	0.4215	0.3449		0.0909	0.0579	0.0158
5	0.5455	0.4463	0.3433		0.2121	0.0579	0.0248
6	0.5455	0.4196	0.2972		0.0909	0.0390	0.0216
7	0.6061	0.4293	0.3475		0.0909	0.0505	0.0168
8	0.5152	0.4170	0.2836		0.1515	0.0505	0.0063
9	0.5152	0.3503	0.2773		0.1212	0.0152	0.0067
10	0.5152	0.4078	0.2719		0.0303	0.0135	0.0030
11	0.5758	0.3838	0.1836		0.1212	0.0269	0.0189
12	0.4848	0.2319	0.1159		0.0606	0.0424	0.0246
13	0.3333	0.1667	0.0889		0.2121	0.1228	0.0682
14	0.2121	0.1131	0.0636		0.3333	0.1852	0.1089
15	0.2424	0.1364	0.0938		0.3030	0.1783	0.0629
16	0.2727	0.1875	0.1619		0.3030	0.1070	0.0778
17	0.3333	0.2879	0.2094		0.1818	0.1322	0.0721
18	0.5758	0.4187	0.3190		0.2424	0.1322	0.0220
19	0.4848	0.3694	0.2273		0.1818	0.0303	0.0000
20	0.4848	0.2984	0.2854		0.0606	0.0000	0.0000
21	0.4848	0.4638	0.4306		0.0000	0.0000	0.0000
22	0.6667	0.6190	0.5550		0.1212	0.0485	0.0121
23	0.7879	0.7064	0.7064		0.0606	0.0152	0.0000
24	0.7879	0.7879	0.7401		0.0303	0.0000	0.0000
25	0.8788	0.8255	0.6924		0.0000	0.0000	0.0000
26	0.9394	0.7879	0.6472		0.0000	0.0000	0.0000
27	0.7879	0.6472	0.6472		0.0000	0.0000	0.0000
28	0.6970	0.6970	0.6758		0.0000	0.0000	0.0000
29	0.8485	0.8228	0.7713		0.0000	0.0000	0.0000
30	0.9697	0.9091	0.8211		0.0000	0.0000	0.0000
31	0.9091	0.8211	0.7937		0.0000	0.0000	0.0000
32	0.8485	0.8202	0.7433		0.0000	0.0000	0.0000
33	0.8788	0.7964	0.6637		0.0000	0.0000	0.0000
34	0.8788	0.7323	0.6238		0.0000	0.0000	0.0000
35	0.7576	0.6453	0.4302		0.0303	0.0101	0.0034

continued

continued

Week	Consecutive dry probabilities				Consecutive wet probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
36	0.6970	0.4646	0.4013		0.0606	0.0202	0.0092
37	0.5455	0.4711	0.2826		0.0606	0.0275	0.0172
38	0.5758	0.3455	0.2111		0.1515	0.0947	0.0631
39	0.4545	0.2778	0.1215		0.1515	0.1010	0.0654
40	0.3333	0.1458	0.0561		0.3030	0.1961	0.1765
41	0.2121	0.0816	0.0233		0.3333	0.3000	0.2654
42	0.1515	0.0433	0.0087		0.5455	0.4825	0.4825
43	0.0606	0.0121	0.0000		0.6970	0.6970	0.5663
44	0.0303	0.0000	0.0000		0.8485	0.6894	0.6894
45	0.0000	0.0000	0.0000		0.7879	0.7879	0.5253
46	0.0909	0.0000	0.0000		0.8182	0.5455	0.4506
47	0.0000	0.0000	0.0000		0.6061	0.5007	0.3204
48	0.1212	0.0606	0.0326		0.5758	0.3685	0.2948
49	0.1212	0.0653	0.0297		0.4848	0.3879	0.1939
50	0.2121	0.0964	0.0000		0.4848	0.2424	0.0000
51	0.1515	0.0000	0.0000		0.3333	0.0000	0.0000

Probabilities of Dry and Wet Spells of Consecutive Weeks (Markov chain probability)

Station: Eluwankulama
Period: 1976-2008 **Limit:** 20

Week	Consecutive dry probabilities				Consecutive wet probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
1	0.4773	0.3943	0.3488		0.1250	0.0375	0.0107
2	0.5758	0.5093	0.4002		0.0909	0.0260	0.0104
3	0.6970	0.5476	0.4162		0.0606	0.0242	0.0121
4	0.6667	0.5067	0.3965		0.0606	0.0303	0.0030
5	0.5758	0.4506	0.4172		0.1212	0.0121	0.0061
6	0.5455	0.5051	0.3788		0.0303	0.0152	0.0121
7	0.7576	0.5682	0.5165		0.0909	0.0727	0.0264
8	0.6364	0.5785	0.4714		0.1212	0.0441	0.0073
9	0.6061	0.4938	0.4024		0.1212	0.0202	0.0067
10	0.6667	0.5432	0.3552		0.0303	0.0101	0.0000
11	0.6667	0.4359	0.2543		0.0606	0.0000	0.0000
12	0.5152	0.3005	0.1944		0.0000	0.0000	0.0000
13	0.4242	0.2745	0.1776		0.1818	0.1136	0.0497
14	0.3333	0.2157	0.1294		0.3030	0.1326	0.0612
15	0.3333	0.2000	0.1263		0.2121	0.0979	0.0280
16	0.3636	0.2297	0.2088		0.1818	0.0519	0.0331
17	0.3636	0.3306	0.2479		0.1212	0.0771	0.0257
18	0.6061	0.4545	0.3788		0.2121	0.0707	0.0079
19	0.5455	0.4545	0.3247		0.0909	0.0101	0.0000
20	0.6061	0.4329	0.4329		0.0303	0.0000	0.0000
21	0.6061	0.6061	0.5852		0.0000	0.0000	0.0000
22	0.7576	0.7315	0.6843		0.1212	0.0303	0.0000
23	0.8485	0.7937	0.7937		0.0303	0.0000	0.0000
24	0.8788	0.8788	0.8255		0.0000	0.0000	0.0000
25	0.9394	0.8825	0.8255		0.0000	0.0000	0.0000
26	0.9394	0.8788	0.7654		0.0000	0.0000	0.0000
27	0.8788	0.7654	0.7654		0.0000	0.0000	0.0000
28	0.8182	0.8182	0.7934		0.0000	0.0000	0.0000
29	0.8788	0.8522	0.8522		0.0000	0.0000	0.0000
30	0.9697	0.9697	0.8815		0.0000	0.0000	0.0000
31	0.9697	0.8815	0.8522		0.0000	0.0000	0.0000
32	0.9091	0.8788	0.8513		0.0000	0.0000	0.0000
33	0.8788	0.8513	0.7449		0.0000	0.0000	0.0000
34	0.9394	0.8220	0.7653		0.0000	0.0000	0.0000

Continued

continued

Week	Consecutive dry probabilities				Consecutive wet probabilities		
	P(2D)	P(3D)	P(4D)		P(2W)	P(3W)	P(4W)
35	0.8485	0.7900	0.5993		0.0000	0.0000	0.0000
36	0.8182	0.6207	0.5214		0.0606	0.0152	0.0076
37	0.6667	0.5600	0.4256		0.0303	0.0152	0.0076
38	0.6364	0.4836	0.2734		0.1212	0.0606	0.0364
39	0.5758	0.3254	0.1723		0.1212	0.0727	0.0455
40	0.3939	0.2086	0.1112		0.1818	0.1136	0.0947
41	0.2727	0.1455	0.0529		0.3030	0.2525	0.2181
42	0.2424	0.0882	0.0126		0.4545	0.3926	0.3926
43	0.1212	0.0173	0.0000		0.5758	0.5758	0.4318
44	0.0303	0.0000	0.0000		0.7879	0.5909	0.5200
45	0.0000	0.0000	0.0000		0.7273	0.6400	0.3556
46	0.0909	0.0303	0.0195		0.6667	0.3704	0.2144
47	0.0606	0.0390	0.0252		0.4545	0.2632	0.1480
48	0.2727	0.1765	0.0882		0.3333	0.1875	0.1250
49	0.3333	0.1667	0.0952		0.2727	0.1818	0.0574
50	0.2727	0.1558	0.0000		0.3030	0.0957	0.0000
51	0.2424	0.0000	0.0000		0.1818	0.0000	0.0000

Eluwankulama
Consolidated data of heavy rainfall

Year	25 <50 Days	Sum	50 <75 Days	Sum	75<100 Days	Sum	More than 100 Days	Sum
1976	0	0	0	0	0	0	0	0
1976	3	94	1	51	0	0	0	0
1976	0	0	0	0	0	0	0	0
1976	4	130	1	52	0	0	0	0
1976	7	224	2	103	0	0	0	0
1977	2	66	0	0	0	0	0	0
1977	5	183.9	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1977	11	399	2	129.8	0	0	0	0
1977	18	648.9	2	129.8	0	0	0	0
1978	0	0	0	0	0	0	0	0
1978	1	35	1	51.1	0	0	0	0
1978	0	0	0	0	0	0	0	0
1978	8	293.1	1	67.3	2	163.6	1	182.2
1978	9	328.1	2	118.4	2	163.6	1	182.2
1979	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0
1979	1	42.5	0	0	0	0	0	0
1979	10	358.7	3	187	1	75.3	0	0
1979	11	401.2	3	187	1	75.3	0	0
1980	0	0	0	0	0	0	0	0
1980	2	74.7	1	55.1	0	0	0	0
1980	0	0	1	63.6	0	0	0	0
1980	4	132.4	1	66.2	0	0	1	106.2
1980	6	207.1	3	184.9	0	0	1	106.2
1981	0	0	0	0	0	0	0	0
1981	2	68.7	0	0	0	0	0	0
1981	4	138.7	0	0	0	0	0	0
1981	4	172.9	1	58.3	0	0	1	126.9
1981	10	380.3	1	58.3	0	0	1	126.9
1982	0	0	0	0	0	0	0	0
1982	0	0	1	58.2	1	91.2	0	0
1982	2	63.7	0	0	0	0	0	0
1982	9	343.4	2	114.1	0	0	0	0
1982	11	407.1	3	172.3	1	91.2	0	0

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
1983	0	0	0	0	0	0	0	0
1983	1	36.8	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0
1983	5	154.4	1	67.3	0	0	1	100
1983	6	191.2	1	67.3	0	0	1	100
1984	10	355.6	2	115.2	0	0	0	0
1984	7	260.1	1	52.8	1	77.8	0	0
1984	3	115	0	0	0	0	0	0
1984	6	194.7	1	54.8	0	0	0	0
1984	26	925.4	4	222.8	1	77.8	0	0
1985	3	82.1	0	0	1	81.5	0	0
1985	2	54	1	51.7	0	0	0	0
1985	0	0	1	68.4	0	0	0	0
1985	3	101.1	3	172	2	176.5	0	0
1985	8	237.2	5	292.1	3	258	0	0
1986	2	70	2	129	0	0	0	0
1986	3	103.9	1	59.3	0	0	0	0
1986	0	0	0	0	0	0	0	0
1986	1	33	1	69.7	1	83.3	2	307.8
1986	6	206.9	4	258	1	83.3	2	307.8
1987	0	0	0	0	0	0	0	0
1987	3	111.4	1	52.2	1	81.5	0	0
1987	2	66.7	1	60.4	0	0	0	0
1987	4	126.7	1	57.4	1	95.6	0	0
1987	9	304.8	3	170	2	177.1	0	0
1988	0	0	0	0	0	0	0	0
1988	7	229.3	2	131.2	2	163.5	0	0
1988	0	0	2	124.9	1	77	0	0
1988	1	27.5	0	0	1	76.2	0	0
1988	8	256.8	4	256.1	4	316.7	0	0

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
1989	0	0	0	0	0	0	0	0
1989	2	70.2	1	55.8	0	0	0	0
1989	0	0	0	0	0	0	0	0
1989	6	196.3	0	0	1	92.2	0	0
1989	8	266.5	1	55.8	1	92.2	0	0
1990	1	34.4	0	0	0	0	1	126
1990	0	0	2	121.6	0	0	0	0
1990	0	0	0	0	0	0	0	0
1990	12	453.1	2	100.8	0	0	0	0
1990	13	487.5	4	222.4	0	0	1	126
1991	0	0	0	0	0	0	0	0
1991	6	172.3	0	0	0	0	0	0
1991	2	77.4	0	0	0	0	0	0
1991	6	209.4	3	187.9	0	0	1	164.8
1991	14	459.1	3	187.9	0	0	1	164.8
1992	0	0	0	0	0	0	0	0
1992	4	128.3	1	61.8	0	0	0	0
1992	0	0	1	50.4	0	0	0	0
1992	4	139.4	1	50.3	0	0	0	0
1992	8	267.7	3	162.5	0	0	0	0
1993	0	0	0	0	0	0	0	0
1993	3	118.2	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0
1993	13	446.7	3	178.4	2	158.5	1	102.4
1993	16	564.9	3	178.4	2	158.5	1	102.4
1994	0	0	2	111.9	1	96.5	0	0
1994	3	111.7	1	54.2	1	78.3	0	0
1994	0	0	0	0	1	86.6	0	0
1994	8	269.4	0	0	0	0	0	0
1994	11	381.1	3	166.1	3	261.4	0	0
1995	0	0	0	0	0	0	0	0
1995	5	178.9	2	124.7	0	0	0	0
1995	0	0	0	0	0	0	0	0
1995	2	74.2	3	192.8	0	0	1	272
1995	7	253.1	5	317.5	0	0	1	272

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
1997	0	0	0	0	0	0	0	0
1997	8	266.9	3	181.9	0	0	1	110.8
1997	9	292.7	3	181.9	0	0	1	110.8
1998	0	0	0	0	0	0	0	0
1998	5	171.9	1	59.6	0	0	0	0
1998	1	35.1	0	0	1	97.2	0	0
1998	9	330.8	2	143.9	0	0	1	132.2
1998	15	537.8	3	203.5	1	97.2	1	132.2
1999	1	30	0	0	0	0	0	0
1999	2	71.8	0	0	0	0	0	0
1999	1	43.5	1	57.3	0	0	0	0
1999	6	221.5	2	125.3	0	0	0	0
1999	10	366.8	3	182.6	0	0	0	0
2000	4	126.7	1	53.8	0	0	0	0
2000	2	51.6	1	55	1	86.5	0	0
2000	0	0	2	122.5	0	0	0	0
2000	2	58.5	0	0	0	0	1	204
2000	8	236.8	4	231.3	1	86.5	1	204
2001	4	130.5	0	0	0	0	0	0
2001	2	62	0	0	0	0	2	215
2001	0	0	0	0	0	0	0	0
2001	4	142.2	1	67.2	0	0	1	136.2
2001	10	334.7	1	67.2	0	0	3	351.2
2002	0	0	0	0	0	0	0	0
2002	4	131	1	67.6	0	0	0	0
2002	0	0	0	0	0	0	0	0
2002	9	330.3	4	233.6	2	169	0	0
2002	13	461.3	5	301.2	2	169	0	0
2003	2	81.2	0	0	0	0	0	0
2003	5	165.2	2	108.8	0	0	0	0
2003	1	28.7	0	0	0	0	0	0
2003	3	108	1	62.2	0	0	0	0
2003	11	383.1	3	171	0	0	0	0
2004	1	26.9	0	0	0	0	0	0
2004	7	242.5	1	68.5	0	0	0	0
2004	1	48.6	1	64.4	0	0	0	0
2004	4	129.9	4	258.8	0	0	1	128.5
2004	13	447.9	6	391.7	0	0	1	128.5

Year	25 <50 Days	Sum	50 <75 Days	Sum	75 <100 Days	Sum	More than 100 Days	Sum
2005	1	27.5	0	0	0	0	0	0
2005	2	58.6	0	0	1	87	0	0
2005	0	0	0	0	0	0	0	0
2005	3	107.4	2	125.4	0	0	0	0
2005	6	193.5	2	125.4	1	87	0	0
2006	1	38.2	0	0	0	0	0	0
2006	3	94	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2006	7	231.4	3	200.3	0	0	1	108.4
2006	11	363.6	3	200.3	0	0	1	108.4
2007	2	70.7	0	0	0	0	0	0
2007	2	66.5	0	0	0	0	0	0
2007	0	0	0	0	0	0	1	110.5
2007	5	210.3	0	0	0	0	0	0
2007	9	347.5	0	0	0	0	1	110.5
2008	2	76.7	0	0	0	0	0	0
2008	5	174.9	1	59.2	0	0	0	0
2008	1	49.7	0	0	0	0	0	0
2008	10	324.3	5	321.8	1	83.5	1	100.6
2008	18	625.6	6	381	1	83.5	1	100.6

Mean, SD and CV of Maximum Temperature, Minimum Temperature and Annual Rainfall in Eluwankulama, 1977 -2008.			
Year	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
Mean	31.3	23.7	1192.6
SD	0.7	0.7	257
CV	2.4	2.8	21.6

Statistical Test Value on Rainfall Trend in Eluwankulama

Data file : Vanathavilluwa_RF.csv

Test statistic		a=0.1	a=0.05	a=0.01	
Mann-Kendall	0.945	1.645	1.96	2.576	NS
Spearman's Rho	1.002	1.645	1.96	2.576	NS
Linear regression	1.045	1.696	2.04	2.745	NS
Cusum	3	7.008	7.813	9.364	NS
Cumulative deviation	0.852	1.123	1.246	1.472	NS
Worsley likelihood	2.204	2.872	3.202	3.866	NS
Rank Sum	-0.81	1.645	1.96	2.576	NS
Student's t	-0.683	1.694	2.038	2.741	NS
Median Crossing	1.061	1.645	1.96	2.576	NS
Turning Point	0.566	1.645	1.96	2.576	NS
Rank Difference	1.316	1.645	1.96	2.576	NS
Auto Correlation	-1.743	1.645	1.96	2.576	S (0.1)

Data file: Vanathavilluwa_MaxT.csv

Test statistic		a=0.1	a=0.05	a=0.01	
Mann-Kendall	2.123	1.645	1.96	2.576	S (0.05)
Spearman's Rho	2.206	1.645	1.96	2.576	S (0.05)
Linear regression	2.329	1.696	2.04	2.745	S (0.05)
Cusum	7	7.008	7.813	9.364	NS
Cumulative deviation	1.638	1.123	1.246	1.472	S (0.01)
Worsley likelihood	3.934	2.872	3.202	3.866	S (0.01)
Rank Sum	-2.576	1.645	1.96	2.576	S (0.05)
Student's t	-2.124	1.694	2.038	2.741	S (0.05)
Median Crossing	2.828	1.645	1.96	2.576	S (0.01)
Turning Point	-1.982	1.645	1.96	2.576	S (0.05)
Rank Difference	-3.494	1.645	1.96	2.576	S (0.01)
Auto Correlation	3.573	1.645	1.96	2.576	S (0.01)

Agricultural Drought	
Station: Eluwankulama	
Year	Drought Period
1995	46-51
No of years : 33	

Agricultural Drought

Station: Eluwankulama	
Year	Drought Period (Week no)
1977	36-39
1978	36-39
1979	38-41
1981	38-41
1983	39-42
1986	38-41
1988	38-41
1989	39-42
1991	36-39
1992	36-39
1993	36-39
1995	36-39
1996	37-40
2001	39-42
2002	36-39
2003	36-39
2005	36-39
2007	37-40
2008	36-39

Drought Information

Station: Eluwankulama

Drought condition	No. of years
No Drought	21 (64%)
Mild Drought	10 (30%)
Moderate Drought	2 (6%)
Severe Drought	0 (0%)
Total	33

Meteorological Drought

Station: Eluwankulama				
Sn.	Year	Annual RF (mm)	Deviation (%)	Drought Condition
1.	1976	876.30	-23.1630	Mild
2.	1977	1329.30	16.5575	No Drought
3.	1978	1271.10	11.4544	No Drought
4.	1979	1182.60	3.6944	No Drought
5.	1980	876.60	-23.1367	Mild
6.	1981	999.30	-12.3780	Mild
7.	1982	1052.80	-7.6869	Mild
8.	1983	713.60	-37.4291	Moderate
9.	1984	1817.40	59.3558	No Drought
10.	1985	1259.90	10.4723	No Drought
11.	1986	1316.90	15.4703	No Drought
12.	1987	1144.70	0.3712	No Drought
13.	1988	1416.30	24.1860	No Drought
14.	1989	839.90	-26.3547	Moderate
15.	1990	1163.60	2.0284	No Drought
16.	1991	1316.80	15.4615	No Drought
17.	1992	908.80	-20.3133	Mild
18.	1993	1552.40	36.1197	No Drought
19.	1994	1317.00	15.4790	No Drought
20.	1995	1179.30	3.4050	No Drought
21.	1996	998.40	-12.4569	Mild
22.	1997	1179.70	3.4401	No Drought
23.	1998	1311.00	14.9529	No Drought
24.	1999	975.80	-14.4385	Mild
25.	2000	1152.50	1.0551	No Drought
26.	2001	1344.60	17.8991	No Drought
27.	2002	1446.10	26.7990	No Drought
28.	2003	1059.50	-7.0994	Mild
29.	2004	1528.00	33.9802	No Drought
30.	2005	901.70	-20.9359	Mild
31.	2006	1297.60	13.7780	No Drought
32.	2007	905.90	-20.5676	Mild
33.	2008	1719.50	50.7716	No Drought

Appendix 3. Extreme Climate Indicators used in this study

TXx	Max Tmax	Annual maximum value of daily maximum temp	°C
TNx	Max Tmin	Annual maximum value of daily minimum temp	°C
TXn	Min Tmax	Annual minimum value of daily maximum temp	°C
TNn	Min Tmin	Annual minimum value of daily minimum temp	°C
TN10p	Cool nights	Percentage of days when TN < 10th percentile	Days
TX10p	Cool days	Percentage of days when TX < 10th percentile	Days
TN90p	Warm nights	Percentage of days when TN > 90th percentile	Days
TX90p	Warm days	Percentage of days when TX > 90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX > 90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN < 10th percentile	Days
DTR	Diurnal temperature range	Annual mean difference between TX and TN	°C

Appendix 4. List of Participants

SLCARP - ICRISAT Stakeholder Consultation and Policy Dialogue on Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience held at "The Sovereign", Colombo, Sri Lanka, 5 April 2011

Sl No	Name	Address
International		
1	Dr NP Singh	Project Coordinator, ICRISAT
2	Dr GGSN Rao	Director (Rtd.), Agro-Met Division, Central Research Institute for Dryland Agriculture (CRIDA) Hyderabad, India
3	Dr MVR Murty	Consultant, ICRISAT
4	Dr Uttam K Deb	Principal Scientist, ICRISAT
National		
5	Hon. Mahinda Yapa Abeywardena	Minister of Agriculture, Govijana Mandiraya, Battaramulla
6	Mr KE Karunathilake	Secretary, Ministry of Agriculture Govijana Mandiraya Rajamal Watta Road Battaramulla
7	Mr S Emitiyagoda	Additional Secretary, Ministry of Agriculture Govijana Mandiraya, Battaramulla
8	Ms Yvani Deraniyagala	Representative of Prof. Mohan Munasinghe/ Manager (Research & Training), Munasinghe Institute for Development, Colombo 4
9	Dr WL Sumathipala	Senior Technical Advisor (Climate Change) Ministry of Environment, Rajamal Watta Road, Battaramulla
10	Dr Janake Ratnasiri	Consultant, No 27, Sudarshana Mawatha. Nawala, Rajagiriya
11	Dr Nimal Ranaweera	Consultant Economist, Kurana, Negambo
12	Dr Terrence Abeysekara	No 17/7, Jasmine Park, Narahenpita Road ,Nawala
13	Prof. Buddhi Marambe	Senior Lecturer Faculty of Agriculture University of Peradeniya Peradeniya
14	Prof. Pradeepa Silva	Senior Lecturer Faculty of Agriculture University of Peradeniya Peradeniya

Sl No	Name	Address
15	Mr K Mankotte	Director General Department of Agriculture Peradeniya
16	Dr (Mrs) Sachi Panawala	Scientific Officer National Science Foundation, Colombo 7
17	Ms Nilmini Ranasinghe	Environment Management Officer, No 82, Ministry of Environment, Rajamal Watta Road, Battaramulla
18	Mr AG Karunaratne	Yaloithwela, Rathkarawwa, Via Haputhale
19	Mr S Premalal	Consultant Meteorologist ICRISAT-SLCARP Project/ Deputy Director, Department of Meteorology
20	Dr WMW Weerakoon	Senior Research Officer Rice Research & Development Institute, Batalagoda, Ibbagamuwa
21	Dr MCM Iqbal	Consultant, (Vulnerability & Adaptation) Ministry of Environment, Rajamal Watta Road Battaramulla
22	Ms Anoja Seneviratne	Assistant Director M\No 498, Disaster Management Centre, Colombo 3
23	Dr H Manthrithilake	Director Sri Lanka Programme, IWMI, Battaramulla
24	Dr Premalal Kuruppuarachchi	Asst. Representative, FAO, No 602, Bauddhaloka Mawatha, Colombo 7
25	Prof. Hemanthi Ranasinghe	Professor, University of Jayawardenapura, Nugegoda No 209, Makola Road, Makola
26	Mr HM Ajith Chandra	Director, Department of Treasury Operations Ministry of Finance and Planning General Secretariat, Colombo 1
27	Dr Wijaya Jayathilake	Consultant Sociologist ICRISAT-SLCARP Project
28	Mr J Ranjith Wimalasiri	Environment Management Officer No 82, Rajamalwatta Road, Sampathpaya, Battaramulla
29	Dr (Mrs) Sanathanie Ranasinghe	Senior Scientist Coconut Research Institute, Lunuwila
30	Dr Inoka Munasinghe	Agronomist, Rubber Research Institute, Agalawathta

Sl No	Name	Address
31	Mr HN Kularatne	Hon. President, Farmer Organization, Galahitiyagama, Horopathana
32	Mr Prasanna Ranasinghe	Member, Farmer Organization, Galahitiyagama, Horopathana
33	Mrs Dilrukshi	Research Officer, Transparency International Sri Lanka, Colombo 3
34	Mr Sampath Weerasinghe	Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo 7
35	Mr Weerakkody	Farmer at Mangalapura
36	Ms Thakshila Jayawardena	Research Assistant, SLCARP
37	Ms Sumudu Jayaratne	Research Assistant, SLCARP
SLCARP		
38	Dr JD Samarasinghe	Chairman, SLCARP
39	Mr Prabath Wimal Kumara	Director/Secretary, SLCARP
40	Dr (Mrs) TU Thilakawardena	Senior Scientist, SLCARP
41	Mr M Sakalasooriya	Research Officer, SLCARP
42	Dr (Mrs) P Girihagama	Senior Scientist, SLCARP
43	Mrs Chandra Padmini	Senior Research Officer, SLCARP
44	Mr WMDB Abeyratne	Accountant, SLCARP
45	Ms Rasika Wijesinghe	Research Assistant, SLCARP
46	Dr Frank Niranjan	ICRISAT-SLCARP Project Co-ordinator/ Senior Scientist, SLCARP
47	Ms Kaumalee Dissanayake	Management Assistant, SLCARP
48	Ms NPC Uddika	Research Assistant, SLCARP
49	Mr D Laksiri	Research Assistant, SLCARP
50	Ms Harshani	Management Assistant, SLCARP

Sri Lanka Council for Agricultural Research Policy

Sri Lanka Council for Agricultural Research Policy (SLCARP) is an umbrella organization of the National Agricultural Research System (NARS) that operates within the Ministry of Agriculture. SLCARP came into existence on the 22 December 1987 to create an environment for more productive agricultural research.

With the Secretariat in Colombo, SLCARP serves as an organization in an advisory capacity for co-ordinating and consolidating research efforts within Sri Lankan NARS, funding research projects/ programmes and promoting scientific research linkages in prioritized areas both nationally and internationally. SLCARP has been instrumental in promoting and facilitating research, by improving and enhancing agricultural research through documentation and communicating latest advances in research to the NARS scientists. SLCARP has identified its own perspective, plans and programs for the future in keeping with the aspirations and National goals proclaimed in Mahinda Chinthana to meet the future challenges in enhancing food security and poverty reduction.

Vision

A vibrant and sustainable agricultural research, development and innovation system assuring socio-economic development of Sri Lanka

Mission

To ensure agricultural research, development and innovations are directed towards national development goals through policy formulation, facilitation, coordination, monitoring and evaluation and impact assessment

About Project

Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience (ADB RETA: 6439)

Aim

To provide science-based solutions and pro-poor approaches for adaptation of agricultural systems to climate change for the rural poor and most vulnerable farmers in semi-arid regions

Expected outputs

- Improved understanding of climate variability and adaptation-coping strategies of the rural poor
- Best practices and institutional innovations for mitigating the effects of climate change
- Strategies to address socioeconomic problems relating to changing weather patterns and availability of a range of initiatives for their alleviation

About **ICRISAT**

ICRISAT Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

ICRISAT is a member of the CGIAR Consortium

The **International Crops Research Institute for the Semi-Arid Tropics** (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, of whom 644 million are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market-Oriented Development (IMOD).

ICRISAT is headquartered in Patancheru near Hyderabad, Andhra Pradesh, India, with two regional hubs and five country offices in sub-Saharan Africa. It is a member of the CGIAR Consortium. CGIAR is a global research partnership for a food secure future.

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