CLIMATE CHANGE AND ITS POTENTIAL INFLUENCES ON AGRICULTURAL ECONOMY OF SRI LANKA

ABSTRACT

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THESIS
SUBMITTED IN FULFILLMENT
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1.1 INTRODUCTION:

Climate is a dynamic component of the environment, which has direct/ indirect influence on man and his activities. Most commonly, climate is known as the long-term average weather conditions prevailing over an area. Climate is dynamic in many respects, for example, it varies in time and space, and changes occur over sufficiently long periods of time. "Climate Change" is the long-term changes in characteristics of climate of a region due to astrophysical, geophysical or human-induced parametric variations. Such changes of climate at global or regional level have significant influences on life processes on earth, especially man and his living environment. The inevitability of the climate change is quite visible in recent years, and a series of technical country reports of the Inter-governmental Panel on Climate Change (IPCC), a UN body is testimony to this process resultant concerns.

Climate change in Sri Lanka is mainly characterised by the temporal and spatial variations of temperature as well as rainfall, two vital parameters of climate. Sri Lanka is (a) a tropical country close to the Equator and (b) is an Island nation with the surrounding sea, the nature of which is providing more uniform ambient conditions as opposed to land masses. Agriculture is the most dominant and important sector of Sri Lanka's economy that plays an extremely vital role in the overall economic development of the country. This sector is heavily weather dependent world over, more so in the tropical monsoon type of climate. As climate affects many aspects of plant and animal biology, the effects of climate elements and their extremes will significantly alter the productivity in agriculture and 'eco-systemic balance', which in turn may generate negative impacts on the socio economic conditions of many societies, specially for the developing countries like Sri Lanka, where agriculture contributed little more than a quarter of the country's Gross Domestic Product (GDP).

1.2 STATEMENT OF THE PROBLEM:

Climate change may adversely affect the water balance leading to serious water scarcity and management problems, thus shrinking agricultural land use and the potential effects on agricultural production in Sri Lanka. Agriculture is the predominant sector of Sri

Lanka's economy, which accounts for over 25 per cent of the GDP. This sector supplies nearly half of the total employment and export earnings and about 40 per cent of government revenues. Over 90 per cent of the rural population directly or indirectly depends on agriculture as a major source of income and livelihood. In recent years, Sri Lanka's agriculture has suffered serious setbacks from abnormal weather conditions. Climate change and its variability could be the main reasons for the sustained yield fluctuations and almost every crop sub-sector has experienced sluggish growth due to it, especially due to rainfall decline. Therefore, it may be necessary to study the partial contribution of climate change on agricultural production and coverage of crops etc.

The agriculture sector consists of two sub-sectors, the non-plantation or domestic food crop sector ('subsistence farming' sector) and the plantation sector. The non-plantation sector mainly consists of paddy, other food grains, maize, soybean, vegetables, perennial crops etc. Frequent abnormal weather conditions witnessed in recent times are the main causes for the reduction of water flow in River Mahaweli. It seriously affects, and has resulted in the reduction of rice production in the Dry zone of Sri Lanka. Plantation sector plays a major role in the Sri Lankan economy and climate change can affect plantation crops, too. This sector comprises tea, rubber and coconut that are the highest net foreign exchange earner of the country. The plantation crop-yields show the widest fluctuations in the period of 1982-1990. Total tea area in the country has declined to 181,172 hectares in the year 2001. The steady upward trend experienced in tea production since 1993 reversed in 2001. The out put, which exceeded 300 million kg. in 2000, declined by 3.3 percent to 295 million kg. in 2001. It was mainly the outcome of the unfavourable weather conditions that prevailed throughout the year, compounded by the failure of Southwest Monsoon, especially during the later part of the year. Past production records of tea industry in the Central High Lands clearly show the inter-year fluctuation of tea production, attributed to the bad weather conditions during recent years. The rubber sector has shown variation in production during the past years. The total rubber production of 96584 metric tons in 1999 declined to 87,636 metric tons in 2000, and has further declined to 86230 metric tons in 2001. Coconut production continued to drop due to the lagged effect of the drought in 2001. Coconut production declined by 10 per cent during the first half of the year 2002. Apart from the other economic reasons, one of the main reasons for this declined was cumulative affects of adverse weather conditions mainly the low rainfall in main growing areas during the period 2000-2001. The fishery industry is expected to be affected by climate change in many ways. As a consequence of the rise of global air temperature, there could be increase in ocean water temperature leading to thermal expansion of oceanic water. It would lead to change of the weather systems in the ocean. Changing pattern of the weather extremes can have adverse effects on the country's fishery productivity, farming, income and nutritional availability of the country, thus jeopardizing the food security of the country.

1.3 OBJECTIVES:

The main objectives of the study are as follows:

(i) To study the present climate changes and the fluctuations, annual and seasonal variability of rainfall and temperature conditions (between 1950 and recent times) with available recent data (since most scientific studies indicate important climate changes after 1970);

(ii) To study the area, production and yield changes within the study are, in respect of the principal crops like rice, tea, rubber and coconut;

(iii) To study the impact of climate changes on the broad Agro-Climatic Zones- the Wet Zone, the Intermediate Zone the Dry Zone in respect to crop production, coverage and yield of the crops; and

(iv) To study the response of varied farming communities to perceived threats of climate change and its consequences.

1.4 RESEARCH QUESTIONS:

During the course of the study the following research questions were addressed:

(i) Located closer to the Equator and surrounded by the sea, the island nation of Sri Lanka is expected to demonstrate a more stable climatic regime. But from studies and empirics available, it appears not to be so, i.e., the island is equally susceptible to climate changes and rise in un-predictability of climate, especially after 1970. There is therefore the need to study specifically, the changes in rainfall regimes and temperature conditions, not only over the entire island but the variations thereof within major agro-climatic regions.

(ii) The second issue relates to the effects of climate change on major farming activities, i.e. subsistence crops like rice, plantation (commercial) crops like tea and rubber and coastal farming like coconut and marine fisheries. All these are of vital consequence to the majority of the population of Sri Lanka and their livelihood system and also that, all these activities are extremely susceptible to long-run and short-run changes in climate, which in effect affects hundreds of thousands of families.

(iii) It is also important that the impacts of climate changes are not uniform over the entire study area. In deed, the variations and fluctuations in rainfall and temperature regimes are much more pronounced at a lower regional scale. The study therefore, also aims at unravelling the specificities of changes at a regional level (within the study area of Sri Lanka that spans all the three major relief and agro-climatic regions) and in the manner that these variations and changes influence various farming practices.

(iv) The final issue to be addressed is how people in general but specific communities like the rice farmers, the plantation farmers and the fishing communities view the climate changes and the manner in which they cope with the problems.

1.5 RESEARCH METHOOLOGY:

(a) SELECTION OF THE STUDY AREA

The ecological demarcation of Sri Lanka has been devised to meet the special requirements of research. It has evolved from a synthesis of the more natural characteristics of climate, relief and soils. With respect to the rainfall the Island has been divided into three Agro-climatic zones. These three major zones are namely: (i) Wet Zone,(ii) Intermediate Zones and, (iii) Dry zone. Since ancient times, the south-western sector has been known as the Wet zone and the rest of the country as the Dry zone. The boundaries of above three zones have been demarcated with consideration of present agricultural land use, distribution of forest species, rainfall data, topography and soils. This Agro-climatic classification has been used for the present study. The study area for current research constitutes of 13 districts of the 25 districts of Sri Lanka. The study area (13 districts) represents all the three major agro-climatic zones, and nearly half of the total geographical area of Sri Lanka.

(b) SOURCES OF DATA

(i) SCONDARY DATA

Secondary data for climate (rainfall and temperature) have been collected from various government and non-government sources, like Meteorological Department, Government of Sri Lanka, Colombo and NRMC (Natural Resources Management Centre) at Peradeniya. Rainfall data at the 33 Meteorological observatories and temperature data for 12 Meteorological observatories for the last 50 years were collected.

Agricultural crop production data have been collected from various authorities and sources, such as official records from districts level publications, maps, and statistical reports and from other authorities. Discussions were carried out with various authorities to collect relevant data. Agricultural statistical information and related documents have been collected from the Department of Statistics and Department of Agriculture, Government of Sri Lanka. Agricultural crop data like those for paddy, tea, coconut and rubber, have been collected from related departments for all the 13 contiguous districts under the present study out of the twenty-five districts of Sri Lanka.

(ii) PRIMARY DATA

Primary data have been collected at the farm level, with particular reference to farmers' response to climate change, and its effects on communities and their livelihood systems. Household and primary farm level information has been collected through a structured questionnaire based survey and through discussions with the village communities and village heads. In addition, district and divisional levels administrative officers, those involved in the agricultural development activities were interviewed.

The primary data collection and surveys aim at eliciting information from communities about their perception and the problems they encounter resulting from impacts of climate change in recent times. The communities considered most vulnerable are the rice cultivators in the Dry Zone, the coconut and fishing communities on the coast (west) and the small tea producers (planters) in higher and middle elevations in the Intermediate Zone. They, whereas represent a variegated rural communities at one level, also represent a variegated climatic zones (i.e., representing a differentiated influences of climate change) and also a variety of relief zones, the low-land coastal areas, mid-level central areas as well as the mid-and high elevations in the Intermediate Zone. The attempt has been to capture a variety of influence of climate change in the island nation as well as a variety of communities as they confront an increasingly unpredictable climate and the manner they are affected by it and the ways perhaps, they manage to cope with the changing environment.

(c) SAMPLING METHODS FOR PRIMARY SURVEY

In Sri Lanka, Paddy is cultivated in the Dry Agro-Climatic Zone to the northwest. The villages are usually small with average household size of less than 100. With a sample size of 50 percent and keeping the average sample size per village at 30 (large sample condition), it was considered adequate to consider 3 villages from the rice community, with a total enumerated sample households of about 100. Kekiriwa division in the Anuradhapura district was selected for the survey with three villages, i.e., Kelepuliyankulama, Kadubodagama and Kadiragama. The selection of households was on the basis of a 50% random sample from the former two villages and a complete enumeration (census) of the latter village, Kadiragama, which is a very small hamlet. Matale district that lies in the Intermediate zone open to both the monsoons was selected for the primary community survey of small tea growers. Two communities with total sample of about one hundred farmers were considered adequate for the purpose. The sampling was carried out on a 50% random sampling system. For the purpose of eliciting information from a fish-coconut community, village Ambakandawila of Puttalan district north-west of Colombo was selected where a 50% random sampling of the households of the village was conducted.

(d) CLIMATE DATA ANALYSES

The study of climate change has been carried out with the help of time-series data of monthly average rainfall and temperature from; Rainfall (33) and temperature (12) weather stations within the three main Agro-Climatic Zones, within the designated study area . The climatic data is for over a fairly long period of time, i.e. from 1959-60 to 2001-02, split into pre- and post-1975 periods. Two factors are considered important here, viz., annual and seasonal variability of rainfall and temperature. Other climatic factors have only marginal impact on Sri Lanka, though they could be of significance in other world regions. The missing data of each rainfall and temperature data series were estimated using Normal Ratio Method. The trend of rainfall and temperature variability of monthly, seasonally and annually have been examined using linear trend analysis to examine negative or positive trends in rainfall and temperature over the entire period under the study. Student's "t-test" was applied to examine the significant level of the trend estimators, 'b' coefficients. Variability of seasonal rainfall and temperature have been computed by standard techniques. Data represent more than 50 year because standard normal 30-year periods stipulated by the WMO (World Meteorological Organisation) for climate change studies. Data have been analysed by year, decades and seasons.

(e) CROP DATA ANALYSES

Trend of paddy production, coverage and yield, trend of tea production, coverage and yields, trends of rubber production, coverage and yield, and trend of coconut production, coverage and yield have been examined using linear trend rates and growth rate per year, for each variables at the districts level, for which reliable data was available. The crop data refers to 1968-69 to 2000-01 period at the district level. The go around the yearly fluctuations moving averages of continuous three-year periods were calculated for 1968-69 to 1970-71, with 1970 as the mid-point, so also for years ending 1970s, 1980s and the

1990s. The periods have been broken to two parts, the 1970s, and the 1980s and 1990s, since the climate changes become quite visible after the 1980s.

(f) CROP-CLIMATE RELATIONSHIP

To examine the relationship between major crops and climate parameters (rainfall and temperature) "Regression and Correlation analyses" have been carried out for selected crops of rice, tea, coconut and rubber. An analysis with "Student's t-test" was applied to test significance of the correlation coefficients.

(g) FORECAST MODELS FOR TEMPERATURE AND RAINFALL

Agro-Climatic Zone wise temperature and rainfall forecasts have been estimated for years 2010, 2020, 2030 and 2050 based on linear trends for 1960-2000 and 1980-2000 climate data. It may be noted, climate variable change rather slowly, probably at a linear rate (as evidenced from station-wise trend estimates). The station averages for given years for each agro-climatic zone was prepared, the trends estimated and forecasts proposed.

(h) CLIMATIC SEASONS

The Meteorological Department has identified four main rainfall seasons as follows. Namely: (For the present study these four seasons have been used for analysis)

- (i) First Inter Monsoon (FIM) season: March to April
- (ii) South West Monsoon (SWM) season: May to September
- (iii) Second Inter Monsoon (SIM) season: October to November
- (iv) North East Monsoon (NEM) season: December to February

(i) CROP YEARS AND CROP SEASONS

The Maha season on October to February In the dry zone the Maha rains vary mostly 750 and 1500 mm, with both the driest areas situated diametrically opposite one another in the Northwest and Southeast. The highest, but rather locally restricted rains, occur on the eastern flank of the Knuckles range, which are fully exposed to the Northeast monsoon relatively high rainfall, between about 1500 and 1750 mm.

'Yala' is the minor cultivation season (March to September) dependent on the short rainy season. During the Yala season the contrast of precipitation distribution is best developed an approximately 1500-2000 mm on the windward slope of the Wet zone but only about 250 mm in the Dry zone on an average. In the Yala seasons the Wet zone and Dry zones are clearly distinguish from one another according to the amount of rainfall the rainfall pattern is much more differentiated in the wet than in the dry zone.

1.6 GENERAL CONCLUSION:

The broader implications of the study could be summarised as follows:

(a) A number of global studies including IPCC do confirm a global level climate change during the last century, but especially after the 1970s. However, region/ country level studies are patchy, but, by and large, agree with the above position. Some recent climatic studies on Sri Lanka (Domores, Chandrapala etc) also confirm a similar process in the Island Nation. The present study that covers nearly half of Sri Lanka (covering all the three major agro climatic zones of the country, 13 out of 25 districts) indicate significant temperature and rainfall (both quantum and seasonal incidence) on the basis of 40 year data for 12 temperature reporting and 33 rainfall reporting stations covering the entire study region. Annual as well as maximum/ minimum temperature conditions are consistently on the rise from 1960s, but are especially pronounced after the 1970s. Both linear trends and growth rates confirm these positions. The position of high altitude area (Nuwaraeliya) is ambiguous due to both being in wet zone as well as the elevations. The same pattern can be seen four main seasons of FIM, SWM, SIM and NEM temperature conditions are consistently on rise from 1970, 1980 and 1990.

(b) There has also a consistent decline in the quantum of annual rainfall over the study area, with exception of a few pockets in the wet and intermediate zones. The slope values (of trend rates) when plotted for seasons, indicate that the decline are more pronounced during the SWM (Yala season) in windward areas, contrary to expectation, and rather has somewhat increased on the leeward areas (of the Central Highlands). On the other hand, during the NEM season, there is a more pronounced decline in areas to the windward side (Dry Zone) as compared to the leeward side (South-western area of the Central Highlands).

(c) Additionally, the overall increase in temperature is associated with a decline in annual average rainfall, especially from mid-1970s, into 1980s and 1990s. This is rather unusual, since a global warming generally could be associated with increased precipitation (suggested by Global Climate Models). The difficulty in this case is, it will be a global trend with disturbed regional as well as seasonal distribution of rainfall. But generally, the rainfall decline is in conformity with global studies that indicate precipitation decline in tropics as against increased rainfall in temperate areas(especially Northern Hemisphere winters). However, since the study is on Sri Lanka, it was not possible to capture the global processes that could be responsible for specific rainfall changes in Sri Lanka.

(d) The above changes in climate have pronounced effects on agriculture in the study region. Rice farming is the principal crop in the dry region (Anuradhapura). An increased in temperature conditions as well as decline in rainfall in the principal growing season (Maha season, NEM season) highly affects the coverage of the crop and consequently the out put. The picture of yield decline is ambiguous, since yield changes respond to number of other factors, technological, farm management practices, prices and so on, well beyond the scope of the present study.

(e) The plantation crops, tea, rubber and coconut are all under rain-fed conditions and are more prone to effects of climate change. These three crops are, however, located more into the either Wet or Intermediate zones. But, never the less, there has been consistent decline in coverage and yield of all the three crops especially into the 1990s, a decade marked by a series of droughts and of high severity. The data for agricultural crops relate to 1970s onward, district-wise. It may be noted that avoid annual fluctuations in crop coverage and yield, the standard method of three-year moving averages were taken. Never the less, the results of trend analysis as well as growth rates confirm consistent declines in plantation crops.

(f) It is examined the possible (statistical) relationships between rainfall and temperature changes with changes in the principal four crops, in terms of changes in output (total production), coverage of the crop and yields. This analysis uses the respective data sets at the district level (13) within the reference study area, between 1970s and 2000. The climatic data, which is station (point) based has been averaged for the respective districts. Simple correlation coefficients and bi-variate regressions were carried out for generalisation purposes. The seasonal analysis has also been carried out for Maha (NE Monsoon) and Yala (SW Monsoon) seasons, wherein the reference segregated production, coverage and yield data and segregated seasonal average rainfall and temperature data has been used.

(g) A variety of socio-economic as well as technological factors are important considerations, along with the role played by bio-physical and climatic elements. The study area (of Sri Lanka) that has been under investigation, samples all the three major agro-climatic areas of the country. But, most farming practices are under rain-fed conditions (particularly, the plantation crops). Therefore, the influence of climate change, especially increasing temperature as well as falling precipitation conditions are likely to have much more pronounced influence on the areal coverage of (rain-fed) crops, whether rice or other plantation crops, which in turn will impact the total out-put of each of the crops. The yield is governed by several socio-economic, technological and farm management practices and are relatively less governed by climatic factors alone, though by no means immune to climatic influences.

(h) The impact of temperature increases associated with decline rainfall has also regional influences, i.e., on the wet zone, the intermediate zone and the dry zone regions in varied degrees. The impacts have been the strongest in dry zone areas, but the other zones have not been immune to the influences. For example, there has been pronounced declines rubber areas and output (wet zone). Tea areas in Wet zone are more affected than probably in the intermediate zones (the Central Highland areas), because of failures of SWM and temperature peaks during NEM and the SIM periods. The coconut areas are confined to the coastal areas, particularly on the west coast and it appears there are serious problems with drying of coconut plants and significant yield decline (These are all in rain-fed conditions).

(i) The perception and adaptive strategy study of the three farming communities indicate invariable unanimity of the recognition by farmers that both the rising temperatures and uncertain rainfall pattern including changes in seasonality have all contributed to their misery, declining incomes and living standards, growing indebtedness. Many opt to move out of the present farming practices by switching to other crops. Many look for greater Government support system and relief and crop insurance system.

(j) The condition of the rice farmers in the Dry zone, especially calls attention. The farmers are either small or marginal and their incomes meagre. The increasing temperature conditions in the last two decades combined with decreasing rainfall during the principal growing season (North East Monsoons) and especially, the uncertainty and unpredictability have been adding to their misery. The crop coverage is seriously affected and since most of the farmers are tied to only farming their conditions worsen by the day. The rainfall long-term predictions (our estimations) show further decline in rainfall year after year, at a rate of about 14 mm per year and this is likely to further aggravate the situation.

1.7 SUGGESSTIONS FOR FUTHER RESEARCH:

Sri Lanka study suffers from the lack of suitable crop models for assessing the impact of climate change. There is a need for crop models for paddy, tea, rubber and coconut, which would require further micro-technical data that was unavailable during the current study. The forecasting method used was quite simple due to lack of data on both other climatic parameters as well as access to some global data which could be incorporated in more sophisticated modelling in climate change itself.

1.8 RECOMMANDATIONS:

The following recommendations are made in light of the study as above:

(i) In light of very strong indications of climate change not only over the study region but for the whole of Sri Lanka and also the forecasts on increasing temperature and declining precipitation conditions in coming decades, model programs could be developed for agricultural crops. The green revolution techniques have to be modified through research to make major crops cultivation sustainable.

(ii) Effective water supply (like, extension of irrigation works into dry regions and water harvesting systems) and management systems are recommended be in placed with a degree of urgency. Even feasibility of trans-basin diversion schemes could be explored to counter climate change impacts by increasing the water availability in the dry zone. Better water management systems could be introduced by strengthening the institutional base to manage water resources economically and increase the efficiency of irrigation by adopting sprinkler irrigation methods and drip irrigation system. A project can be started to test the efficacy of small reservoirs for regulating the base river flow also feasible. This will increase crop diversification and cropping intensity.

(iii) There is a need for revising the existing agricultural policy taking into account the climate change impacts. These need strong action plan prepared for implementing the agricultural policy. Particular attention should be placed on for high droughts resistant crops varieties and the development of irrigation water management practices especially in the drought prone areas.

(iv) Sri Lanka present agricultural land use system is bedevilled with problems such as stagnant level of agricultural out put, decline in farm incomes and widening social problems. The response strategy in the agricultural sector has to focus on the potential for diversifying agricultural production and the food habits of the people. A comprehensive approach to rice cultivation is necessary. The dependence of rice and wheat has to be reduced and other crops less susceptible to droughts could be promoted like, yams, tubers and other food crops. The elements of such a strategy should include development of rice varieties with high yields which are droughts resistant and use less water, agricultural practices which use less water, sound water management systems, cultivation of alternative crops, and conversion of uneconomic rice lands into other high value uses. In long term the introduction of agricultural systems, which are less dependants upon the monsoon cycle may be necessary. This may require changes in cropping pattern, agricultural systems, cultural practices, as well as perceptions and attitudes of farmers. Changes in crop varieties, new agricultural systems and cultural practices such as mixed farming, inter-cropping, dry farming and other similar systems have been advocated to deal with theses problems.

(v) It is also essential that adequate funds are provided for conducting research to address the impacts of climate change on agriculture, particularly in development of drought resistant crop varieties, development of cropping pattern suitable to agro climatic zones and enhanced research on climate and crop simulation models to reach ideal conditions.

(vi) There is also the need to promote rain-fed farming and the efficient utilisation and conservation of water through development of integrated farming system in relation to climate change.

(vii) Finally, there is the need to create community awareness and farmers education on climate change and its possible hazards and in the manner different farming communities could possibly cope with the changing conditions and prepare themselves. No doubt, much of this requires a proactive position of the Government and the district administrations to enable the farming communities to come to terms with the risks involved in their chief occupations and livelihood systems.

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January, 2005

I, K.W.G. Rekha Nianthi, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of my previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institute.

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Chapter - I

Introduction

1.1 Introduction

Climate is a dynamic component of the environment, which has direct/ indirect influence on man and his activities. Most commonly, climate is known as the long-term average weather conditions prevailing over an area. Climate is dynamic in many respects, for example, it varies in time and space, and changes occur over sufficiently long period of time.

"Climate Change" is the long-term changes in characteristics of climate of a region due to astrophysical, geophysical or human-induced parametric variations. Such changes of climate at global or regional level have significant influences on life processes on earth, especially man and his living environment. One characteristic of climate, under normal circumstances is its stability and predictability which govern not only human activities like given agricultural practices, but even other living beings, say for example timely flowering of plants, regulating the reproductive behaviour of animals and so on. With climate change, the predictability of climate is destroyed; and that creates a lots of problems to cope with by both the living world in general, but human beings, in specific. Throughout earth's history, climate has never been same over time and space. With climate change, corresponding changes occur in the human activities, particularly in the agriculture that invites attention of the scientists to probe into the problem associated with such changes.

Most scientists agree that the global climate is changing, especially during the past century, which in turn may drastically affect the biophysical environment of man and the society. On the other hand, the local climate may change due to global climate change (its impact on a regional scale) that has given rise to regional variations or reasons specific to local factors. Such impacts could be varied over countries, depending on the scale of regional impacts as well as the economic and technical ability of the specific countries in tackling these impacts. No nation can remain immune to the direct or indirect effects of climate change, and Sri Lanka is no exception to it. The inevitability of the climate change is quite visible in recent years, and a series of technical -country reports of the Inter-governmental Panel on Climate Change (IPCC), a UN body is testimony to this process and resultant concerns.

Climate change in Sri Lanka is mainly characterised by the temporal and spatial variations of temperature as well as rainfall conditions, two vital parameters of climate. Sri Lanka is (a) a tropical country close to the Equator and (b) is an Island nation with the surrounding sea, the nature of which is providing more uniform ambient conditions as opposed to land masses. Other climatic parameters are, perhaps relatively less important in the instant case. Moreover, these two parameters are the most influential factors affecting agriculture, which is going to be one of the main thrust areas of the present study.

Agriculture is the most dominant and important sector of Sri Lanka's economy that plays a vital role in the overall economic development of the country. This sector is heavily weather dependent world over, more so in the tropical monsoon type of climate. Agricultural crops are extremely susceptible to fluctuations in climatic factors such as rainfall and temperature conditions, especially their seasonality and (un)-predictability. Climate change has significant economic effects on agriculture including changes in farm productivity, cropping pattern, profitability, price, supply, and trade. The variability of climate poses major challenge for the large peasantry and small farmers of the country.

Agricultural productivity is sensitive to global climatic changes in the country and therefore, its impacts needs to be evaluated. As climate affects many aspects of plant and animal biology, the effects of climatic elements and their extremes will significantly alter the productivity in agriculture. The disturbance to 'eco-systemic balance' may generate negative impacts on the socio economic conditions of many societies, specially for the developing countries like Sri Lanka, where agriculture contributes little more than a quarter of the country's Gross Domestic Product (GDP).

1.2 Statement of the Problem

Climate change may adversely affect the water balance leading to serious water scarcity and management problems, thus shrinking agricultural land use and the potential effects on agricultural production in Sri Lanka. In 1996 Sri Lanka experienced a decline in the real growth rate of Gross National Products (GNP) from 6 per cent in 1995 to 3.1 per cent (real GDP growth declined from 5.5 per cent in 1995 to 3.8 per cent in 1996).

The depressed conditions at the beginning of 1996 were due to unfavourable weather conditions resulting from the severe droughts and accompanying power cuts. Due to its strong dependence on hydropower, Sri Lanka's electricity generation declines during the drought periods, and it directly affects some of the plantation industries and other sectors related to agriculture in the country.

Agriculture is one of the predominant sectors of Sri Lanka's economy, which accounts for over 25 per cent of the GDP (Central Bank, 1994). This sector supplies nearly half of the total employment and export earnings and about 40 per cent of government revenues. Over 90 per cent of the rural population directly or indirectly depends on agriculture as a major source of income and livelihood. In recent years, Sri Lanka's agriculture has suffered serious setbacks from abnormal weather conditions. Climate change and its variability could be the main reasons for the sustained yield fluctuations and almost every crop sub-sector has experienced sluggish growth due to it, especially due to rainfall decline. Positive growth in one year has been followed by decline in the succeeding year. Consequently, major crop production declined drastically that resulted in a sudden decrease in export-earnings, deficiency in food supply, and a massive increase in import of foodstuffs. However, it is to be recognised that other factors like price response to commercial crops like tea, coconut and rubber, input prices and governmental policies do affect agricultural output. Therefore, it may be necessary to study the partial contribution of climate change on agricultural production and coverage of crops etc.

Sri Lanka experienced severe shortages in agricultural production, aggravated by climatic fluctuations during the last three decades. The contribution of the agriculture sector to the national economy has declined drastically, from 46 per cent of GDP in 1950 to the about the current level of twenty percent. The rate of growth of agricultural output has slowed in recent years from 4.5 per cent in 1999 to 1.8 per cent in 2000. This resulted in a decline in the sectors' contribution to Gross Domestic Products (GDP) from 21.3 per cent in 1999 to 20 per cent in 2001. Besides the contribution to GDP, the agriculture sector provided 19 per cent of export earnings in the year 2001 (Ministry of Plantation Industries, 2003).

The agriculture sector consists of two sub-sectors, the non-plantation or domestic food crop sector ('subsistence farming' sector) and the plantation sector. The non-plantation sector, which mainly consists of paddy, other food grains like, maize, soybean, vegetables, perennial crops etc. accounts for 76 per cent of the total cultivable land, whereas the plantation sector accounts for the balance 24 per cent.

Rice is the staple food crop in Sri Lanka, which account for about 37 per cent of per capita calories and 30 per cent of the per capita protein on the average, in Sri Lankan diet (Statistical Abstract, 1991). Climate change research in Asia (Sri Lanka Country Report, 1994) reveals the possibility of some adverse future impacts on agriculture of the country. Coarse grains and legumes will be subject to severe fluctuations in annual production. Rice cultivation too, will be similarly affected. According to the statistics, the paddy production has stagnated over the last few decades. Analysis of impacts on rice using a crop model developed by Seshu and Cady (1983) shows that rice cultivation will drop by about 6 per cent with a temperature increase of 0.5^0 C in the year 2010. This will reduce the Gross National Products (GNP) at current prices, by 0.2 per cent. Moreover, Mahaweli Development Project (MDP), which diverted water from the Wet Zone to Dry Zone for agricultural purposes has not fulfilled its primary objective mainly due to less of rainfall and consequent reduced discharge of the river. Frequent abnormal weather conditions witnessed in recent times are the main causes for the reduction of water flow in River Mahaweli. It seriously affects, and has resulted in the reduction of rice production in the Dry zone of Sri Lanka.

Plantation sector plays a major role in the Sri Lankan economy and climate change can affect plantation crops, too. This sector comprises tea, rubber and coconut that are the highest net foreign exchange earner of the country (SRs. 71 billion per annum). Plantation sector provides employment for about 380,000 workers in the plantation districts and it is equal to 20 per cent of employment in the economy as a whole. The plantation crop-yields show the widest fluctuations in the period of 1982-1990 (Central Bank, 1991). The GDP value addition of the plantation crops has declined by 6.4 percent in year 2001. This was mainly attributed to the failure of both the Northeast and Southwest monsoons. The production of all major plantation crops declined during the year 2001 mainly due to the adverse weather conditions (Ministry of Plantation Industries, 2003).

Sri Lanka is one of the major players in the global tea industry, accounting for 10 per cent of world tea production and 21 per cent of tea exports. Sri Lanka's tea industry is the country's highest net foreign exchange earner, which accounts SRs. 59.32 billion or

US dollar 663 million in 2001. It provides direct employment for about 600,000 people, out of which 380,000 belong to large plantations or estates, and the rest to smallholdings. The last completed tea survey in 1994/95 recorded the total tea area in the country as 189,000 hectares contributing 42 per cent in low country, 30 per cent in mid country and 28 per cent in up-country. Total tea area in the country has declined to 181,172 hectares in the year 2001. The steady upward trend experienced in tea production since 1993 reversed in 2001. The out put, which exceeded 300 million Kg. in 2000, declined by 3.3 percent to 295 million Kg. in 2001. The decline was mainly the outcome of the unfavourable weather conditions that prevailed throughout the year, compounded by the failure of Southwest Monsoon, especially during the later part of the year. Past production records of tea industry in the Central High Lands clearly show the year-to-year fluctuation of tea production, attributed to the bad weather conditions during recent years. The breakdown of the hydropower generation of the country, which resulted in power cuts during the second half of the year (2001), aggravated the situation by directly affecting the tea production.

Rubber is the second largest plantation (export) crop in Sri Lanka. It is an important raw material used for local and foreign manufacturing industries. The total land area under rubber presently covers only 157,000 hectares (continuous shrinkage of 19 per cent during past ten years). The rubber sector has shown variation in production during the past years. The total rubber production of 96584 metric tons in 1999 declined to 87,636 metric tons in 2000, and has further declined to 86230 metric tons in 2001.

Coconut continues to be an important plantation crop, which contributes about 2.6 per cent of the GDP and 3.4 per cent to the foreign exchange earnings annually. It provides livelihood for about 5 per cent of the total workforce, which signifies the socio-cultural importance of coconut. The most important contribution of the coconut crop is as source of food, providing on an average 22 per cent of the per capita calorie intake in the daily diet, thus ensuring nutrition security of a large segment of the population of the country. The total area of coconut cultivation is 442,000 hectares. It is estimated that 150,000 persons are directly employed, and around 750,000 families are dependent on the coconut industry as a whole. Generally 70 per cent of the coconut production is consumed locally, the balance 30 per cent is absorbed by the processing industries. The total coconut production from 1995 to 2001 were 2755, 2546, 2632, 2561, 2822, 3000 and 2700 million nuts, respectively. This scenario has changed in 2001 with the decline in production. Coconut production continued to drop due to the lagged effect of the drought in 2001. Coconut production declined by 10 per cent during the first half of the year 2002. Apart from the other economic reasons, one of the main reasons for this declined was cumulative affects of adverse weather conditions mainly the low rainfall in main growing areas during the period 2000-2001 (Ministry of Plantation Industries, 2003).

Coastal-marine fisheries contribute 85 per cent of all fish production in the Island and provides about 65 per cent of animal protein, 13 per cent of the total protein consumed in Sri Lanka. It is a vocation that provides full or part time employment to about 100,000 persons. The fishery industry is affected by climate change in many ways.

As a consequence of the rise of global air temperature, there could be increase in ocean water temperature leading to thermal expansion of oceanic water. It would lead to change of the weather systems in the ocean. Changing pattern of the weather extremes can have adverse effects on the country's fishery productivity, farming, income and nutritional availability of the country, thus jeopardizing the food security of the country. Further, a temperature rise of about 2 ^{0}C can have substantial impacts on the distribution, growth and reproduction of fish stocks, due to the resulting changes in distribution patterns of spawning areas. Further, as the coastal region contains about 21 per cent of all paddy land and most of the coconut land of the country, the changing pattern of the climate, can be expected to significantly lower national agricultural output, especially as coastal agriculture constitute about one-sixth of the total agricultural GDP.

The production patterns of agricultural crops are uneven and the yields low due to uncertain weather conditions over the major Agro Climatic Zones in Sri Lanka. This marked disparity of agricultural production influences the economic conditions across regions in Sri Lanka. Sri Lanka has three major Agro Climatic Zones depending on the differences in altitudes, climatic and soil factors. However, seasonal changes and inter-seasonal variations of rainfall and temperature conditions within the climatic zones are very crucial to fresh-water regimes and the agricultural economy that remain relatively less investigated. Hence, it is a timely need to understand spatial and temporal changes of rainfall and temperature conditions in the major climatic zones in order to undertake appropriate policy responses to mitigate the possible negative impacts of the changing climate and its impact on agriculture. Therefore, the present study will examine the spatial and temporal changes of rainfall and temperature conditions with concern to the major agricultural crops in selected districts over the major Agro Climatic Zones in Sri Lanka. Although there have been some studies on fluctuations of the rainfall in different rainfall stations in Sri Lanka, detailed and specific regional studies have not been carried out in main Agro-Climatic Zones from the view point of spatial and temporal changes, seasonality in rainfall and temperatures regimes and their relationship with the agricultural production.

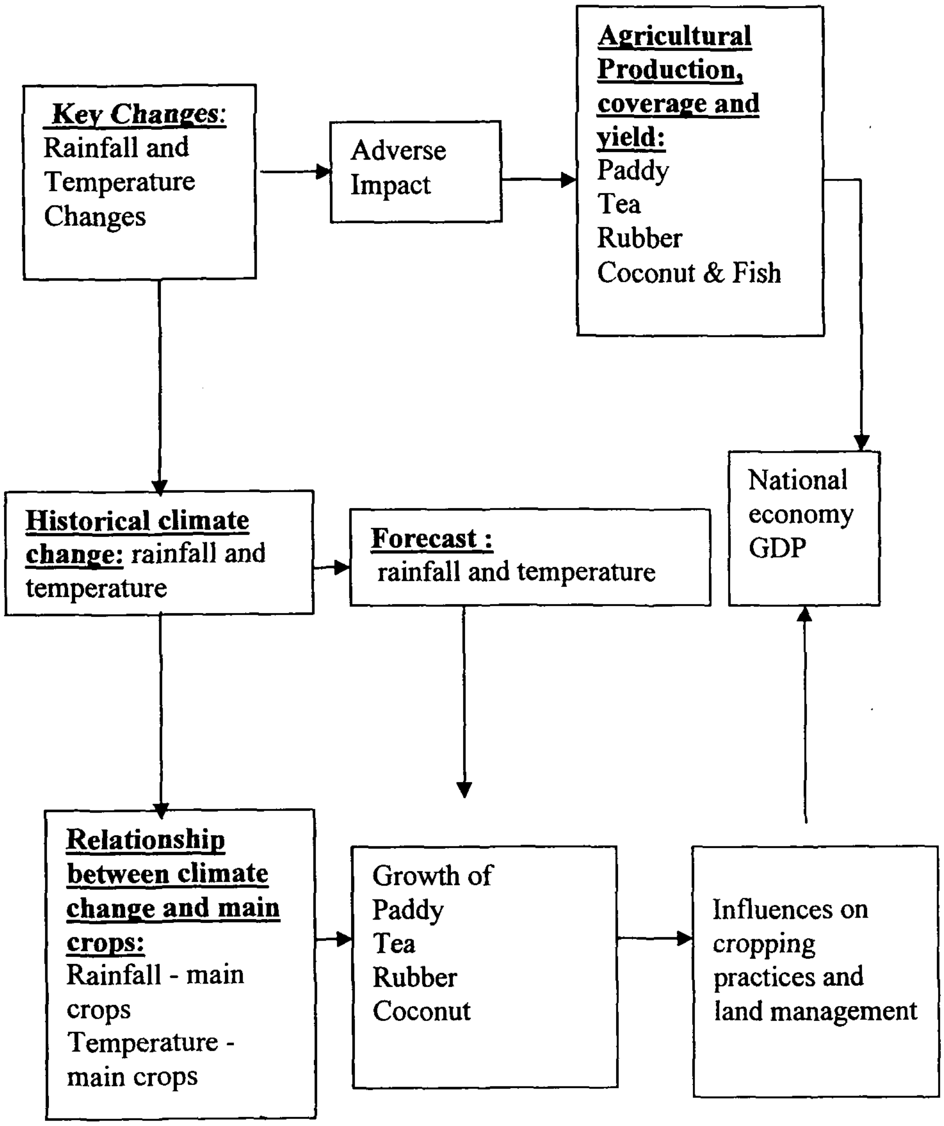
In this regards, proposed study attempts to examine following issues:

(i) The present situation of climatic change specifically in relation to temperature and precipitation changes; and

(ii) The effect of climate change on agricultural production across the major three Agro-Climatic Zones.

1.3 Conceptual framework of Climate Change Impact on Agriculture Development

Figure 1.1: Conceptual framework of Climate Change Impact on Agriculture Development of Sri Lanka



1.4 Objectives of the Study

The main objectives of the study are as follows:

(i) To study the present climate changes and the fluctuations, annual and seasonal variability of rainfall and temperature conditions (between 1950 and recent times) with available recent data (since most scientific studies indicate important climate changes after 1970);

(ii) To study the area, production and yield changes within the study area, in respect of the principal crops like rice, tea, rubber and coconut;

(iii) To study the impact of climate changes on the broad Agro-Climatic Zones- the Wet Zone, the Intermediate Zone the Dry Zone in respect to crop production, coverage and yield of the crops; and

(iv) To study the response of varied farming communities to perceived threats of climate change and its consequences.

1.5 Research Questions

During the course of the study the following research questions were addressed:

(i) Located closer to the Equator and surrounded by the sea, the island nation of Sri Lanka is expected to demonstrate a more stable climatic regime. But from studies and empirics available, it appears not to be so, i.e., the island is equally susceptible to climate changes and rise in un-predictability of climate, especially after 1970. This debate needs to be addressed and some degree of resolution is necessary, particularly in respect of the changes in rainfall regimes and temperature conditions, not only over the entire island but the variations thereof within major agro-climatic regions.

(ii) The second issue relates to the effects of climate change on major farming activities, i.e. subsistence crops like rice, plantation (commercial) crops like tea and rubber and coastal farming like coconut and marine fisheries. All these are of vital consequence to the majority of the population of Sri Lanka and their livelihood system and also that, all these activities are extremely susceptible to long-run and short-run changes in climate, which in effect affects hundreds of thousands of families. Measuring productivity changes, cropping pattern changes and these, to the extent influences by climatic changes is one of the major objectives. Indeed, major cropping practices are localised in distinctive regions within the country, i.e., rice in dry-zones, but lower elevations to the north, rubber and tea around the central and south-central high lands and coconut and fishing in coastal areas.

(iii) It is also important that the impacts of climate changes are not uniform over the entire country. In deed, the variations and fluctuations in rainfall and temperature regimes are more pronounced in a lower regional scale. The study therefore, also aims at unravelling the specificities of changes at a regional level (within the study area of Sri Lanka that spans all the three major relief and agro-climatic regions) and in the manner these variations and changes influence various farming practices.

(iv) The final issue to be addressed is how people in general but specific communities like, the rice farmers, the plantation farmers and the fishing communities view the climate changes and the manner in which they cope with the problems.

1.6 Organisation of the Study:

The study has been organised into three major parts and nine chapters. Outline of the study contents can be summarised as follows:

Part I: Chapter I to IV

(i) Chapter I: Introduction:

Chapter I (Introduction) includes introduction, statement of the problem, the conceptual frame-work of the study, objectives, research questions, the organisation of the study etc.

(ii) Chapter II: Literature Review:

Chapter II deals with a detailed review of scientific literature on the subject and consists sub-sections on global climate change, regional changes and the present situation of climate change in Sri Lanka, especially on temperature and rainfall. Previous studies have been mentioned in related to climate change and its effects on agricultural production.

(iii) Chapter III: Data and Methodology:

Chapter III deals the methods and techniques of data collection and analyses of the study. Study areas for different analyses are also discussed in this chapter.

(iv) Chapter IV: Biophysical Environment, Agriculture and Socio-Economic Conditions in Sri Lanka, with Special Reference to the Study Area:

Chapter IV deals with the general background of Sri Lanka, with special reference to the study area, in particular reference to the biophysical environment and socio economic conditions, along with major relief and agro-climatic zones that become important both from the point of view of evaluation influences of climate change at a lower regional scale. It also to discuss geographical distribution of Agro-Climatic zones and regions, agricultural production of selected crops, land use pattern, brief review of the fisheries industry and agricultural polices with related to agricultural systems of Sri Lanka.

Part II: Chapter V to VIII

(v) Chapter V: Climate Change:

Under Chapter V analysis of climate change, particularly in respect of temperature and rainfall changes for a 40 year period has been carried out. This chapter devoted to comprehensive analysis of rainfall and temperature changes, their variability over time and space, and analysis of extreme events.

(vi) Chapter VI: Agricultural Changes:

Chapter VI examines changes in area, production and yield of major crops (1970-2000). This chapter devoted to the study of changes in crop production, coverage, yield of major crops as outlined in respect to the designated districts in Agro Climatic Zones for the past few decades.

(vii) Chapter VII: Impacts of Climate Change on Major Crops:

Chapters VII examine the impacts of climate change on major crops: (crop production, coverage and yield) in districts wise in three major Agro-Climatic Zones.

(viii) Chapter VIII: Adaptive Response of Farming Communities:

Chapter VIII is included an adaptive response of farming communities: With the help of primary data at the farm level, response of farming communities to climate change have been studied. Three farming communities have been concerned for this analysis.

Part III: Chapter IX

(ix) Chapter IX: Findings and Conclusion:

The first section of this chapter summarises the specific outcome of the present study. The second section of the chapter deals with generalisations arising out of specific findings. The final section deals with limitations of the study, suggestion for further research, recommendation as well as policy implications of the study.

Chapter – II

Review of Literature

2. Introduction

The review of literature contains four main parts: Part I briefly discusses the past and present situation of the climate change research on the global scale. What is climate change and its causes and the impact in regards some of the major parameters (temperature and precipitation) on global and regional scale? Reviews have been carried out on studies of present and future predictions of climate change on global and regional scale. Part II contains relationship between global climate change and agricultural crops based on regional scale studies. Part III deals with past and present climate change studies and the predication for future climate change in Sri Lanka. Part IV discusses research conducted on climate change and its relationship with major agricultural crop in Sri Lanka, in specific.

Part I

2.1 Global Warming and Greenhouse Effect and Global Climate Change

The earth receives short wave radiation from the sun, one third of which is absorbed by the atmosphere, ocean, ice, land and living organisms. The energy absorbed from solar radiation is balanced, in the long term, by the out going radiation from the earth and atmosphere, through infrared spectra. While short wave radiation from the sun can easily pass through the atmosphere, the long wave radiation emitted by the warm surface of the earth is partially absorbed by trace gases in the atmosphere called Green House Gases (GHG).

The global warming is defined as a general rise in temperature on a global scale caused by enhanced greenhouse effects. The greenhouse gases include water vapours, Carbon di-oxide, Stratospheric ozone, Nitrous oxide and Methane, which are transparent to short wave radiation (incoming radiation) but non-transparent to long wave radiation (out-going). If no steps are taken to slow down greenhouse gas emissions, it is quite possible that levels in the temperature level of the atmosphere will increase substantially by the year 2100.

According to current projections, higher atmospheric concentrations of these gases will cause the average global temperature to rise by 1.4^0 to 5.8 ^{0}C by the year 2100. This warming would be much larger and much more rapid than any temperature change experienced over at least the last 10000 years. It would have significant impacts on human society and the natural environment (UNEP, 2001:3).

The green house effect is a natural feature of the earth's environment, keeping the planet's surface at a warm average temperature of 15 ^{0}C. The natural process of CO_2 and the other greenhouse gases form a blanket of gases that do not allow all the radiation to escape back into the outer space that is known as the "Greenhouse Effect". The Greenhouse Effect is essential to maintain the Earth's temperature at a habitable level.

The problem is that human activity is making the blanket of gases "thicker" and thereby enhancing the greenhouse effect. By 1995, most of the research concluded that the main culprit was CO_2 emissions, produced by the burning of fossil fuels (Coal, Gas, and Oil) in factories and power stations, and motorised vehicles. When coal, oil, and natural gases are burnt, huge amounts of CO_2 are spewed into the earth's atmosphere filling it up with large amounts of greenhouse gases, much more than what required for the natural process of maintenance of habitable temperature conditions. When forests are destroyed, the carbon stored in the bio-masses escapes to the atmosphere. Other basic activities, such as raising cattle and planting rice also emit some amount of methane, Nitrous oxide, and other Greenhouse gases. If emissions continue to grow at the current rates, it is almost certain that atmospheric levels of CO_2 will double from pre-industrial levels, during the Twenty-first century itself.

2.1.1 The Inter-Governmental Panel on Climate Change (IPCC)

The Inter-Governmental Panel on Climate Change (IPCC) was set up jointly by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) in 1988 to provide authoritative international statements of scientific opinion on climate change. Most of the studies on global climatic changes have been summarised in the IPCC's reports and these assessments form the standard scientific references for all concerned with climate change and its consequences in academia, government and industry, worldwide. The IPCC prepared its first comprehensive assessment report in 1990, with subsequent supplementary reports in 1992 and 1995.

Since 1990, the IPCC's periodic volumes and reports are available with the up-to-date facts including climate change impacts, adaptations, and mitigation options. The panel also established a special committee on the participation of developing countries to promote the participation of those countries in its activities.

The IPCC's first Assessment Report was completed in 1990 and helped to inspire the intergovernmental negotiations that led to the 1992 United Nations Framework Convention on Climate Change (Montreal). Its second assessment report was published in 1996 and played a role in the Kyoto Protocol Negotiations (Dec. 1997). The 2001 third assessment report concentrated on new findings since 1995 and paid special attention, to what is known about 'climate change at the regional level'.

2.1.2 The Global and Regional Climatic Changes: Temperature and Precipitation:

Owing to the great concern shown by the scientists the world over to the climate change (global and local, and long and short term), a large literature has come out studying these changes which analyses different variables of climate, the reasons behind them and their possible impacts on the man, his activities and the environment as a whole. The scientists have also suggested models of future climate changes and possible human adaptation to it.

Most scientists agree that the global climate has changed significantly in the past century. The IPCC has estimated that the South Asia (5^0-30^0 N 70^0-105^0 E) has minor changes in precipitation in winter and generally increased throughout the region by 5 to 15 percent in summer. According to large-scale analysis, rainfall has decreased in the

Northern Tropics, over land area, since the 1950s (Diaz et al, 1989). Among the other reasons, the high inter-annual variability of the South Asia Monsoon System depends on the El-Nino phenomena too. El-Nino occurrences have been correlated with low rainfall and La-Nina years with high rainfall events. (Domroes and Schaefer, 2000:203)

According to large-scale analysis of global precipitation changes, it is found that, rainfall has shown a decrease in the subtropics of Northern Hemisphere and increases in the mid latitudes and Southern Hemisphere (IPCC, 1990). The global annual average surface temperature has increased by about 0.5 ^{0}C since the later-half of the last century (Houghton et al, 1990). The global average temperature was 13.8 ^{0}C in 1950 and in 1997 it increased to 14.6 ^{0}C. The trend of warming has been occurring since 1861 and the warmest year has been recorded in 1998, and the warmest decade has been recorded as the 1990s (IPCC). Temperature has increased within the eight kilometres in the lower layer of the atmosphere (Troposphere) in past four decades. The recent warming has been the greatest over the mid-latitudes (continental) in winter and spring, with a few areas of cooling, such as the North Atlantic Ocean. Precipitation has increased over land areas in high latitudes of the Northern Hemisphere, especially during the winter season (IPCC, 2001).

The Sahel region of the West Africa has experienced persistent drought conditions for more than twenty years with significant inter-annual changes (Houghton et al, 1992). It is reported that Sahel rainfall, like the Indian Monsoon (1880-1990) displays large year-to-year changes in seasonal mean rainfall. The mean rainfall during the

Monsoon regime has also been observed to have shifted over India and China during 1950 to 1970.

The Global Mean Surface Air Temperature (GMSAT) has increased by 0.3 to 0.6 degree Celsius since the late 19^{th} Century (Houghton et al, 1992). The IPCC has estimated minor changes in precipitation in winter, and a general increase throughout the region by 5 to 15per cent during the summer in Southern Asia (5^0 to 30^0N and 70^0 to 105^0E). The recorded precipitation appears to have increased in most of the regions, except Southern Europe, the Sahel Region of Africa, Indo-China, Japan and Chile. Pant and Rupa (1996) summarised the mean annual precipitation over South Asian Region that shows statistically significant increasing long-term trends. The annual winter and autumn surface temperature over this region shows increasing long-term trends. The impacts of climate change vary over space, and these variations are of concern to policymakers operating at regional, national or international levels because of the consequences of these spatial differences on policy and planning.

2.1.3 IPCC's Major Findings

IPCC has further summarised following conclusions for climate change based on various recent research in different scale (Microsoft Encarta Encyclopaedia, 2003).

(a) Temperature

(i) The global average surface temperature has increased over the 20th century by about 0.6 ^{0}C. The global average temperature will increase by 1.4^0 to 5.8 ^{0}C in 1990 to 2100.

(ii) Generally, since 1950 to 1993 diurnal maximum temperature during the daytime has increased by 0.2 ^{0}C per decade.

(iii) Lower layer of the atmosphere within the 8 kilometres, the temperature has increased the past 4 decades.

(iv) Globally, it is very likely that the 1990s was the warmest decade, and 1998, the warmest year on record, since 1861.

(v) Frequency and intensity of the drought especially in Africa and Asia regions have been increasing in the past few decades.

(vi) According to the recent model predications, global average temperature on the surface will increase, especially in the Northern High Latitudes areas, and it will affect the more during the winter seasons.

(vii) Diurnal temperature ranges (differences between maximum and minimum temperature) have been decreasing during the 21st century.

(viii) According to the IPCC (computer based models), the "Best Guess" is Global average temperature will increase by 1^{0}C in the 2030, and by the end of 21st century, it may increase up to 3 ^{0}C.

(b) Precipitation

(i) According to the IPCC`s GCM model results, compositions of average water vapour of the atmosphere will increase in the 21^{st} century.

(ii) During the second half of the 21^{st} century, precipitation will increase in the Northern, middle and high Antarctic, especially in the winter months.

(iii) Year to year changes of precipitation can be expected in various part of the world.

(iv) Due to increased temperature, evaporation will also increase and it will increase the rainfall in coastal areas.

(v) According to the GCM results, most affecting areas of climate change have been identified. For example, Sahel of Africa` s temperature will increase and reach to 0.2^0 to 2.2^0 C and average precipitation will increase in some areas, and decrease in some other areas. Further, moisture of the soil will decrease during the summer season, resulting in soil desiccation. Most of the areas the rainfall intensity will also increase.

(vi) Instability of climate system and frequency of abnormal weather systems will be encountered and increases in natural hazards such as Cyclones, Storms, Droughts, Floods, Heat waves and Tornadoes could be experienced in increased frequency.

Part II

Part II contains relationship between climate change and agriculture, which is based on the regional scale studies.

2.2 Climate Change and its Impacts on Agricultural Crops: Regional studies

Substantial research have been conducted on the impacts of climate change on agriculture, since the 1990 IPCC assessment, with new studies for different sites and countries covering many areas of the world. From agriculture point of view, the crop yield and productivity changes will vary considerably across regions of the world. Thus, the pattern of agricultural production is likely to change in a number of regions (High confidence). Based on global agricultural studies using doubled CO_2 equilibrium of GCM scenarios (Marufu et al, 1995: 429-440), lower latitude and lower income countries have more negative impacts. Again, crop model simulation results vary widely, e.g., ± 20percent changes in yield, for specific countries and sites across studies and GCM scenarios (Medium confidence). Vulnerability to climate change depends on physical and biological response but also on Socio economic characteristics (Marufu et al, 1995: 429-440).

Most of the national studies have shown incremental additional costs of agricultural production/ per unit area under scenario of climate change, which could create a serious burden for some developing countries (Medium confidence). Variations in agricultural and climatic conditions across the world may lead to different local and regional impacts. The effect of climate change on local, national and regional economies and food supplies depend on future economic and agricultural conditions and on the conditions of international supplies and trade, which could adversely affect food security of many developing nations, especially in the tropical areas.

Changes in large-scale atmospheric dynamics such as the El Nino/Southern Oscillation (ENSO) and tropical Monsoon could cause significant shifts in rainfall patterns with consequent effects on agricultural production, but climate scientists have not resolved how ENSO events may be affected by long-term climate change in general due to global warming.

In tropical and sub-tropical areas where temperature variation is less extreme throughout the year than in temperate areas, season length and seasonal variation depend on regular patterns of precipitation. Temperature, solar radiation, relative humidity, wind and precipitation vary not only over the season and the year, but also on a daily basis. Extreme climatic events (e.g., storms with high winds, flooding, heavy rains, and hail-storms, late or early frosts) can be responsible for severe or total crop losses.

A variety of models that integrate understanding of crop yield and climate relationships have been used for estimating changes in the potential crop yield, zonal production shifts, and regional and global production patterns. Climate and related other factors strongly interact to affect crop yields. Models have provided an important means for integrating many different factors that affect crop yield over the season (Rotter, 1993).

Higher temperatures would necessitate increase in crop water demand. Global studies have found a tendency for increased evaporative demand to exceed precipitation increases in tropical areas—a unfavourable PE ratio and thus, rise in aridity (Rosenzweig and Parry, 1994), but this result varies locally and across climate situations. Large changes in the seasonal pattern of rainfall or changes in the consistency of rainfall within the crop-growing season would likely matter more for annual crops than changes in annual precipitation and potential evaporation rates.

2.2.1 Climate Change and Agriculture: Research in South and Southeast Asia

The greater variability in rainfall amounts and temperature changes, directly affect the crops and other calendar agricultural activities in the tropics. South and Southeast Asia include the southern portion of Asia from Pakistan in the West to Vietnam in the East as well as Indonesia and the Philippines. Population in South Asia are vulnerable because of heavy dependence on agriculture and high population density. Agriculture accounts for more than 30per cent of GDP in most countries in the region. Seasonal Monsoon is the most dominant climate feature that affects agriculture. Tropical storms are important features of the climate, around which current systems operate. These storms can be destructive but also are one of the main sources of moisture. Changes in their frequency or severity would have significant impacts.

Climate changes are already showing their impacts on various fields of human activity, especially agriculture. This will influence the global climatic patterns and hitherto modify the crop productivity. Due to the complexity of the crop environment interactions, crop yield responses to climate changes are frequently non-linear with small climate changes producing large effects on yield (Parry and Carter, 1988).

Parry et al. (1992) showed yield impacts that vary across the countries of Thailand, Indonesia and Malaysia and across growing seasons. Coastal inundation was also estimated to be a threat to coastal rice, and to fish, prawn and shrimp ponds. These authors estimated that a 1 meter sea level rise could cause a land ward retreat of 2.5 km in Malaysia; such a rise was estimated to threaten 4200 hectares of productive agricultural land an area equal to slightly less than 1per cent of Malaysia's rice-paddy area. Model results showed that under Goddard Institute for Space Studies (GISS) doubled CO_2 climates, erosion rates in three Malaysian river basins increased from 14 to 40 per cent and soil fertility declined on average by 2 to 8 per cent. It will be definitely negatively affect to crop cultivation (Marufu et al, 1995:440).

The increases of temperature and level of the carbon dioxide will also increase the rates of biological productivity of some of the crops, and so that crop production rates may also increases. For this, scientists have to study the prevailing climatic conditions and adjust crops or varieties to match new patterns of agricultural potentials. It is likely that increasing trends on production will be maintained through a combination of shift of agricultural zones and adjustment of crop varieties (Salinger, 1991). Parry and Swaminathan (1992) suggest, "... the changes in climate could provoke serious reduction in food production potential, particularly in regions that are at present vulnerable to climate variability such as the agricultural zones in semi-arid and humid tropics" (Yash et al, 1996:4).

Brammer et al. (1994) conclude that, among other things, the diversity of cropping systems does not allow a conclusion of magnitude or direction of impact to be made for Bangladesh at this time. Matthew et al. (1994a, 1994b) have estimated the impacts on rice yield for many countries in the region for equilibrium climate scenarios of three major GCMs that predict temperature and precipitation increases for the region. The results show substantial variation in impact across the region and among the GCMs (Table 2.1).

Table 2.1: Selected crop studies for South and Southeast Asia

Study	Scenario	Geographic scope	Crops	Yield impacts (percent)	Other comments
Rosenzweig & Iglesias (eds.), 1994[1]	GCMs	Pakistan India Bangladesh Thailand Philippines	Wheat Wheat Rice Rice Rice	-61 to +67 -50 to +30 -6 to +8 -17 to +6 -21 to +12	UKMO, GFDL, GISS and +2C,+4C, and +-20 percent precip; range is over sites and GCM scenarios with direct CO2 effect; scenarios w/o CO2 and w/adaptation also were considered; CO2 effect important in off setting losses of climate only effect; adaptation unable to mitigate all losses GGCMs included UKMO, GFDLQ, CSIRO9, CCC and BMRC; GCM results scaled to represent 2010, includes CO2 effect.
Qureshi & Hobbie, 1994	Average of 5GCMs	Bangladesh India	Rice Wheat	+10 decrease	Low estimates consider adaptation; also estimated overall loss of farmer income ranging from \$10 to \$130 annually.
		Indonesia	Rice Soybean Maize	-3 -20 -40	Maize yield affected by reduced radiation (increased clouds); variation in yield increase; range is across seasons.
		Pakistan Philippines Sri Lanka	Wheat Rice Rice *Soybean* Coarse Grain Coconut	-60 to –10 decrease -6 -30 to +1 decrease decrease	Range across GISS, GFDL, and UKMO GCM scenarios and crop models; included direct CO2 effect; *varietal adaptation was shown to be* capable of ameliorating the detrimental effects of a temperature increase in currently high-temperature environments.
Parry et al.,1992	GISS	Indonesia	Rice Soybean Maize	approx.-4 -10 to increase -65 to –25	
		Malaysia	Rice Maize Oil palm Rubber	 -22 to -12 -20 to –10 increase -15	
	3GCMs	Thailand sites	Rice		
Matthews et al., 1994a 1994b		India Bangladesh Indonesia Malaysia Myanmar Philippines Thailand	Rice	-5 to +8 -3 to +28 -9 to +14 +6 to +23 +2 to +27 -14 to +22 -14 to +14 -12 to +9	

Notes: [1]Country studies were done by Qureshi and Lglesias, 1994: Rao and Sinha, 1994: Karim et al., 1994; Tongyai, 1994; and Escano and Buendia, 1994, for Pakistan, India, Bangladesh, Thailand, and the Philippines, respectively. UKMO= United Kingdom Meteorological Office, GFDL= Geophysical Fluid Dynamics Laboratory, GISS= Goddard Institute for Space Studies, CSIRO= Commonwealth Scientific and Industrial Research Organisation, CCC= Canadian Climate Centre, BMRC= Bureau of Meteorology Research Centre.

Source: Marufu et al, 1995: 429-440.

Sastri and Urkurkar (1996) have analysed climate variability and crop productivity relationship in Chhattisgarh region of Central India. They have found that extreme inter annual fluctuation of rainfall affects agriculture especially rice production that is unstable and uncertain in this region, and this is the main reason that the inputs are not increasing as in other parts of the country, keeping the productivity low and almost stagnant over the decades.

Pant et al. (1996) have examined that the mean annual surface air temperature over India that shows a significant warming of about 0.4 ^{0}C/100 yr. during the past century (1901-2000) but the rate of increase appears to have slowed down in the recent 3 decades. This warming is mainly due to the increasing maximum temperature. They have also pointed out that the annual, winter and autumn surface temperatures over this region show increasing long-term trends but the trend is statistically significant only for the autumn temperature.

Variation of agriculture systems, climates, resources, and economic characteristics across and within countries may be more important in determining the effects of climate change than difference in climate scenarios themselves. Agricultural policy is an important consideration in most regions. Climate change is generally not among top policy priorities for policy makers. Climate change could affect the cost and livelihood of millions of people in developing countries, such as food adequacy and reduction of chronic hunger, export competitiveness, arresting regional and national economic and social development, farm income, and the viability and quality reducing or reversing land degradation and soil loss through erosion, and other conservation and environmental objectives.

Part III

This part discusses past and present research studies about the climate change in Sri Lanka. Scenario and future predictions about climate change also briefly mentioned. More emphasis is given to the climatic parameters like temperature and rainfall.

2.3 Climate Change Research in Sri Lanka

Climate related a few scientists have started studies since 19th century and most of their studies are based on the descriptive level research. Marshal (1846) identified how climatic factors influence river structure and how the Southwest and Northeast Monsoon influence them. Tennet (1859), Ferguson (1887) and Eliot (1887) have done some of the descriptive studies regarding climate of Sri Lanka. Cook (1931) examined spatial seasonal distribution of rainfall and their influences.

Thambiyahpillay (1952) started statistical analysis on climate and he examined relationship and variation between elevation and annual average rainfall. Further, he has conducted various researches on rainfall pattern of Sri Lanka. Farmer (1956) analysed variability and its ranges of rainfall in Sri Lanka. Sirinanda (1970) and Domroes (1970) examined the rainfall pattern in the Uva basin of Sri Lanka and identified some of the causes of this variation such as convection, storms and depressions.

A numbers of studies have been carried-out on climate change in Sri Lanka since later part of the last century. Initially, De Mel (1971) indicated some obvious changes in the rainfall pattern of Sri Lanka, particularly during the Southwest Monsoon period. Madduma Bandara (1971) examined rainfall exposes in the western and eastern sides and he found that the highest rainfall is received on the Central Highland of Sri Lanka. Madduma Bandara and Kuruppuarachchi (1988) have found that during the last century annual rainfall has been decreasing on the Central Highlands of Nuwaraeliya rainfall station.

The trends and patterns of the Sea Surface Temperature (SST) around Sri Lanka indiçated the almost same variations as with the Northern Hemisphere Sea Surface Temperature reported by Jones and Bradley (1992).

The climate change around Sri Lanka was reported by Kayane et al. (1995). They indicated that the precipitation in the Southwest Monsoon season decreased in the Central Highland of Sri Lanka since 1870's. In particular, the trend of precipitation was in inverse relation between the Southwest coastal sites and central highland sites. They also discussed the effects of the global warming to the hydrological phenomenon and the increase of sea surface temperature over the Indian oceans. The sea surface temperature around the Island recorded since the later half of last century also indicates clearly a positive trend. It has intensified the Indian Monsoon circulation, and the intensified Monsoon increases the coastal windward rainfall and decreases the mountainous and leeward rainfall in Sri Lanka.

According to the studies by Fernando and Chandrapala (1995) the surface air temperature has shown an increasing trend at most parts of the country and the annual rainfall has shown a decreasing trend during the more recent period (1961-90) at most of the stations except those in the North-western sector of the island. They also found that there is a positive correlation between the occurrence of thunder activity and temperature.

Domroes (1996) examined rainfall variability over Sri Lanka and found very large fluctuations over the secular period 1853-1993 and 1931-1960. The negative anomaly is noticed, which is most strikingly indication of decrease in the amount of rainfall in the more recent decades such as 1960-1990. In every year, rainfall over Sri Lanka reduced by average 10 mm. In contrast, the secular trends showed an inconsistent pattern for the annual totals, expressing decreasing as well as increasing trends. It was not possible to identify certain contiguous regions of Sri Lanka with a positive or negative trend. As far as seasonal tends are concerned the results are controversial, although many similarities to the annual trend are noticed. Secular seasonal trends indicate increasing as well as decreasing patterns of rainfall whereas the trends over the more recent period, 1960-1993 show consistently a decreasing trend for all seasons. The observation also expresses high standard deviations and high variability of rainfall and in both the cases; the values are higher over the recent decades than for the secular series of observations. The trend of all Sri Lanka annual rainfall anomalies relative to 1853-1993 shows a negative sign, which indicates decreasing rainfall over the recent past. This is confirmed for the period 1960-1993 over, which a very strong negative trend of rainfall anomalies is noticed underlining a more striking decrease of rainfall in the recent past, than over the entire last 140 years.

Kumar and Patil (1996) have analysed long-term variation of rainfall and surface air temperature over Sri Lanka and found that all Sri Lanka mean surface air temperature series indicates a very high and statistically significant warming trend throughout the year on monthly as well as annual basis. The warming is of the order of 0.3 ^{0}C /100 years in the annual mean temperature, with relatively higher trend in the NEM and SWM seasons (0.35 ^{0}C/100 years) and lower trend in SIM season (0.2 ^{0}C/100 years). A monthly scale decrease of rainfall has been statistically significant in the month of June.

Schaefer (1996) indicated that the reasons for the increase of temperature in Sri Lanka are in particular the increases of Carbon dioxide in the atmosphere and the strong influences of the El-Nino phenomena. The changes in Climatological elements over Sri Lanka are summarised by Miyashita (1997). The air temperature of almost all area of the island shows an increasing trend, and the lapse rate of Sri Lanka decreased by about 0.038 ^{0}C/100m in the last 100 years. The decrease in the lapse rate of Sri Lanka means that the air temperature at the central highland area increases more than low land area temperature. He analysed the time series of annual precipitation at 7 observation stations in Sri Lanka of Wet Zone rainfall stations indicating decreasing trends of annual precipitation after the 1960s.

The trend of precipitation decreases at almost all area excluding South-western coastal area. In particular, the trend of precipitation at the Central Highland area and Eastern Coastal area in the Semi-arid region, which shows a clear decrease in the Southwest Monsoon rains and in the Northeast Monsoon also. Chandrapala (1996), Domroes (1996) and Schaefer (1996) have confirmed that the climate of Sri Lanka has been changing since the last century and the same process will further continue in future.

Miyashita (1997) examined the temporal variation of Sea Surface Temperature (SST) around the Island of Sri Lanka and the trend analysis was made for the annual average for SST. All sea area around Sri Lanka shows an increasing trend of sea surface temperature and the regression co-efficient are about 0.86-0.95 $^{0}C/100$ years. Punyawardena and Cherry (1999) have found that El Nino conditions in the central and eastern Pacific Ocean can affect the rainfall pattern in Sri Lanka, particularly during the Second Inter-Monsoon period. Schaefer (Manfred et al, Undated: 103-117) has examined monthly temperature and rainfall data from 13 meteorological observation stations, which are distributed over the whole country. According to his study, annual temperature shows increasing trends over the period of 1895-1996 at almost all stations under study (0.11-1.37^{0} C). The positive temperature trends are increased Northeast Monsoon (0.27-1.33^{0} C) and First Inter Monsoon (0.21-1.62^{0} C) temperatures, while the increasing trends during the Southeast Monsoon (0.18-1.44^{0} C) and the Second Inter Monsoon (0.20-1.12^{0} C) are comparatively low. Similar observations are given for the period 1960-1996 showing that annual (0.30-1.52^{0} C) and seasonal temperature is increasing at all stations under study. In addition, the rainfall shows decreasing trend (9-620 mm) at almost all stations for period 1895-1996. In this study, rainfall also experiences seasonal differences. The highest decrease was observed during Northeast Monsoon season (10 to 119 mm) and Southwest Monsoon seasons (up to 387 mm), whereas the trends during the

First Inter Monsoon (6 to 45 mm) and Second Inter Monsoon (up to 104 mm) seasons are comparatively smaller.

Domroes and Schaefer (2000) studied on the climate change in Sri Lanka (for temperature and rainfall) over the past 102 years (1895-1996) indicates that the intensity of climate change process increased over the more recent past (1960-1996). As far as temperature is concerned a distinct increase could be shown over the recent past with a strong trend of warming in the island country. On the contrary, the incidence of rainfall shows stronger decreasing trend over the same recent period. The change is especially the most strikingly (temperature increase and rainfall decreases) in the Northeast Monsoon Season.

Rekha and Mohapatra (2003) examined the temperature changes of nine representative stations from major climatic zones (Wet, Intermediate and Dry zones) in Sri Lanka during the period 1950-2002. The study indicates increasing trend of annual temperature as well as maximum and the minimum temperatures. Most of the annual temperature series indicated significant increasing trends. Rekha (2003) has examined the changes in annual averages of monthly averages of rainfall and temperature in the major climatic zones of Sri Lanka. The results show increasing trend of temperature while wet zones temperature showed sharp increases than other zones. Rainfall also showed some increasing trends over the wet zone but decreasing trends over other zones especially in recent times.

Most of these recent studies indicate that the annual rainfall over a major part of the country has shown a decreasing trend from 1961 to 1990. The increase of mean temperature would increase the "temperature maxima" of the existing temperature cycle. These changes will result in an increase in warmer conditions as well as decrease in the moisture in the atmosphere, which can give negative effects on the ecosystem of the island. Any anomaly of temperature or rainfall may drastically affect the biophysical environment and consequently, the society of the entire Island nation of Sri Lanka. Extreme weather events such as drought, floods and some influences of the El-Nino/ Southern Oscillation (ENSO) events are the most significant evidences of it. However, numerous doubts still exit about the magnitude of the climate change on the regional scale. Therefore, it is necessary to conduct studies on a regional as well as local scale that allows a more precise assessment of the phenomenon.

2.3.1 Climate Change Research on Mountain Environment in Sri Lanka

Central Highland is generally defined as the region above 300 m. contour in Sri Lanka. This plateau is geologically close to the Dharwarians and Cuddapahs of southern peninsular India, differentiated from the mainland India by the Palk Strait. It is located in the south centre of the island with many peaks including the Piduruthalagala of 2,524m. above the sea level, the highest peak in Sri Lanka. This area covers about 15,000 km^2 (approximately one-fourth of the total land area of the island). However, within this region, topography is highly diverse with mountain ranges, valleys, plains, ridges, peaks, plateaus, basins and even, escarpments. Due to the central mountain complex relief plays an important role in the rainfall distribution of Sri Lanka.

Climate changes have also occurred on this mountain environment too, and a number of studies have been conducted on the region. Madduma Bandara and Kuruppuarachchi (1988) found that the annual precipitation at Nuwara Eliya in the Central highlands has decreased during the last century. During this period the land use of the area has undergone a significant change. For example, between 1956 and 1981, area under tea and forests decreased from 61per cent to 39per cent and from 17 per cent to 15 per cent, respectively. On the other hand, the homestead and croplands increased from 7 per cent to 17 per cent and from 7 per cent to 15per cent, respectively.

Wickramagamage (1988) studied the impact of large-scale deforestation, undertaken for the expansion of plantation agriculture on the Central Plateau of Sri Lanka. He has shown that large-scale deforestation in this region has caused changes in the local climate (micro-climate) as exhibited by rainfall and temperature records. However, these trends are not uniform everywhere in the plantation areas of the plateau. The temperature has risen a few degrees over a period of about a century and quarter in the stations in the plateau, while rainfall has declined significantly at some other stations. He also reported that these changes seem to be a result of the interaction of both global and local factors, although some of these changes could be due to global warming.

Kayane et al. (1995) have shown that rainfall during the Southwest Monsoon Season has decreased in the Central Highland of Sri Lanka since 1870's. They also suggested that significant decline in rainfall in the plateau could be related to global warming and the rise of 'sea surface temperatures' in the surrounding Indian Ocean. Further, they have pointed out that the increased sea surface temperature over the Indian

Ocean will intensify the Indian Monsoon circulation, which in turn may increase the coastal windward rainfall with a comparative decrease of rainfall to the leeward areas in Sri Lanka.

Rekha and Punyawardena (2003) have found that negative anomalies of rainfall are evident western slopes of the Central Highland in Sri Lanka where Southwest Monsoon is the dominant rainfall governing mechanism. Their analyses clearly show that increased variability is the most dominant feature of the rainfall regime in the Central Highlands during recent time than that of any other trend.

In general, all the climate change studies reveal that the annual average surface air temperature has been rising in all parts of Sri Lanka. The positive temperature trends are noticeable during the Northeast Monsoon (winter) and the First Inter-Monsoon period (March-April). On the contrary, rainfall has been decreasing in most of the stations during the more recent period. Precipitation in the Southwest Monsoon decreased in the Central Highlands of Sri Lanka since the last century. Some of the studies have found that the negative anomalies of rainfall are evident on the western slopes of the Central Highlands in Sri Lanka where Southwest Monsoon is the dominant. There is a generally increasing annual rainfall trends in the lowland wet zone as represented by Colombo area whereas a significant decline at some of the stations in the Highland, especially in the Intermediate Zone could be observed. Increased variability is the most dominant feature of the rainfall regime in the Central Highlands during the recent time. The Dry Zone lowlands also show a slightly increasing annual rainfall trends although it was not so marked as in the Wet Zone. These conclusions are arrived in different studies, which indicate certain discrepancies due to different methodologies adopted or due to different lengths of data records used for the analysis. However, further studies are needed to generalise on the basis on rainfall and temperature from the agro-climatic point of view. Hence, predicting future rainfall and temperature scenarios for major climatic zones cannot be made without applying further analytical tests.

2.3.2 Comparison of Sri Lanka Situation with Global Climate Change Trends

The reasons for the increase of temperature in Sri Lanka are due particularly to the build up of carbon dioxide in the atmosphere and the strong influences of the El Nino phenomena (Schaefer, 1996). However, there are reasons to doubt the authenticity of the "CO_2 build-up theory" without specific empirical data to indicate that. Sri Lanka is surrounded by open sea and is on the route of major wind systems and cyclonic disturbances that easily disperses Tropospheric CO_2 build-up. It is still little industrialised. However, the incidence of high altitude "tropical grey clouds" over the Indian Sub-continent over recent years, could be an important reason, but well beyond the scope of the present study. As far as rainfall is concerned, the observations of decreasing trends in Sri Lanka also correspond with the global trends. According to large-scale analysis in the tropics rainfall decreased over land areas since the 1950s. In any case rainfall shows a high inter-annual variability, which is typical for the South Asian Monsoon system depending on an El Nino/ENSO.

The pattern of temperature warming in Sri Lanka was compared with the global observations applying with principal components analysis (Schaefer, Undated: 103-117).

He analysed All Sri Lanka annual temperature series by applying the Principal Component Analysis (PCA) with the first Principal Component indicating a linear positive trend of 2.63, corresponding to an increase of 0.43^0 C. Global temperature trend for the same period indicates a trend of 0.57^0 C. Therefore, the trend of temperature increase over Sri Lanka corresponds broadly with the global warming trend. The observed climate change therefore fits into the general observations about global climate change. The trend of warming can be compared with global trends as about 50 per cent of the observed temperature trends over Sri Lanka correspondent to the global temperature increased. The constructed all Sri Lanka annual temperature series is correlated with the global temperature anomalies and the agreement during the last decades is very striking. Further more, his analysis clearly indicates that the existing climate change in Sri Lanka temperature shows a striking trend of warming, which is mainly based on the temperature increases during the Northeast Monsoon and the First inter Monsoon. As far as rainfall is concerned the observations of a decreasing trend in Sri Lanka also corresponds with the global trends.

2.3.3 Predictions of Climate Change in Sri Lanka

Climate change scenario developed by the Commonwealth Science and Industrial Research Organisation (CSIRO, 1992) for Sri Lanka indicates significant changes in both temperature and rainfall in the year 2070 under the mid and high scenarios. The study concludes that the temperature increases in Sri Lanka will be very significant and that the 2070 mid-scenarios seem more appropriate for Sri Lanka than the 2070 high (scenarios).

With regard to the rainfall the changes, the study indicates a + 20 per cent change for 2070. Rainfall changes for the high scenario range from –5 per cent to +15per cent, which might increases in the frequency of extreme events such as floods accompanied by some increases in magnitude as well. Therefore, climate change impacts on extreme weather events such as floods, droughts, and landslides are likely to be very significant. Impacts of climate change on water resources need further studies. Although the incidence of rainfall will increase significantly by 2070 during, Northeast Monsoon season in both the dry and wet zones of Sri Lanka, the increases in wetness can be determined by several factors. If the increases in rainfall indicated is manifested in extreme rainfall events or increased rain in a fewer number of days, much of the water will be lost through runoff to the sea.

The rise in temperature can be observed from greater frequency of "warmer spells, warmer months and warmer seasons". The median temperature condition would move up towards the upper quartile and upper extremes would reach beyond present upper extremes. Evaporation losses would increase under such a scenario. According to this study the combined effects of sea level rise and the increased frequency of extreme rainfall and storm events as indicated by the climate change scenarios will cause adverse impacts in the coastal ecosystem, and also to the fisheries industries in the country.

Part IV

This part deals with the studies on climate change and its relationship with agricultural crops (Paddy, tea, rubber and coconut) in Sri Lanka. Emphasis is given to the climatic parameters like temperature and rainfall changes and fluctuations in crop production, coverage and crop yields.

This part deals with the studies on climate change and its relationship with agricultural crops (Paddy, tea, rubber and coconut) in Sri Lanka. Emphasis is given to the climatic parameters like temperature and rainfall changes and fluctuations in cropping pattern, coverage and crop yields.

2.4 Impacts of Climate Change on Agriculture in Sri Lanka

The agricultural economy of Sri Lanka is made up of a basic sectoral duality, i.e., those of subsistence farming like rice etc for home consumption and those based on export oriented plantation crops like tea, rubber and coconut. The indications from GCM and literature are for a trend in climate change, which point to increased intensity in both dry spells and often, heavy rains that will pose major challenges for agricultural production in Sri Lanka. Agricultural productivity will be sensitive to global climate change and therefore, needs to be evaluated for appropriate adaptation strategies in agricultural management. Some agricultural scientists have attempted to assess the impact of climate change in Sri Lanka.

The cropping intensity of paddy and seasonal crops during the respective seasons is primarily a function of water availability, although institutional and management factors may also have a role to play. Under the rain-fed cultivation, the intensity is very low in the Dry zone during the 'Yala' season and even during the rainy season, some areas have relatively low intensities presumably due to rainfall variability (Sirinanda, 1983). In the case of annual and seasonal crops particularly paddy, the risk of crop failure is rather high in areas of rain-fed cultivation or those without dependable supplies of water.

Yoshino et al. (1983) examined climatic fluctuations and their effects on paddy production in Sri Lanka. This study concluded that the secular variation of total paddy production for Sri Lanka during the recent 110 years shows that the inter-annual variations was relatively small in the years before 1900 with slow increases, while it was large variation during 1900-1924. Since 1945, sharp increase was observed and the year-to-year fluctuation was extraordinary great. These anomalies have shown close relationship to rainfall variability.

CSIRO predicts some adverse impacts on agriculture. For example, analysis of impacts on rice using a crop model developed by Seshu and Cady (1983) shows that rice cultivation will drop by about 6percent with a temperature increase of 0.5° C in the year 2010. Therefore, there is a need of improved and reliable models for climate impacts analysis for major crops such as rice and also plantation crops like coconut, tea and rubber in Sri Lanka. However, the climate change scenario developed by CSIRO indicates that the most significant changes in temperature and precipitation in Sri Lanka will be only for the year 2070 mid- and high-scenario.

An increase in temperature is likely to affect the crop calendar in countries such as Sri Lanka. Increase by 1^0 C warming would necessitate a major adjustment of the finely tuned crop calendar. Changing pattern of rainfall and temperature will have major impacts on agricultural production in Sri Lanka (Panabokke, 1992:9-23). As a result of climate change, the economy of Sri Lanka will move out of its heavy dependence on primary production that is highly vulnerable to influences of climate change. Rise in temperature above tolerance levels of crops would have an adverse impact on crop yields (Parry and Swaminathan, 1992).

The impacts of climate change in the form of extreme weather events, such as floods, droughts and landslides are likely to be very significant. The climate change scenarios show increases in the frequency and severity of such events, which will increase damages and losses to crops. Therefore, temperature and moisture changes coupled with changes in the frequency of flood and droughts will require significant adjustment in cropping practices and patterns or even to switch to different crops altogether.

Rainfall variations affect the annual variability of rice production distinguished from its long-term trend. Zubair and Somasundera (2002) have examined the influences of El-Niño-Southern Oscillation on rice production in Sri Lanka. It has been two decades that the rainfall variability in Sri Lanka has been significantly influenced by the El-Niño-Southern Oscillation (ENSO) phenomena. Recently, they have discovered a relationship between the Sri Lankan rainfall and Indian Ocean weather conditions as well. Their study has shown a clear link between ENSO, rainfall and the production of rice in Sri Lanka. This provides a basis for using ENSO based predictions for policy analysis and formulation and agricultural practices. In addition, they are now investigating the influence of the Indian Ocean Dipole phenomenon on the production of rice.

Tea and coconut are important tropical plantation crops in Sri Lanka. These crops are particularly vulnerable to climatic variability and change. Coconut is vulnerable in particular to droughts. Tea in Sri Lanka derives its distinctive flavours and reputation for quality from its particular regional and seasonal climatic history. Climatic anomalies thus have a direct bearing on both tea and coconut. Over a million people depend on plantations for their livelihoods in Sri Lanka. Any decline in production or quality will have a direct impact on both livelihood system of the people and on the Sri Lankan economy in general. Tea and rubber, together account for 50per cent of national exports of Sri Lanka in 1986. A large fraction of the tea production in Sri Lanka, is undertaken within the Mahaweli basin. How can these crop plantations, cope with climatic variability and adapt to climate change? -- the question that a multi-sectoral team of scientists in Sri Lanka are seeking to answer. In doing so, they will also in the process build capacity for climatic and crop modelling and integrated assessment.

Wijeratne (1996) has examined the vulnerability of Sri Lanka tea production to global climate change. He has pointed out the following findings: (a) the tea industry is Sri Lanka's main net foreign exchange earner and source of income for a large share of labour force of the country. (b) Tea yield is greatly influenced by weather, and especially by droughts, because of the tea shrubs sensitivity to temperature and its dependence on rain-fed conditions and not irrigation though sprinkler systems are now being increasingly used during the dry spells. (c) At the other extreme, heavy rains erode the topsoil and wash away fertilisers and other chemicals, applied to the plantations. In recently published Sri Lanka Country Report on Climate Change, it was reported that the Island would experience extreme rainfall intensities and warmer temperatures as a result of climate change. The possibility of a 10per cent increase in the length of dry and wet seasons per year, in the main plantation areas was also indicated. Thus, both drought damages and soil losses in tea production areas will increases in the years to come. An analysis of the results of field experiments with weather data shows that increase in temperature, soil moisture deficiency, and saturation vapour pressure deficit in the low elevations will adversely affect growth and yield of tea. Report has also shown, that about 30 cm. of topsoil has already been eroded from upland tea plantations. Under these circumstances, the tea industry in Sri Lanka is clearly vulnerable to predicted climate changes, and subsequently greater economic, social, and environmental problems.

2.4.1 Centre for Climate Change (CCC): Meteorological Department of Sri Lanka:

CCC was established in 2000, for aiming of various activities in related to climate change phenomenon in Sri Lanka. As per the, Cabinet Memorandum for the establishment of the Centre, a major function of the centre is conducting research into climate change in the country. Research activities in the CCC in Sri Lanka can be summarised as follows:

(i) To encourage scientists to carry out research into climate change related issues such as impacts, mitigation and adaptation measures

(ii) To provide data available in the Department of Meteorology to scientists to carry out research on climate change and related issues.

(iii) A study of the variation of thunderstorm activity over Sri Lanka: Department of Meteorology.

(iv) Impact of climate change on coconut production in selected regions of Sri Lanka: Coconut Research Institute, Lunuwila.

(v) Assessment of evidence, causes and implications of change in daily temperature regimes in Sri Lanka: University of Peradeniya, Department of Meteorology, Department of Agriculture.

(vi) A comparative study of the Ambient air temperature trends at Anuradhapura and Maha Illuppallama: Ministry of Environment, Natural Resources and Department of Meteorology.

(vii) Effect of climate change on rubber plantations in Sri Lanka: Rubber Research Institute, Agalawatte.

(viii) Variation of Air temperature and rainfall during the Yala and Maha agricultural seasons: Department of Meteorology, Ministry of environment and Natural resources.

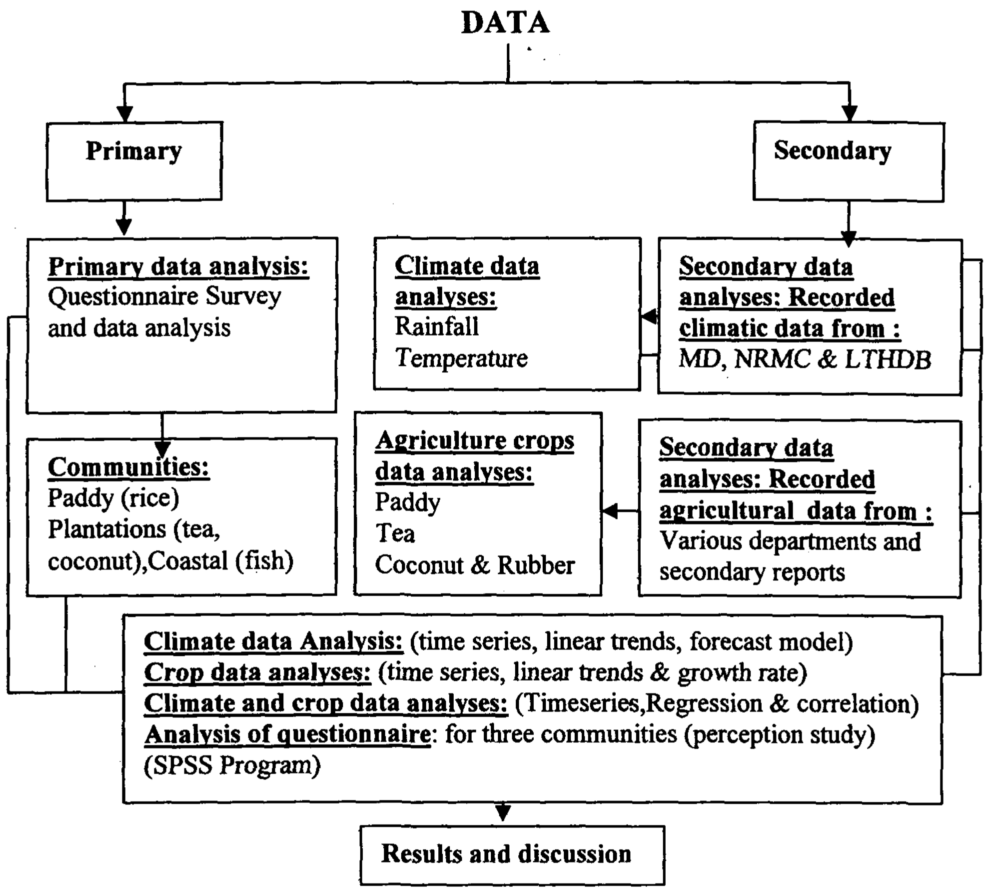
(ix) Analysis of Droughts in the DL1 Region of the Dry Zone of Sri Lanka Department of Agriculture and University of Peradeniya.

Chapter – III

Materials and Methodology

In the present chapter, details procedures of the data collection, the methods and techniques of data analysis, classification of major Agro-Climatic Zones, major agricultural practices (rice, coconut and tea) in relation to output and yield trends and the study based on field data on three communities and their perceptions and problems arising out of climate change. The framework for data collection and methodology is as follows:

Figure 3.1: Procedures of the Data collection and Methodology



Note: MD= Meteorological Department, Sri Lanka; NRMC= Natural Resources Management Centre, University of Peradeniya; & LTHDSL= Long term Hydro-meteorological Data in Sri Lanka

3.1 Data Sources for Secondary and Primary Data

(a) Secondary Data Collection

(i) Climate Data

Secondary data for climate (rainfall and temperature) have been collected from various government and non-government sources, like Meteorological Department, Government of Sri Lanka, Colombo and NRMC (Natural Resources Management

Centre) at Peradeniya. Other sources on climate data have been collected from Long-term Hydro-meteorological Data book in Sri Lanka (Nakagawa et al, 1995). Rainfall data at the 33 Meteorological observatories and temperature data for 12 Meteorological observatories for the last 50 years were collected.

(ii) Agriculture Data

Agricultural crop production data have been collected from various authorities and sources, such as official records from districts level publications, maps, and statistical reports and from other authorities. Discussions were carried out with various authorities to collect relevant data. Agricultural statistical information and related documents have been collected from the Department of Statistics and Department of Agriculture, Government of Sri Lanka. Agricultural crop data like those for paddy, tea, coconut and rubber, have been collected from related departments for all the 13 contiguous districts under the present study out of the twenty-five districts of Sri Lanka.

(b) Primary Data Collection:

Primary data have been collected at the farm level, with particular reference to farmers' response to climate change, and its effects on communities and their livelihood systems. Household and primary farm level information has been collected through a structured questionnaire based survey and through discussions with the village communities and village heads. In addition, district and divisional levels administrative officers, those involved in the agricultural development activities were interviewed.

The primary data collection and surveys aim at eliciting information from communities about their perception and the problems they encounter resulting from impacts of climate change in recent times. The communities considered most vulnerable are the rice cultivators in the Dry Zone, the coconut and fishing communities on the coast (west) and the small tea producers (planters) in higher and middle elevations in the Intermediate Zone. They, whereas represent a variegated rural communities at one level, also represent a variegated climatic zones (i.e., representing a differentiated influences of climate change) and also a variety of relief zones, the low-land coastal areas, mid-level central areas as well as the mid-and high elevations in the Intermediate Zone. The attempt has been to capture a variety of influence of climate change in the island nation as well as a variety of communities as they confront an increasingly unpredictable climate and the manner they are affected by it and the ways perhaps, they manage to cope with the changing environment.

The Sampling methodology for questionnaire survey is as the following:

(i) Questionnaire Survey on: Paddy Community

In Sri Lanka, Paddy is cultivated in the Dry Agro-Climatic Zone to the northwest. The villages are usually small with average household size of less than 100. With a sample size of 50 per cent and keeping the average sample size per village at 30 (large sample condition), it was considered adequate to consider 3 villages from the rice community, with a total enumerated sample households of about 100. Kekiriwa division in the Anuradhapura district was selected for the survey with three villages, i.e., Kelepuliyankulama, Kadubodagama and Kadiragama (Location Map, 8.1). The selection of households was on the basis of a 50 per cent random sample from the former two villages and a complete enumeration (census) of the latter village, Kadiragama, which is a very small hamlet.

(ii) Questionnaire Survey on Small -holding Tea Community (Plantations)

Matale district that lies in the Intermediate zone open to both the monsoons was selected for the primary community survey of small tea growers. Two communities with total sample of about one hundred farmers were considered adequate for the purpose. The sampling was carried out on a 50% random sampling system (Location Map, 8.1).

(iii) Questionnaire Survey on: Coastal Community (Coconut and Fish)

For the purpose of eliciting information from a fish-coconut community, village Ambakandawila of Puttalan district north-west of Colombo was selected where a 50 per cent random sampling of the households of the village was conducted (Location Map, 8.1).

3.2 Selection of the Study Area

3.2.1 Importance of the Study Area:

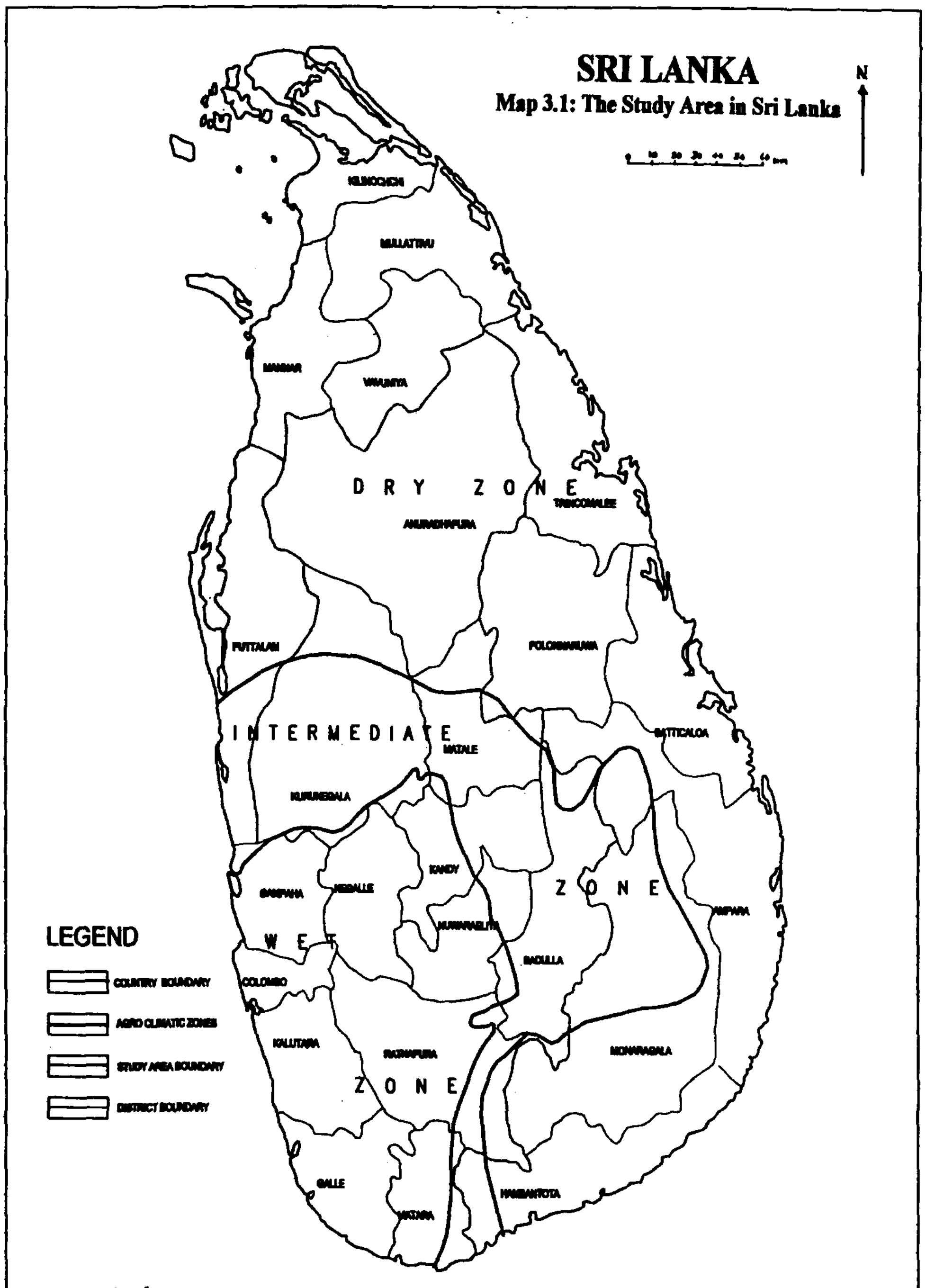
The study area for current research constitutes of 13 districts of the 25 districts of Sri Lanka, roughly accounting for nearly 52% of the geographical area and population of the country. The justification for selection of such a large region (Map 3.1) was essential from the following points of view:

(a) The study region must represent all the three major agro-climatic zones;

(b) The region must represent the three principal relief zones, highlands, gentle slopes towards the coastal areas and the coastal low-lands;

(c) Since, climate does not vary over short distances (unless influenced by sudden altitudinal changes), from the objective of research it is necessary to study a larger region to keep in view certain climatic variabilities and in the manner these variabilities are affected by climate change, if any. It is also to be noted that in case of island territories, the surrounding sea blunts these variabilities to a great extent, since sea conditions are climatically much more homogeneous than variations across landmasses; and

(d) Finally, the very requirement of studying all the major agricultural practices makes it imperative to make a choice of a large area for study that includes all the principal crops, agrarian practices as well as the farming communities.



Source: Author

3.2.2 Classification of the Agro-Climatic Zones and Regions:

The ecological demarcation of Sri Lanka has been devised to meet the special requirements of research, extension, regional specialization of crops and regional development. It has evolved from a synthesis of the more natural characteristics of climate, relief and soils. With respect to the rainfall the Island has been divided into three Agro-climatic zones. These three major zones are (Map 3.1), namely:

(i) Wet Zone

(ii) Intermediate Zones

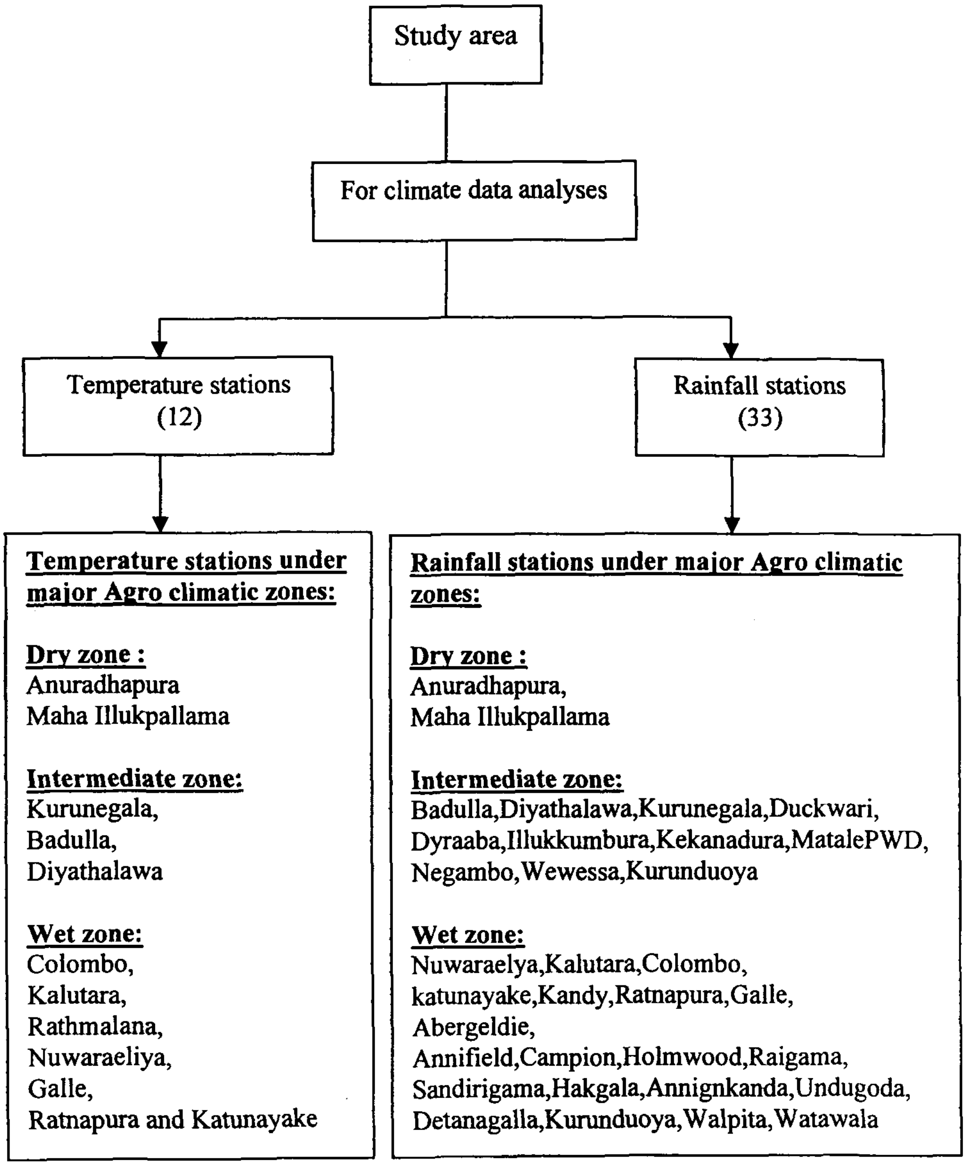
(iii) Dry zone

Thus since ancient time the south-western sector has been known as the wet zone and the rest of the country as the dry zone. The boundaries of above three zones have been demarcated with consideration of present agricultural land use, distribution of forest species, rainfall data, topography and soils. This agro-climatic classification has been used for the present study.

3.3 Secondary Data Analyses

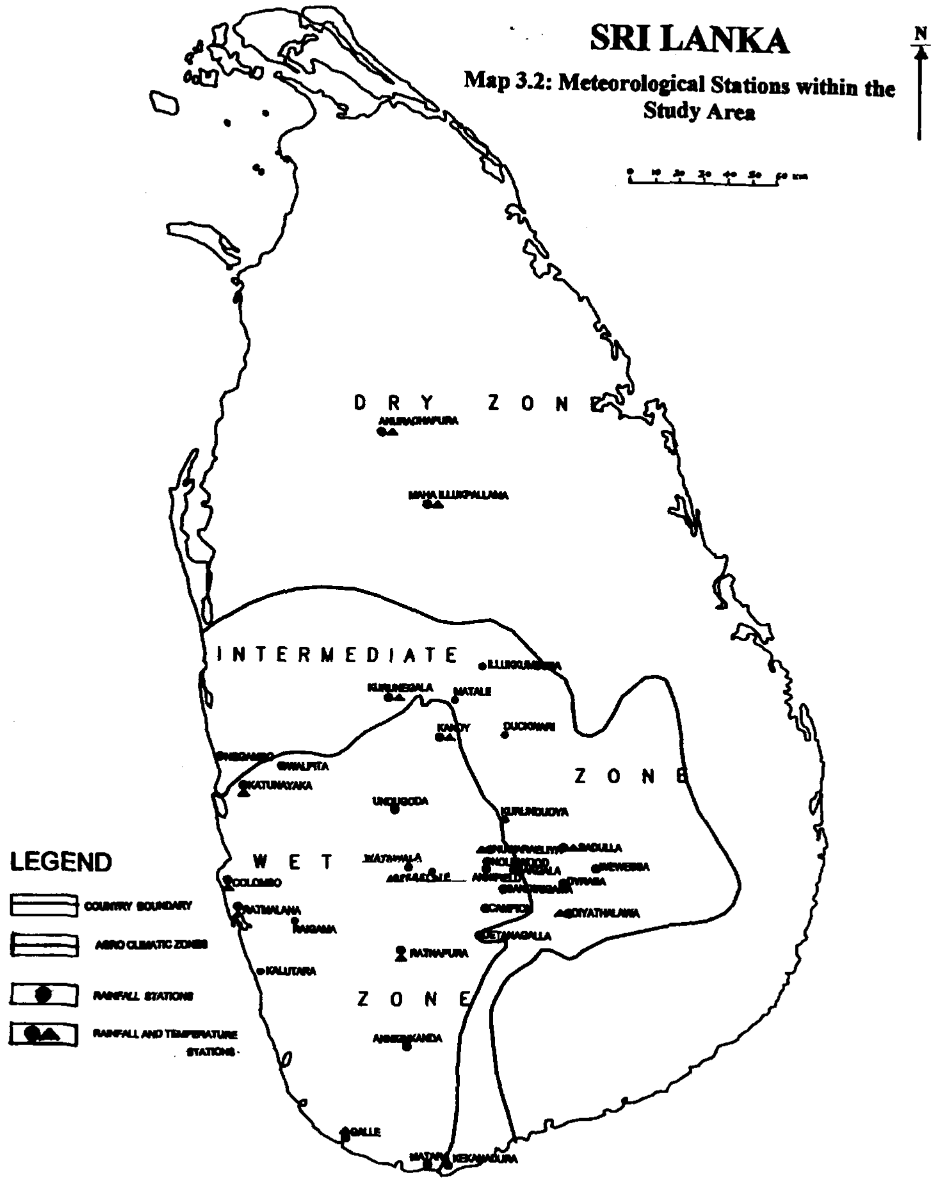
(a) Climatic Analyses: Rainfall and Temperature:

Figure 3.2: Rainfall and Temperature Stations in the Study Area



SRI LANKA

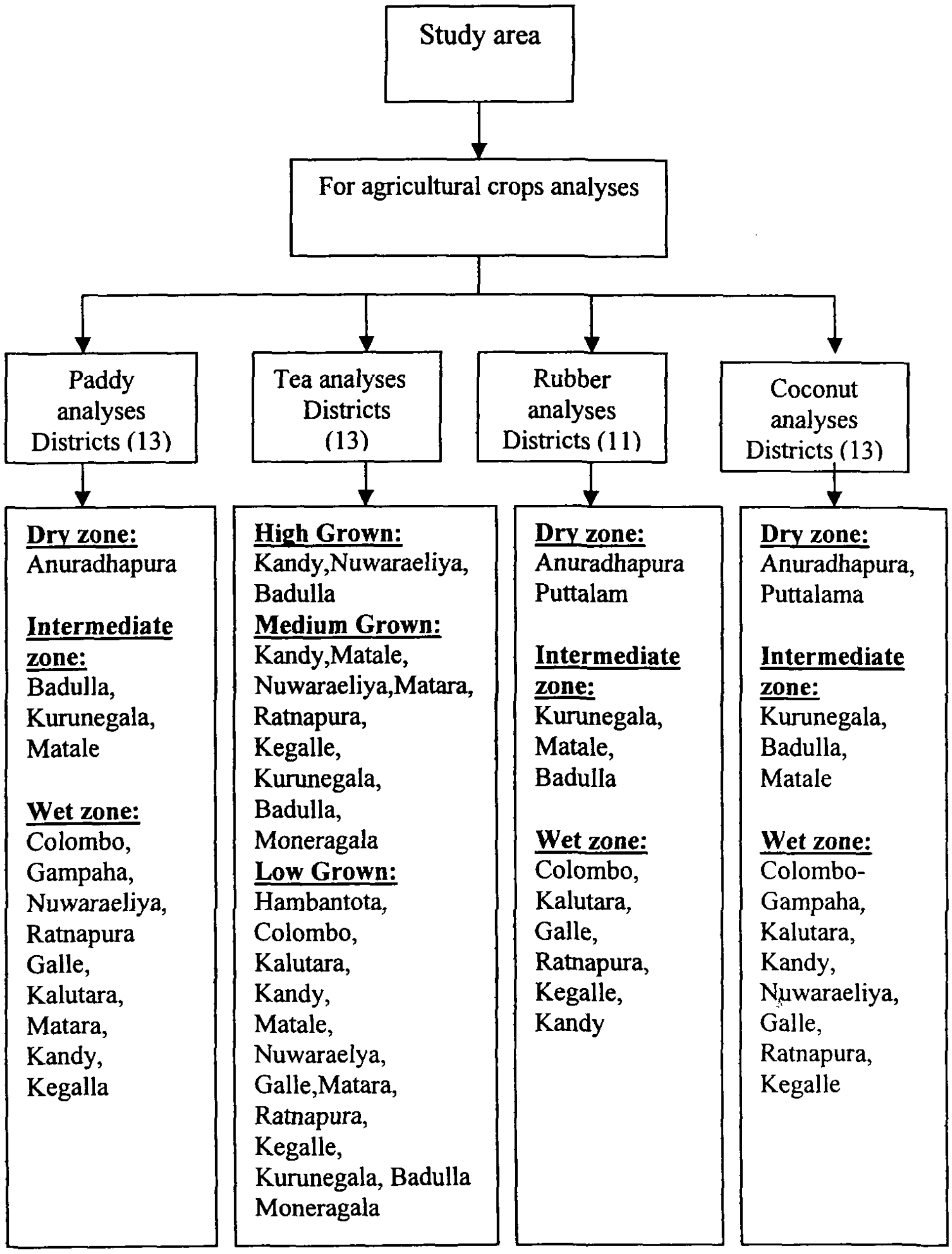
Map 3.2: Meteorological Stations within the Study Area



Source: Department of Meteorology, Colombo.

(b) Agricultural Crops Analyses: Paddy, Tea, Coconut and Rubber:

Figure 3.3: Selected Study Areas for Agricultural Crop Analyses (Paddy, Tea, Coconut, Rubber)



(c) Agricultural Crops and Climate Relationship Analyses for Paddy

Figure 3.4: Selected Study Area for Paddy and Climate Relationship Paddy Production and Area Extent

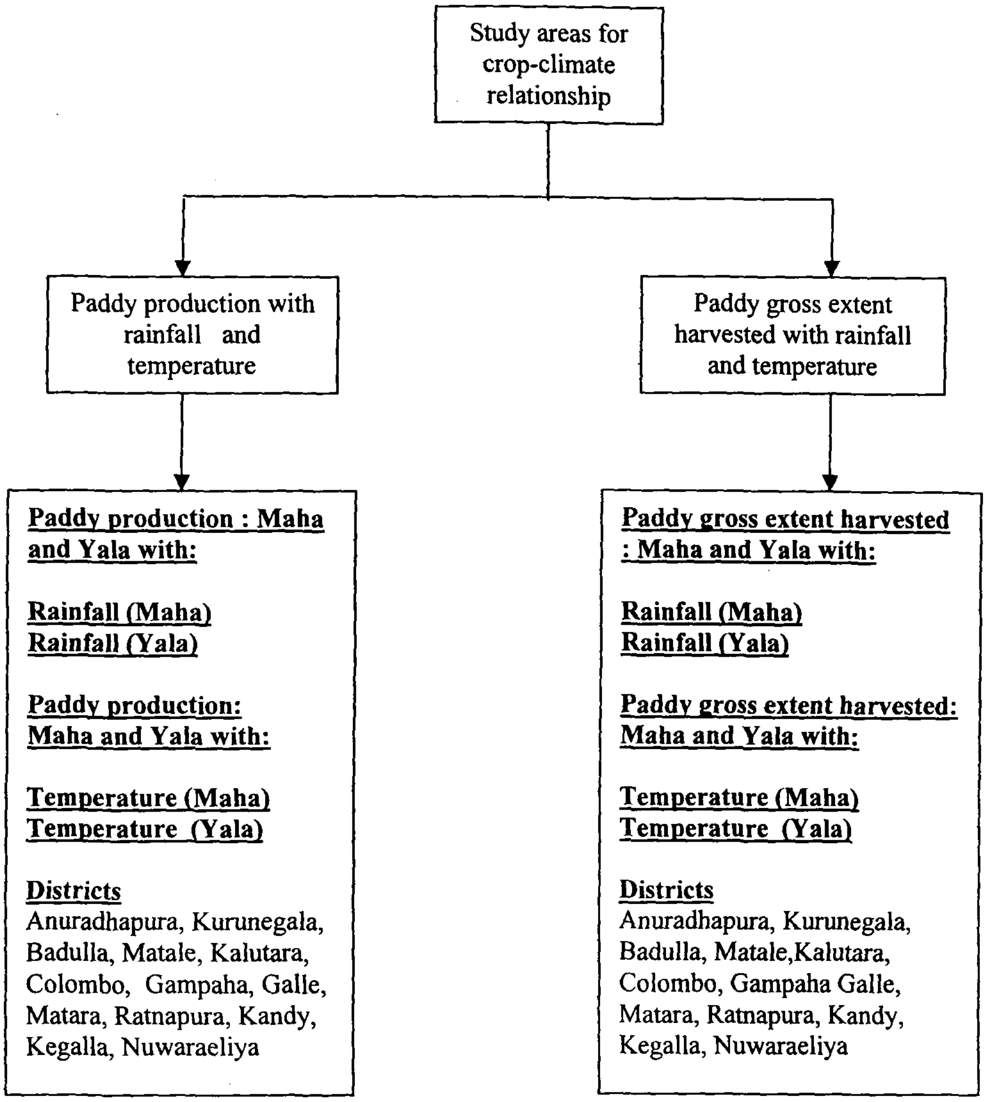
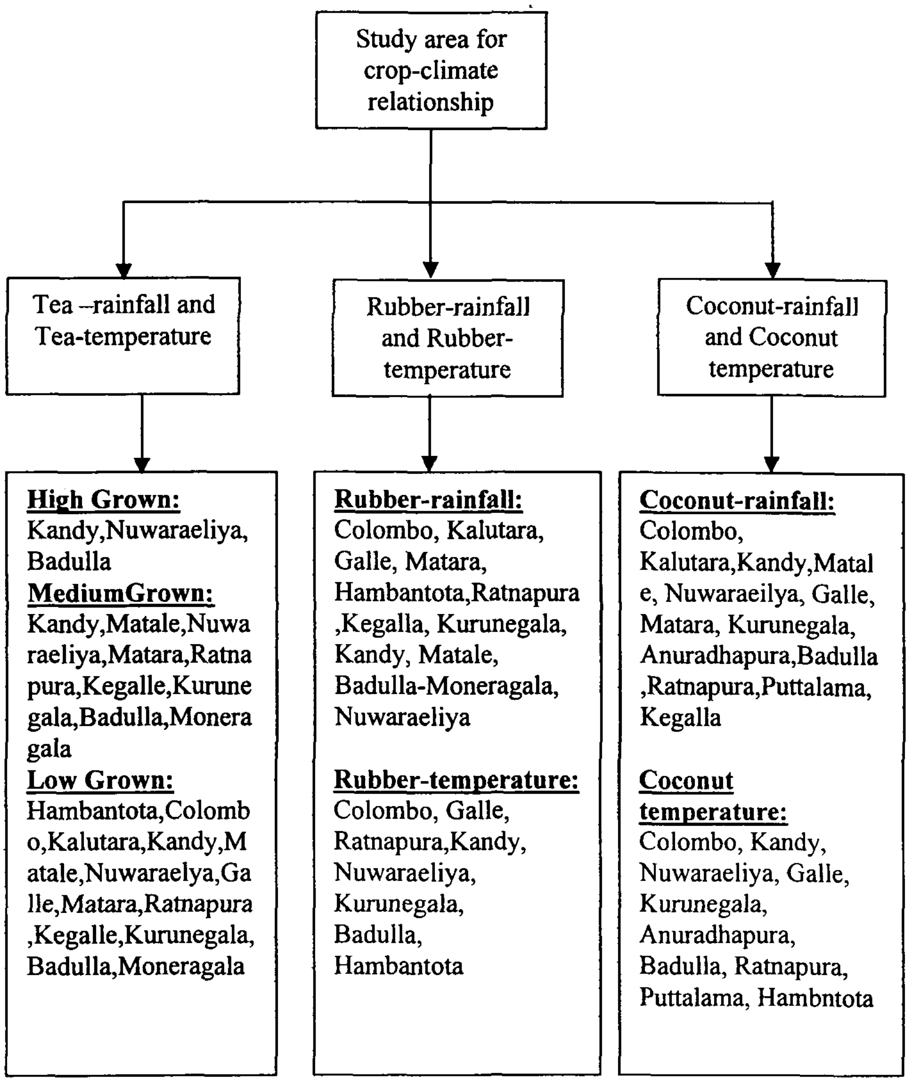


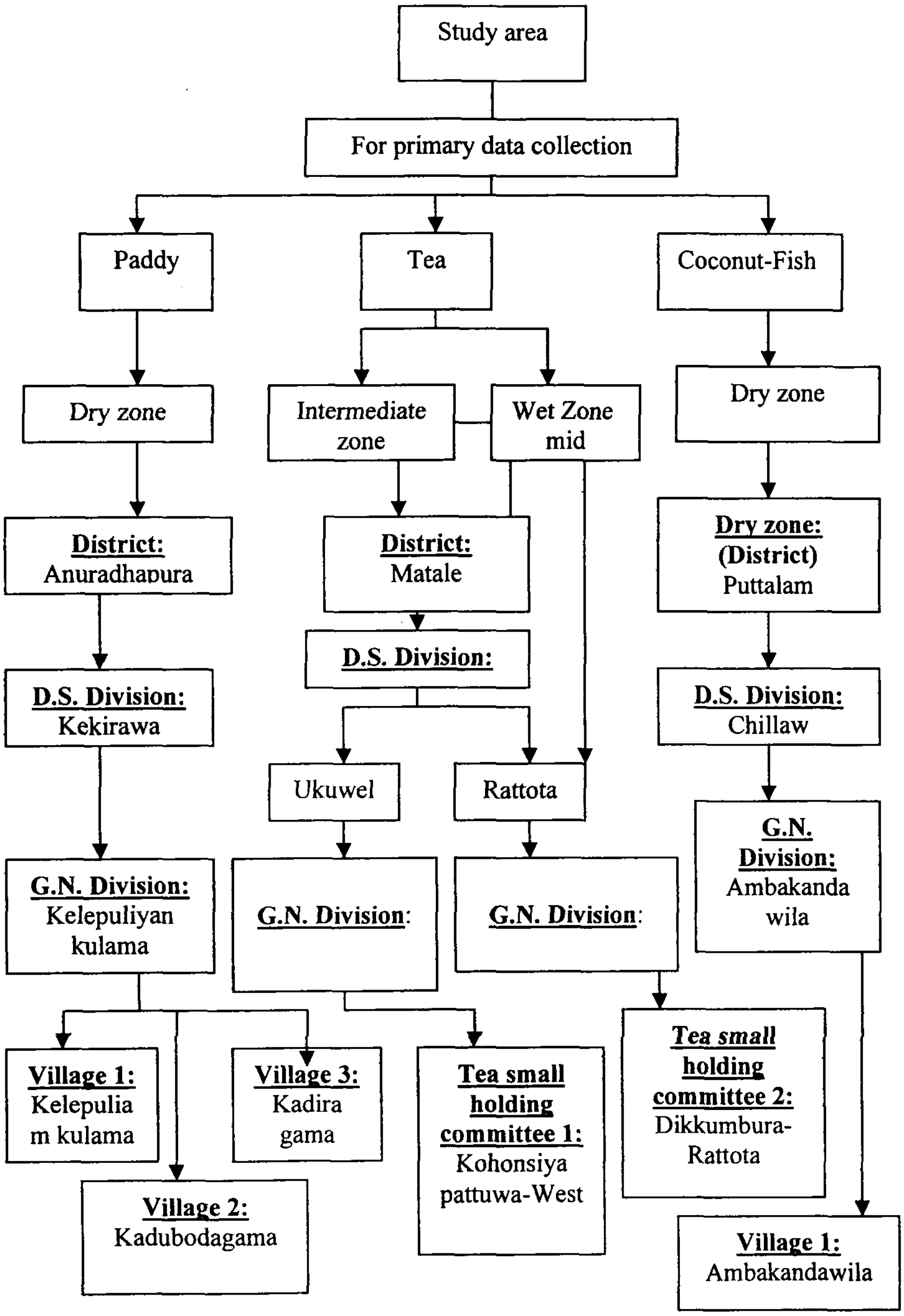
Figure 3.5: Area for Plantation Crops and Climate Relationship Analyses for: Tea, Coconut and Rubber



3.4 Area for Primary Data Collection and Analyses

(a) Study Area for Questionnaire Survey (Primary Data): Paddy, Tea and Coconut-Marine Fishing

Figure 3.6: Selected Study Area for Questionnaire Survey: Paddy Communities, Tea Plantation Communities and Coastal Communities



3.5 Methodology

3.5.1 Methodology and Techniques

The study contains three major aspects as outlined in the conceptual framework:

(a) The analysis of climate change based on historical data and predictions of future changes;

(b) The impact of climate changes on crop production and coverage and crop yields; and

(c) The study of perception and problems of three distinct farming communities, the rice farmers, the small tea growers and the coconut-fishing communities along the coastal areas affected by varying degrees due to perceptible changes in climate.

(i) Climate Data Analyses (Rainfall and Temperature)

The study of climate change has been carried out with the help of time-series data of monthly average rainfall and temperature from; Rainfall (33) and temperature (12) weather stations within the three main Agro-Climatic Zones, within the designated study area (Map 3.2). The climatic data is for over a fairly long period of time, i.e. from 1959-60 to 2001-02, split into pre- and post-1975 periods. Two factors are considered important here, viz., annual and seasonal variability of rainfall and temperature. Other climatic factors have only marginal impact on Sri Lanka, though they could be of significance in other world regions. The missing data of each rainfall and temperature data series were estimated using Normal Ratio Method. The trend of rainfall and temperature variability of monthly, seasonally and annually have been examined using linear trend analysis to examine negative or positive trends in rainfall and temperature over the entire period under the study. Student's "t-test" was applied to examine the significant level of the trend estimators, 'b' coefficients. Variability of seasonal rainfall and temperature has been computed by standard techniques. Data represent more than 50 year because standard normal 30-year periods stipulated by the WMO (World Meteorological Organisation) for climate change studies. Data have been analysed by year, decades and seasons.

(ii) Crop Data Analyses

(a) Trends of Production, Coverage and Yield of Major Crops

Trend of paddy production, coverage and yield, trend of tea production, coverage and yields, trends of rubber production, coverage and yield, and trend of coconut production, coverage and yield have been examined using linear trend rates for each variables at the districts level, for which reliable data was available. The crop data refers to 1968-69 to 2000-01 period at the district level. The go around the yearly fluctuations moving averages of continuous three-year periods were calculated for 1968-69 to 1970-71, with 1970 as the mid-point, so also for years ending 1970s, 1980s and the 1990s. The periods have been broken to two parts, the 1970s, and the 1980s and 1990s, since the climate changes become quite visible after the 1980s.

(b) Crop-Climate Relationship

To examine the relationship between major crops and climate parameters (rainfall and temperature) "Regression and Correlation analyses" have been carried out for selected crops as follows:

(1) Paddy production (both Maha and Yala seasons) with rainfall (District wise)

(2) Paddy production (both Maha and Yala seasons) with temperature (District wise)

(3) Paddy gross extent harvested (Maha and Yala) with rainfall (District wise)

(4) Paddy gross extent harvested (Maha and Yala) with temperature (District wise)

(5) Tea production with rainfall and temperature (High, Medium and Low elevations)

(6) Tea area grown with rainfall and temperature (High, Medium and Low elevations)

(7)Tea yield with rainfall and temperature (High, Medium and Low elevations)

(8) Rubber area extent with rainfall and temperature (District wise)

(9) Coconut extent with rainfall and temperature (District wise)

An analysis with "Student's t-test" was applied to test significance of the correlation coefficients.

(c) Forecast Models for Climate Change (Rainfall and Temperature)

Agro-Climatic Zone wise temperature and rainfall forecasts have been estimated for years 2010, 2020, 2030 and 2050 based on linear trends for 1960-2000 and 1980-2000 climate data. It may be noted, climate variable change rather slowly, probably at a linear rate (as evidenced from station-wise trend estimates). The station averages for given years for each agro-climatic zone was prepared, the trends estimated and forecasts proposed.

(d) Crop Model

The impact of climate on various crops in terms of area cultivated, production and yield rates are of different orders. Under irrigated conditions, the climatic influences are minimal, if not zero, where as other socio-economic and farm management practice, very important. Under rain-fed agriculture, the influence of temperature and rainfall, both quantum and periodicity are of overwhelming nature. Within the designated study districts, the plantation crops are into the wet or intermediate agro-climatic zones, the quantum of rainfall though generally stable, its periodicity or seasonal incidence could be a problem. Rice farming is generally, carried out in the dry zones (Anuradhapura) but without any assured water supply system. The irrigated districts are not within the study area. Therefore, the influence of temperature and rainfall significantly influence the rice cultivation area (coverage), thus the overall out put. To associate climatic elements with crop production, coverage and yield simple correlation and bi-variate regression techniques were used, since explaining yield changes is not among the primary objectives of the study.

The climate change impacts were studied at the regional scale that represent the three broad Agro-Climatic zones (the three zones) as well as the crop production that has clear regional locations, like the paddy in the dry-zone (irrigated and rain-fed), tea in the intermediate zone (on the plateau) and rubber and coconut in the coastal and wet zones. These crops and the zones also define differences in livelihood systems and community economies, like the rice (peasant) farmers and plantation worker (tea) etc.

A survey design therefore becomes imperative for primary data collection for the study of the above two or three communities representing different livelihood systems, agro-climatic zones as well as different farming practices. This will help in assessing their response to climate change or variability as well as the manner in which they respond to the changing situation in terms of livelihood practices, habitat changes and community structures, responding to the environmental change.

3.6 Climatic Years for the Present Study

Since spatial and temporal diversities associated with rainfall are substantially more pronounced than those involving other climatic parameters, rainfall provides the main basis for dividing the year in to climatic seasons and the country into climatic regions. The Meteorological Department has identified four main rainfall seasons as follows. Namely: (For the present study these four seasons have been used for analysis)

(i) First Inter Monsoon (FIM) season: March to April

(ii) South West Monsoon (SWM) season: May to September

(iii) Second Inter Monsoon (SIM) season: October to November

(iv) North East Monsoon (NEM) season: December to February

3.7 Crop Years and Crop Seasons:

A water year in Sri Lanka is divided in to two seasons specially from the point of view paddy cultivation. The rainfall under the Southwest monsoon condition is striking on the Southwest part of the Central highlands called 'Wet zone' from the end of May to the end of September whilst the rainfall under Island from October to March. The former is called 'Yala' and the latter, 'Maha' season. Agriculture in the Dry zone is extremely sensitive to the variation of the monsoons, which bring rainfall.

(a) Maha Season (Large) or the Wet Season from October to February:

The Maha rainy season continue at least 3 months from October to December in the Dry zone. The Maha rainfall is reliable and the amount is enough to raise one crop of rice in a normal year under tank irrigation. If water is abundant, two crops can be raised in the dry zone but severe drought results in a year of scanty rainfall. In the year 1981 most part of the Dry zone of Sri Lanka experience a spell of drought conditions due to the failure of Maha rains. 'Maha' is the major cultivation season in Sri Lanka.

The Maha season on October to February presents a great spatial differentiation of rainfall over Sri Lanka which reaches its greatest extent in the border regions between the Wet and Dry zones, particularly in the uppermost regions of the highlands, in the Uva Basin, the Knuckles ranges and in the southern parts of the Sabaragamuwa Hill country. In the dry zone the Maha rains vary mostly 750 and 1500 mm, with both the driest areas situated diametrically opposite one another in the Northwest and Southeast. The highest, but rather locally restricted rains, occur on the eastern flank of the Knuckles range, which are fully exposed to the Northeast monsoon relatively high rainfall, between about 1500 and 1750 mm.

(b) Yala Season (Small) or the Dry Season from March to September:

'Yala' is the minor cultivation season dependent on the short rainy season. During the Yala season the contrast of precipitation distribution is best developed an approximately 1500-2000 mm on the windward slope of the Wet zone but only about 250 mm in the Dry zone on an average. In the Yala seasons the Wet zone and Dry zones are clearly distinguish from one another according to the amount of rainfall the rainfall pattern is much more differentiated in the wet than in the dry zone. In the wet zone rainfall is high and consistently exceeds 1000 mm even rising to 3000-3500 mm in the low altitudes of the western slopes of the highlands namely on the edge of the Hatton Plateau and the flanks of Adam`s Peak.

Chapter – IV

Biophysical Environment, Agriculture and Socio-Economic Conditions in Sri Lanka, with Special Reference to the Study Area

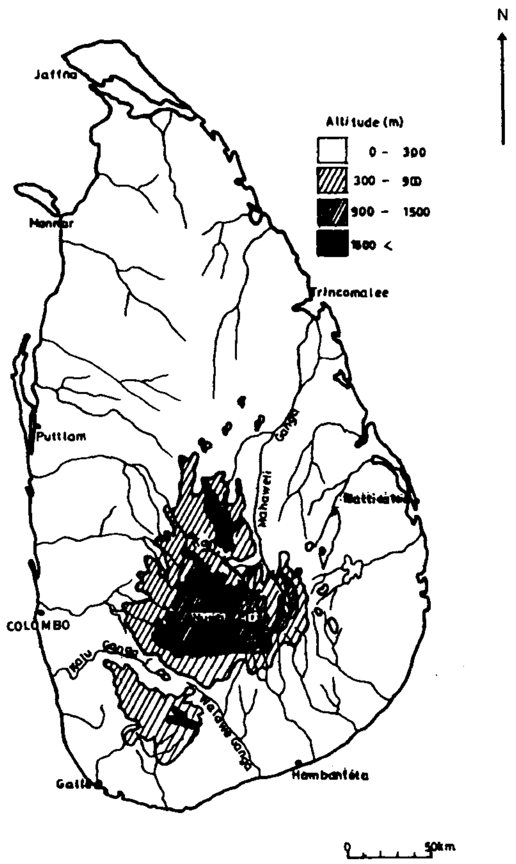
This chapter contains three main parts. Part I contains brief introduction of Biophysical environment of Sri Lanka. Part II, focuses on climate change and agriculture. It contains land use pattern, agricultural land use and cropping patterns with related to climatic and other related factors. It also discusses geographical distribution of Agro-Climatic zones in relation to agricultural production of selected crops, brief review of the fisheries industry and agricultural polices with related to agricultural systems of Sri Lanka. Part III briefly introduce the Socio economic situation in Sri Lanka.

Part I

4.1 Bio-Physical Environment

Sri Lanka is an island country in the Northern Indian Ocean, right south of the Indian sub-continent. It extends in latitude from 5^0 55' to 9^0 55' North and from 79^0 42' to 81^0 52' East Longitudes. Sri Lanka has an area of 65,525 square kilometres. Country has a maximum length of 435 kilometres in the direction of North-south, a maximum width of 240 kilometres in east-west direction; and the length of the shoreline is about 1600 km. The core region of the Central Highlands contains many complex topographical features such as ridges, peaks, plateaus, basins, valleys and escarpments. Therefore, orography plays an important role in the rainfall distribution of Sri Lanka.

Map 4.1: Physiographical features of Sri Lanka



Source: Somasekaram et al, 1997

The remainder of the island is practically flat except for several small hillocks that rise abruptly from the lowlands. These topographical features, strongly affect the spatial pattern of wind systems, seasonal rainfall, temperature, relative humidity and other climatic elements, particularly during the monsoon seasons. The general topography and physiographic features of the island are shown in Map 4.1.

4.1.1 Topography:

Based on altitude and landforms, Sri Lanka could be divided roughly into six major topographical regions. There are:

(i) Central Highland

(ii)The Southwest country

(iii) The East and Southeast country

(iv) The uplifted belt of low lands, uplands and highland along the axis of maximum uplift

(v) The Northern lowlands including the Jaffna Peninsula and the Islands

(vi) The coastal fringe consisting of a series of lagoons, marshes, sand bars, spits, peninsulas, dunes, islands and other associated features.

4.1.2 Geology:

Most of the country is underlain by crystalline rocks of Precambrian Age, the rest being made up of chiefly of Miocene limestones in the North and North-western coastal regions and Quaternary deposits along the North-western, Southern and Eastern coastal regions. Two small basins of Jurassic age are faulted into the Precambrian basement in the Northwest. The Precambrian rocks, which are a part of one of the very ancient stable parts and are sub divided into three main and one subordinate unit based on the rock types and structures.

(i) The highlands Complex (HC), occupying the Central Highlands and extending from the Southwest to the Northeast of the Island

(ii) The Wanni Complex (WC), formerly known as the Western Vijayan Complex and occupying the lowlands to the west of the HC

(iii) The Vijayan Complex (VC) formally known as the eastern Vijayan complex and occupying the lowlands to the east of the HC

(iv) The Kadugannawa Complex (KC), which lies within the HC but consists of rock types markedly different from those of the HC

4.1.3 Soils:

Fourteen great soils groups have been recognised in Sri Lanka. The major factors influencing soil formation in the country is climate (rainfall), followed by parent materials and topography.

(i) Soils of the Dry Zone and Semi- Dry Intermediate Zone:

Reddish Brown soils are the major soils of this area. It has special interest because in no other part of the world are they developed so distinctively as in the dry zone of Sri Lanka. The colour of the surface 'A' horizon is a characteristics reddish brown. This is the most important and widespread great soil group in the country and it occupies the largest extent compared to all other soils. Next to the *reddish brown earth, Low Humic Gley* soils are the most extensive great soil group in the dry zone. These soils are characterised by wetness and gleying below the surface. It has periodically high water table during the wet season. *Non-Calcic Brown* soil group is extensively developed on weathered products of acid rocks. The colour of the surface 'A' horizon is dark brown to dark greyish brown, and that of the sub soil or 'B' horizon is yellowish red to yellowish brown.

The ***Red yellow latosols*** occupy a very distinctive landscape position in the coastal regions of north western, northern and north-eastern Sri Lanka. ***Yellow latosols*** differ from the ***red latosols*** mainly in respect of their colour, which range from yellowish brown to yellow red and in their drainage. ***Alluvial*** soils mostly have been deposited on flood plains. Soils on *old Alluvium* occur mainly on the old depositional plains of rivers. ***Solodized Solonetz*** soil group is found on different landscape positions such as marine deposition of tidal flats, old terraces and in the bottom of inland valley in the very dry or arid regions. ***Regosols*** soils are sandy and formed on very recently with transported materials found along or near the coastline. Total extent of ***Grumusols*** soils is very small. ***Rendzinas*** or ***Rendzina*** soils occur in the low-country dry zone as well as in the mid-country intermediate zone, they are formed on soft limestone or on weathered hard limestone, and their presence is indicated by the occurrence of low outcrops of the underlying limestone rock.

(ii) Soils of the Wet Zone and Semi-Wet Intermediate Zone:

Red Yellow Podzolic soils are the modal soils of the wet zone of Sri Lanka both in the lowlands as well as in the Central highland. ***Reddish Brown Latosolic*** soils ***brown latosolic*** soils are best expressed within the 1900 and 2500 mm rainfall isohyets. The colour of the surface 'A' horizon is dark brown to dark grey brown and contains many micaceous minerals. ***Bog and Half- Bog*** soils have been previously named as *peat soil, organic soils, muck soils* etc. and they are mainly confined to the low-lying lands of west and south west of the country.

4.1.4 Water Resources and Drainage

In Sri Lanka, the only source of surface fresh water is rainfall. The distribution of water is uneven over both geographical space and time. The rivers of Sri Lanka radiate from the Central highlands towards to the sea of Island. Except for the Mahaweli Ganga, which is 335 kilometres, all the others are less than 160 kilometres in length. Country has 103 river basins, the southwest quadrant accounts for seven major basins, with their area ranging from 620 to 2,700 square kilometres. This area is adequately supplied with an annual mean rainfall of 2,300 mm. The remaining area, popularly known as the Dry zone, has an annual mean rainfall of 1,300 mm.

The primary source of ground water in Sri Lanka is also rainfall. Its distribution is mainly related to the geological formations and rainfall intensity. In general, only a part of the rainfall contributes to the ground water recharge. This is about 7% to 30% in many areas of the Dry zone. The quality of ground water in most parts of the country is good and relatively constant throughout the year.

4.1.5 Forest, Flora and Fauna

Sri Lanka was almost entirely surfaced by natural forest until the turn of 19th century. After introduction of the plantation agriculture by the British forests were cleared drastically and other land use changes are also changed due to population pressure. By the year 1900, the forest cover was estimated at 70% of the land area of the country. As forest, cover in Sri Lanka has rapidly shrunk from 50 to 20% during the past 50 years and the serious loss of rainfall particularly in the highland may results from deforestation. According to forest classification in Sri Lanka there are 8 forest types are identified, namely: Montane forests, Sub-montane forests, Lowland rain forests, Moist monsoon forests, Dry monsoon forests, Riverine dry forests, Mangrove forests and sparse forests.

In terms of the average number of species per 10,000 square km, the bio diversity in Sri Lanka is much higher than in any other country in Asia. Depending on the factors such as climate, soil and altitude, which mainly determine the species composition of particular area and different vegetation types, can also be recognised. The present flora of Sri Lanka is represented by six floristic elements, namely: Sri Lankan, Indo-Sri Lankan, Himalayan, Malayan, African and Pan-tropic and Cosmopolitan (Abeywickrama, 1956). The indigenous flora of Sri Lanka is amazing in that it has about 7,500species. The diversity of Sri Lanka's fauna is both rich and unique; within the confines of this island of Sri Lanka are to be found 628 species of terrestrial vertebrates, while its inland and territorial water has over 1,000 species of freshwater and marine fishes.

4.1.6 Climate

The climate of Sri Lanka is 'tropical' and 'monsoonal' with a marked seasonal rhythm of rainfall. The two monsoon periods and the two inter monsoon periods control the rainfall rhythm in the country. Thus, the climate is determined mainly by seasonal rainfall, temperature, pressure and the wind systems. In the course of a year, Sri Lanka comes under the influence of two monsoons, coming from opposite directions and having entirely different circulation characteristics. These two monsoons are the Southwest and Northeast monsoon of south Asia that essentially determines the seasonality of climate of Sri Lanka. Temperature shows hardly any variation throughout the year, and therefore the seasons are distinguished only by means of the timing of the two monsoons and the transitional periods (inter monsoon) separating them.

(a) Distribution and Seasonality of Rainfall

Despite the small area of the Island, the annual rainfall shows remarkable spatial variation ranging from 1000 mm in the driest parts to more than 5500 mm in the wettest parts. Mean annual rainfall ranges from under 1000 mm in the North-western and South-eastern coastal areas to over 5000 mm in the western slopes of the Central Highlands. The topography has a strong influence on the spatial variations of rainfall over Sri Lanka. In the Southwest sector, the maximum rainfall is in the lower to middle altitude of the western slopes (300-1000 m), and above 1000 m the rainfall decreases again. There is no continuous increase of rainfall with elevation. From the small area of peak, annual incidence at the lower altitudes of western slopes of the highland, rainfall decreases fastest towards the highest part of the highland but, more slowly towards the coastal plains to the Southwest. In the low lands, the rainfall differences are much smaller than in the mountainous interiors of the island, ranging from 1250 to 2000 mm. The driest regions of the island are situated diametrically opposite to one another in two peripheral regions of Sri Lanka, the Southeast and the Northwest; both regions receive annual average rainfall of between 1000 and 1250 mm.

During the Southwest Monsoon season this contrast is best developed. Agriculture in the Dry zone is extremely sensitive to the variations of Southwest monsoon. The Southwest Monsoon is the most important source of rain for the South-western and the western areas of the Central Highlands. The period of October to November (Second Inter Monsoon Season) and the following Northeast monsoon season are important rainfall periods for the Dry zone, which consists of the North and Eastern lowlands and the Eastern part of the Central Highlands.

Most of the rainfall in Sri Lanka is received from weather phenomena that occur in association with the migration of the Inter Tropical Convergence Zone (ITCZ) and from the Southwest and Northeast Monsoons. Therefore, the rainfall exhibits a marked seasonality in its spatial and temporal aspects. The First Inter Monsoon season of March to April experiences rainfall produced by the northward migration of the ITCZ, while the rainfall of the Second Inter monsoon season (during October to November) is associated with the Southwest migration of the ITCZ. The annual rainfall could be considered as in four distinctive periods. Detailed characteristics of each rainfall seasons are noted as follows:

(i) First Inter Monsoon (FIM) Season: March-April

FIM season occurs, March to April during which convection over land by afternoon and convergence activity in the Inter Tropical Convergence Zone (ITCZ) play the main role. In the FIM season, rainfall is the highest (more than 60 cm) over a relatively small area around the lower Southwest slopes of the highlands, and rapidly decreased all around to about 30 cm in the South-western sector of the Island. Over the rest of the country, the rainfall ranges between 10 and 30 cm. As such, this season is characterised by low rainfall over a major part of the country.

(ii) South-West Monsoon (SWM) Season: May-September

SWM occurs May to September when depressions, cyclonic wind circulation comes to pass in the low and mid Troposphere, and orography also controls the rainfall. Convectional activity can also cause the rain in the east of the country in month of May. The spatial variability of rainfall is the highest during the SWM season, ranging from 20 to more than 150 cm. The highest rainfall is concentrated in the South-western sector of the island, while the rest of the island gets rainfall of less than 50 cm. The area of the highest rainfall is on the South-western slopes of the highland at an altitude of about 1000 m. The South-eastern and North-western coasts get the lowest rainfall less than 20 cm. The distribution of rainfall over Sri Lanka during the SWM season is largely the result of the presence of the highlands across the Southwest Monsoon currents. The elevation of the mountains (Central Highlands) is up to 2524 metres (peak, Pidurutalagala). The Southwest Monsoon currents, that is, loaded with moisture owing to its long journey over the Indian Ocean. It is forced by the highlands to rise along the slopes and condenses by the Orographic rains in the windward side of the highlands. On the leeward side, the monsoon current relieves its moisture, and appears as a dry katabatic wind. Even before reaching the highest regions of the highlands, the Southwest Monsoon would already have lost a great deal of its moisture.

(iii) Second Inter Monsoon (SIM) Season: October-November

October to November, during which, convection, cyclonic wind circulation and convergence activity make the rainfall widespread. The SIM season is the most important rainy season over the whole Island. SIM season has the most evenly balanced distribution of rainfall over the whole of Sri Lanka, with the exception of the localised peak rainfalls (above 70 cm.) on the Southwest slopes of the highlands. The rainfall ranges from 40 to 70 cm. over the major part of the Island. Thus, for the Island as a whole, this season is the wettest.

(iv) North-East Monsoon (NEM) Season: December-February

NEM occurs from December to February when orographic waves in the easterly air streams, cyclonic wind circulation and convections influence the rainfall. In the Northeast Monsoon season the seasonal rainfall ranges from 30 to 70 cm. and the highest values (above 70 cm.) are observed over the North-eastern parts of the highland, extending to the eastward part.

(b) Temperature:

The small island of Sri Lanka, situated in the tropical latitude is free from extremes of temperature. The consequence of small size and location attributes result in uniformly high average temperature throughout the year, except when modified by elevation. The monthly average temperature is low. The influence of the Oceans is felt usually in the coastal fringes where the sea breeze by day mitigates the heat of the sun.

The tropical temperature conditions of Sri Lanka is characterised by larger diurnal than seasonal and annual temperature ranges. In the lowlands as well as mountains, the diurnal temperature ranges are small in comparison to other tropical regions. The average annual temperature ranges in Sri Lanka, which is the different between the warmest, and coldest months, varies between 1.5°C and 4.3°C. Also small values are true for the daily temperature ranges, which amount to 5°C to 10°C on the average for the whole year; yet they vary regionally.

The air temperature over the Island varies slightly throughout the year, except in the mountainous Central Highland. In the low lands, the mean annual temperature is 27^0C and mean daily range is 6^0C. The annual mean air temperature is largely uniform over the lowlands (26.5°-28°C), that rapidly decreases towards the Central Highlands. In the highlands, the surface temperature decreases quickly with altitude reaching 15.4°C over the peaks. The decrease in temperature with increasing altitude is greater on the western than on the eastern slopes of the Highlands. This is due to the dry and warm 'Kanchan' wind that blows down the eastern slopes of the highlands during the Southwest Monsoon season and causes quicker warm up with decreasing altitude.

The annual range of temperature is small and the month-to-month variations are almost imperceptible. The temperature regime is thus dominated by the diurnal variations, typical of the low latitudes. The mean annual range of temperature over Sri Lanka varies from around 4°C (Trincomalee) to as little as 1.5°C (Ratnapura). Thus, this is the characteristic of low annual temperature range can be observed almost all over Sri Lanka. Within the small variations in temperature during the course of year, one can discern a slight maximum in April and May and a minimum during December to February. The annual range of temperature is relatively small in the south-western sector of the country, including the Highland.

(c) Pressure:

The pressure gradient across the country from May to September is in the south-western direction with higher pressures in the Southwest and lower values to the Northeast. From December to February, the pressure gradient is northerly with high pressure in the north and lower values to the south. The pressure distribution is uniform during the months of March-April and October-November. The seasonal movement of the Equatorial Trough of Low Pressure (ETLP) determines the changes in the gradient of pressure system. Air from the two sub tropical high-pressure systems converges into this trough of low pressure. Hence, the ETLP is also referred to as the Inter Tropical Convergence Zone (ITCZ).

(d) Wind:

The Southwest Monsoon occurs from May to September. The onset of the monsoon is associated with a cyclonic wind circulation in the low troposphere (1,500 m) or with a depression. Occasionally, strong westerly winds (Low level Westerly Jet) occur just prior to the onset of the persistent rain. When the monsoon is fully established the westerly winds extend up to the mid-troposphere (6,000 m) and is overlain by easterly winds in the upper troposphere (9,000 to 12,000 m).

The surface wind is dominated by three factors, which combine to different degrees to result in complex patterns of surface winds over Sri Lanka. Of course, the topography plays a critical role in defining the winds patterns over the regions. Three basic genetics factors, which govern the wind patterns, over any region and in any part of the year in Sri Lanka. Namely: (a) The monsoon winds, (b) The land and sea breezes, (c) The mountain and valley winds.

The South-western monsoon determines the wind condition over Sri Lanka for 4 to 5 months, while the Northeast monsoon does so, for about 3 months. The Southwest monsoon winds near the surface have predominant westerly components, while the

Northeast monsoon winds have an easterly component. Although the Northeast monsoon is not a rain-bearing wind system compared to the Southwest monsoon. The depressions and cyclones, which are many hundred miles in diameter, occur in the Bay of Bengal spread over a period of several hours. During the inter monsoon season, the wind directions are not so clearly defined.

4.1.7 Main Factors Governing the Climate of Sri Lanka

The factors governing the climate of Sri Lanka emerge as three major components;

(i) The geographical position of Sri Lanka and resulting from this its affiliation to the South Asian monsoon regimes

(ii) The insularity of Sri Lanka, together with the small area of the Island, clearly illustrated by the fact that nowhere on the Island is the coast further than 110 km distant

(iii) The relief of Sri Lanka characterised by the Central Highland

These three major components overlap in their effect and their influences on the climate of Sri Lanka.

Part II

Part II concentrates mainly all about the agriculture and its relationship with the climate and climate change of Sri Lanka.

4.2 Climate and Agriculture

Due to the location of the Island in the tropics, its agriculture is mainly influenced more pronouncedly by rainfall other climatic elements. Significant anomalies in climate are caused by the temporal and spatial variations of rainfall, which have a strong impact on agricultural activities in the country.

From the viewpoint of agricultural land use the climatic division into the wet and dry zones is clearly underlined namely by the cultivation of perennial and annual crop in the wet zone and by the cultivation of annual crops only in the dry zone. Both regions vary too in the intensity of crop cultivation showing a much higher ration in the wet than in the dry zone. A remarkable feature of the agricultural land use of Sri Lanka is the distinct vertical zonation in the Central Highlands. Three altitudinal belts with characteristics crops in each can be distinguished, which are best documented on the western slopes of the mountains: These are: (i) the belt of mixed coconut palm and paddy cultivation in the low lands, (ii) the rubber belt, and (iii) the tea belt.

In the Wet zone, commercial crops like, tea, rubber and coconut palms are predominant, whereas in the Dry zone, rice is by far the leading crop. Besides, it is important to take into consideration the remarkable spatial differences of the cultivated crops within the Wet zone. The coconut palms, for example, are the most important in the Colombo and Kurunegala districts, whereas rubber is predominant in the Kalutara and Kegalle districts, and tea, in Kandy and Nuwara Eliya districts.

By comparison with the Wet Zone (67%) or the Intermediate Zone, the proportion of cultivated land is extremely less in the Dry zone (29%). The Dry Zone will therefore, be increasingly converted to agriculture and rice cultivation will be in areas where irrigation will be assured. The Wet Zone, occupying the Southwest sector, together with the Central Highland, is marked by perennial crops, which are mostly grown in plantations and to a small degree by smallholdings. However, in the dry zone, land utilisation pattern is almost exactly the opposite. Apart from some concentration of coconut farming and *Palmyra*, (oil) palm plantations, other perennial crops are almost absent here. Wherever agriculture takes place on a large scale in the Dry Zone, the cultivation of rice, Sri Lanka staple food crop is prominent. Compared to rice, all the other crops such as manioc, sweet potato, yam, millet, maize, onions, are of secondary importance, just as sugar-cane, cotton and tobacco. The 'cash crops' that are processed in Sri Lanka do not so far play a significant role. Shifting cultivation practised in Sri Lanka, is only typical of the Dry zone and it is absent in the Wet Zone.

Different areas of cultivation of the most important crops of Sri Lanka can be clearly observed by a cross section from Colombo on the west coast to Tirrukovil on the east coast. In this, a distinct vertical, multi-storeyed differentiation of the cultivated crops can be observed, beginning with the coconut palm in the coastal plains and low lands, to rubber in the lower hill-country, to tea in the middle- and higher altitudes of the Central

Highlands. The upper most regions of the Piduruthalagala Massif and Adam`s Peak are not cultivated. The cross section also clearly shows the contrast between land utilisation in the low lands in the west and in the east. In the west, coconut palms and rice are cultivated together while in the eastern lowlands; only rice is grown, with the exception of an occasional, small coastal fringe of coconut palms. On the basis of these observations on land utilisation pattern of Sri Lanka, it becomes obvious that tea, rubber, coconut palms and rice are the most important cultivated crops in Sri Lanka.

The Wet zone generally encompasses the south-western plains and the mountainous areas of the Central Highlands, and covers an area of about 12205 square km. The agricultural development in this zone is mainly by rain-fed cultivation together with a few barrage schemes diverting the stream water without any irrigation reservoirs. The cultivation in the low lands had generally been paddy with mostly by double cropping. These have been quite successful in the Wet zone, despite there being no storage reservoirs because of the reliability of the rainfall in the area.

The Wet zone receives moderate high mean annual rainfall over 2500 mm without pronounced dry periods. In the Wet zone, as it rains all the year, there are few agricultural problems; while in the Dry zone it mainly rains during the North-eastern monsoon, with dry season during the South-western monsoon, and also the annual variation of precipitation is so large that there are serious agricultural problems (periodic droughts).

Dry zone covers the northern, eastern and the south eastern sections of the island or about three quarters of the area, and is an excellent example of a tropical country where man and the biophysical system have had a long history of struggle with water shortages. On the annual basis, the variation of rainfall in the Dry zone is greater than Wet zone. The mean annual rainfall falls below 200 cm here, and though this figure appears to be rather high to be an upper limit for a zone to be termed dry, there are certain climatic characteristics that justifies the use of the term. The noticeable dryness in the said area is supported by the fact the 75% expectancy of annual rainfall, amazingly ranges between 50 and 100 cm. Further the 75 per cent expectancy of dryness for the period January to March and May to September ranges between 6.5 to 7 months for all places.

Thus the spatial pattern of the rainfall in different seasons indicate that the south-western sector of the island receives the highest rainfall in all season except in the Northeast monsoon season, which makes it the zone of maximum rainfall even in the annual rainfall pattern. However, the spatial distribution of rainfall in this season does not suggest any differentiation between the wind-ward or rain shadow slopes of the Highland, except over Knuckles Range (north-eastern part of the Central Highland), where the eastern slopes (windward sides in the Northeast Monsoon circulation) receives considerably higher rainfall than the western slopes (leeward side).

During the convectional seasons, rainfall occurs all over the island, whereas during the months of May to September, i.e., the Southwest Monsoon season, the Southwest lowlands and Western highlands receive the highest rainfall. However, the rest of the Island (two-thirds in area) receives little or no rain during this period. The contrasting climatic region, i.e., the Dry zone in Sri Lanka's does not receiving rain at this time, due to the influence of the Central Highlands. In other words, during the months of May to September the Dry zone gets the negative effect of the Southwest monsoon due to the leeward effect of the Central Highlands.

The Dry zone receives a mean annual rainfall of less than 1750 mm. with distinct dry seasons from May to September, whereas the Intermediate zone receives a mean annual rainfall between 1750 to 2500 mm. with a short and less prominent dry season. There are parts of the eastern slopes of the Central Highlands, which show similar characteristics, but relatively modified. These sections fall under the Intermediate zone which separate the Dry and Wet zones of the Island. Nevertheless, in some years, rainfall regime of the Intermediate zone could represent either of the Wet zone or Dry zone characteristics depending on the state of the general circulation of the atmosphere. The Dry zone that covers the remaining 80 per cent of the Island (including Intermediate zone, area 52385 square km.) exhibits wide variations in average annual precipitation and run off and in its spatial distribution. The variation of precipitation and run off about the mean in the Wet zone is much smaller than that of the Dry zone, which signifies lesser reliability of run off in the latter.

A water year in Sri Lanka is divided into two seasons especially from the point of view paddy cultivation. The rainfall under the Southwest monsoon striking the Southwest part of the Central Highlands, is called Wet zone (end of May to the end of September), and the rainfall (from November to March) during the Northeast Monsoon affects the Dry Zone and Intermediate Zones. The former is called 'Yala' and the latter, 'Maha' seasons. Agriculture in the Dry zone is extremely sensitive to the variation of the monsoons.

4.2.1 Land Use

The total land area of Sri Lanka is about 6.5 million hectare or 16 million acres. Of this, about one third has been utilised for plantations and agricultural holdings. A little over 20% is under woodlands, and about 6.4 per cent under grass and scrublands. All other uses cover about 30 per cent of the total land area. The drastic reduction in land under forests from 44 per cent in 1950 to around 22 per cent today, has serious implications on water resources. Land in Sri Lanka is predominantly under state ownership. It is estimated that over 80 per cent of the total land area of the country comes under the ultimate ownership of the Government. With the increase of population during the recent decades, land per person has declined rapidly, and with a present population of over 18 million, per capita lands available is now less than half a hectare.

The pattern of the land use has been changing rapidly. In 1800, the population was small and forest covered most of the land. Clearing up the forests for plantation agriculture was the greatest change that took place during the 19th century. In 1901, the population was 3.6 million and the forest cover was 70 per cent. However, by 1996, the population had risen to 18.2 million and the forest cover had declined to 23.9 per cent of dense forest and 6.9 per cent of sparse and open forest, making 30.8 per cent under forest. The area covered by settlements has grown along with the population. Large multipurpose schemes involving the construction of reservoirs for irrigated agriculture and power generation and settling people in theses areas by clearing the forests are other land use changes that have occurred during this country (Table 4.1 and 4.2).

Table 4.1: Land Use Patterns of Sri Lanka

Type	Area (Hectares)	Percentage
Agricultural land	1,598,090	24.36
Inland water	290,520	4.43
Homestead	781,280	11.91
Sparsely used crop land	1,246,770	19.00
Scrub land	502,720	7.66
Land under forest	1,757,740	26.79
Built up land	22,460	0.34
Others	361,400	5.51
Total land area	6,560,980	100.00

Source: Department of Census and Statistics, 1995.

Definitions:

(i) **Agricultural land:** Land under paddy, Permanent crops and other temporary crops.

Inland water: Sea, lagoons, tanks & reservoirs and major rivers.

(ii) **Homestead:** Family residential units surrounded by home gardens and open spaces.

Sparsely used cropland: *Chena* (Shifting cultivation) recently abandoned or abandoned tea, rubber and coconut lands and land under development.

(iii) **Scrub land:** Low growing vegetation with more than 50% area coverage, including trees with less than approx. 40% crown closure.

(iv) **Land under forest:** This includes dense forest, Open forest, Forest plantations.

(v) **Built up land:** Residential (including hotels), industrial, commercial, institutional, administrative, transportation, power plants and urban open spaces.

Table 4.2: Overall Land Use

Land Use	Hectares	Percentage
Land to be excluded	1,025,200	15.7
Forest	2,000,000	30.5
Agriculture	1,752,100	26.7
Homestead	900,000	13.7
Other Uses	165,000	2.5
Sparsely used and balance land	710,200	10.9
Total	*6,552,500*	*100.0*

Source: Somasekara et al, 1997:84.

4.2.2 Agriculture and Agricultural Land Use

Sri Lanka's economy has been based on agriculture from ancient times and will continue to be the primary source of the nation's economic activity for many more decades to come. The agriculture sector consists of two sub sectors, the non-plantation or domestic food crop sector and the plantation sector.

(i) The non plantation sector, mainly consists of paddy, other food grains, maize, soybean, vegetables, perennial crops etc., and accounts for 76 per cent of the total cultivable lands

(ii) The plantation sector, mainly consists of tea, rubber and coconut etc., accounts for the balance 24 per cent of the total cultivable lands

Of the plantation crops which cover 57.9 per cent of the total cultivated area of Sri Lanka, coconut palms, tea and rubber area of outstanding importance, whereas cocoa and cinnamon negligible due to small acreage. As a plantation crop tea is a major export crop of Sri Lanka and is grown extensively in the upper altitudes; and rubber is grown at lower altitudes of the highlands. Coconut is the main crop grown along the coastal belts and paddy cultivation has been carried out for several centuries on the plains.

The rate of agricultural output has slowed in recent years from 4.5 per cent in 1999 to 1.8 per cent in 2000. This resulted in a decline in the sector's contribution to Gross Domestic Products (GDP) from 21.3 per cent in 1999 to 20 per cent in 2001. Share of Agriculture in GDP (%) are also given in the table 4.3.

Table 4.3: Share of Agriculture in GDP: Percentage

Year	Share of Agriculture
1978	30.3
1990	23.2
1993	20.9
1994	20.5
1995	20.0
1998	21.1
1999	20.7
2000	19.9
2001	20.1

Source: Central Bank of Sri Lanka, Annual Report, 1996

Over the last few years, contribution of the agriculture sector to the national economy has declined drastically, from 46 per cent of GDP in 1950 to the current 20 per cent. Besides the contribution to GDP, the agriculture sector provided 19 per cent of export earnings in the year 2001. In 2002, the economy is on a path of recovery from the depressed performance and negative growth during 2001. The GDP grew by 1.4 per cent during the first half of the previous year. The information for 1995 on Non-plantation (paddy) and plantation crops have been presented in Table 4.4. In agriculture, the recovery was mostly due to the favourable performance in domestic agriculture. In plantation industry, production of tea recovered strongly during the second and third quarters. The production of rubber also increased in second and third quarter due to favourable improvement in rubber prices. However, coconut production continued to drop due to the lagged effect of the drought in 2001. The changes in the areas since 1946-1995, under the four main crops are given in table 4.5.

Table 4.4: Agricultural Land Use of Sri Lanka: 1995

Agricultural Crops	Land (hectares)	Percentage
Paddy	732,000	41.8
Tea	193,000	11.0
Rubber	161,000	9.2
Coconut	442,000	25.2
Other export crops	66,500	3.8
Sugar	10,600	0.6
Tobacco	6,000	0.3
Subsidiary food crops	141,000	8.1
Total	1,752,100	100.0

Source: Somasekara et al, 1997:82.

Table 4.5: Changes under Major Crops (hectares)

Crops	1946	Percentage	1962	Percentage
Paddy	370,000	29.6	459,000	33.1
Tea	215,000	17.2	231,000	16.7
Rubber	233,000	18.6	229,000	16.5
Coconut	433,000	34.6	466,000	33.7
Total	1,251,000	100.0	1,385,000	100.0

Table 4.5 continued

Crops	1982	Percentage	1995	Percentage
Paddy	500,000	38.6	732,000	47.9
Tea	207,000	16.0	193,000	12.6
Rubber	171,000	13.2	161,000	10.5
Coconut	416,000	32.1	442,000	28.9
Total	1,294,000	100.0	1,528,000	100.0

Source: Somasekara et al, 1997:84.

Agrarian reforms based on tenurial conditions, provision of agriculture credit, the guaranteed price scheme and crop insurance were major advances made to combat institutional problems of paddy farmers operating small scale farming units. It was however, the collective operation of the entire tract of about 40 hectares that orchestrated the regulatory and management aspects of paddy production.

There has been a persistent policy commitment of successive governments over the past few decades to the objective of increasing agricultural production and wherever possible, diversifying agricultural output, for both import substitution as well as increasing exports. In fact, the principles of welfare and equity referred to above have often been considered consistent with and conducive to efforts at increasing the contribution of agriculture to employment generation and overall economic growth. The importance attached to the involvement of the government, the provision of related agricultural services has varied from time to time. Agricultural sector, in general and peasant agriculture, in particular, require the support of the government in advisory services, credit and input supply, crop insurance and marketing, remains widely acknowledged at all times.

4.2.3 (a) Major Crops: Under Non-Plantation Sector:

(i) Paddy

Rice is the staple food in Sri Lanka and farmed on a small-scale in the rural regions, principally in the Northern and Eastern plains. Rice production is acutely dependent on rainfall in Sri Lanka. The principal cultivation season, known as 'Maha', is from October to March. During this season, there is usually enough water to sustain the cultivation of all rice fields. The subsidiary cultivation season, known as 'Yala', is from April to September. Usually there is only enough water for cultivation of half of the land during 'Yala'. Rice is highly susceptible to rainfall variability of both deficient and excess rainfall conditions that were found to have significantly contributed to reduction of rice yields (Yoshino and Suppiah, 1984). Within each season, there are significant spatial variations in the climatic conditions, due not only to the different circulation characteristics but also to the influence of the Central Highlands. In general terms, the *factors governing the climate of Sri Lanka can be classified in terms of three major* components (Domros, 1974) namely, (a) The geographical position (tropical and monsoon), (b) Insularity and (c) Topography (Central Highland).

4.2.3 (b) Major Crops: Under Plantation Sector:

The plantation sector which comprises tea, rubber, and coconut is the highest net foreign exchange earners of the country and brings in about SRs.71 billion per annum. This sector provides employment for about 380,000 workers in the plantation districts and it is equal to 20 per cent of employment in the economy. The GDP value addition of the plantation crops declined by 6.4 per cent in 2001. The decline in GDP could be attributed to the failure of both the Northeast and Southwest monsoons. The production of all major crops, tea, rubber and coconut declined during the year 2001 mainly due to these adverse weather conditions.

(i) Tea

Sri Lanka is one of the major players in the global tea industry accounting for 10 per cent of world tea production and 21 per cent of tea exports. The Sri Lankan tea industry is the country's highest net foreign exchange earner which accounts SRs. 59.32 billion or US dollar 663 million in 2001. It provides direct employment for about 600,000 people and out of these, 380,000 belongs to large plantations or estates and the rest to smallholdings. In addition, at least another 200,000 serve in tea related industrial sector.

The last completed tea land survey in 1994/95 recorded the total tea area in the country as 189,000 hectare and it contributes 42 per cent in Low country, 30 per cent in mid-country and 28 per cent in up-country. Total tea area in the country has declined to 181,172 hectares in the year 2001. During the last two decades total tea area in the country has come down by about 63,746 hectares or by 26 per cent from 1981. However, the altitudinal distribution and the area managed by the corporate sector and smallholders are not available yet. Although the mid and up country tea areas have decreased, the low country area has increased by about 15 per cent during the same period. Despite the decline in land area, the total production has increased due to high productivity over the period.

The steady upward trend experienced in tea production since 1993 was reversed in 2001. The output, which exceeded 300 million Kg. in 2000, declined by 3.3 per cent to 295 million Kg. in 2001. It was mainly an out come of the unfavourable weather conditions that prevailed throughout the year, compounded by the failure of Southwest monsoon during the later part of the year. The breakdown of the hydropower generation of the country, which resulted in power cuts, during the second half of the year aggravated the situation by directly affecting the tea production.

(ii) Rubber

Rubber is the second largest plantation export crop in Sri Lanka. The total land are under rubber presently covers only 157,000 hectares, as a result of the continuous shrinkage of area, i.e., by 19 per cent during past ten years. Out of this extent, 101,175 hectares are under the smallholder sector and it contributes to around 60 per cent of the rubber production. The rubber sector has shown variations in its production during the past years. The total rubber production was 96 584 metric tons in 1999 that declined to 87 636 metric tons in 2000, and has further declined to 86 230 metric tons in 2001.

(iii) Coconut

Coconut continues to be an important plantation crop, which contributes about 2.6 per cent of the GDP and 3.4 per cent to the foreign exchange earnings annually. It also provides livelihood for about 5 per cent of the total workforce, which signifies the Socio cultural importance of coconut. Coconut has declined in importance as an export crop during the last ten years; it is still important as industrial raw material and a food commodity in the domestic market. The area under coconut cultivation is 442,000 hectares. It is estimated that 150,000 persons are directly employed and around 750,000 families are dependent on the coconut industry as a whole. In the year 2000, the coconut production experienced a bumper harvest of 3,000 million nuts, but it declined by 110 per cent to 1238 million nuts during the first half of the year 2002. Desiccated coconut and coconut oil production decreased by 58 per cent and 7 per cent, respectively. The coconut production in 2002 has been low. One of the main reasons for the shortfall was the cumulative effect of adverse weather conditions, mainly the low rainfall in the main growing areas during the period 2000/2001. Coconut plantations were severely affected by the droughts that prevailed in latter part of the year 2001 and beginning of the 2002.

Present annual average yield is around 6300 nuts per hectare. Generally, the average estimated optimum yield is around 10000 nuts per hectare per annum. The low yield in coconut sector is mainly the result of poor cultivation practices adopted by the smallholders, neglect of field maintenance, insufficient usage of scientific and modern cultivation practices apart from the unfavourable weather conditions (that prevailed during the period 2000/2001).

4.2.3 (c) Fishing Industry

Fishing industry is a medium scale industry employing about 700,000 people directly and indirectly. Marine fish production plays the dominant role accounting for about 91 per cent of the total catch followed by fresh water fish (7%) and aqua-culture 2 per cent. The entire fishing industry contributes about 2.8 per cent to the GNP of Sri Lanka. About 5 per cent of the fish is converted into dry fish. The post harvest loss is very high, (as high as 40 per cent due to bad handling and insufficient cold storage) though there are ice and cold storage plants in major landing sites. About 80 per cent of the fresh fish is traded by the private sector and the balance by the state owned Ceylon Fisheries Corporation (CFC), which has better facilities than private sector. There are ten coastal districts that are involved in the fishing industry. For the purpose of administration, each district is in charge of one Extension Officer with a number of junior officers. There are 1038 fishing villages with 82, 593 households. The fisheries resources of Sri Lanka are administrated by the Ministry of Fisheries.

4.2.4 Mahaweli Project and History of Settlement:

The Mahaweli Development Programme (MDP) is the largest settlement scheme in Sri Lanka. MDP diverts water from Mahaweli Ganga (the longest river) in order to irrigate lands, aiming at two crops cultivation in the dry zone on a grade scale. The first area to be developed under this programme is area 'H', located in the Kala Oya basin covering an area of approximately 71000 acres. Nearly 25000 families were settled in this area through a network of family farms (each farm comprising two and half acres of irrigable land and half acre of un-irrigated land). With the initiation of Mahaweli Development Programme, the economic landscape of area 'H' has completely transformed. The population of the area has increased rapidly with the influx of new settlers.

Part III

4.3 Socio Economic Condition of Sri Lanka

In the part III, the Socio-economic development of Sri Lanka since independence, has been commented upon briefly. The Socio-economic development of Sri Lanka shows several turning points since its Independence on 4th February, 1948. Due to the British colonial rule, Sri Lanka's agriculture has concentrated on plantation crops, especially coconut, rubber, and tea, and efforts to cultivate coffee failed. These three products accounted for more than 90 per cent of all export revenue up to the 1970s causing a strong economic dependency on the primary sector.

Table 4.6: Percentage Sectoral Contributions to GNP: 1959-1996

Selected Sectors	1959	1970	1980	1990	1996
Agriculture	39.1	28.4	24.6	23.2	18.8
Manufacturing	11.6	16.5	13.8	17.3	21.4
Construction	4.8	5.7	5.5	6.8	7.0
Transport/storage/communication	9.2	9.7	9.5	11.2	11.8
Wholesale and retail trade	13.6	18.5	19.8	20.5	22.1
Banking/Insurance/Real Estate	0.9	1.2	2.1	5.1	6.3
Public administration/ defence	5.1	4.0	4.9	4.9	4.4
Other Services	12.3	11.2	13.2	3.8	3.8

Source: Central Bank of Sri Lanka, Annual Report, 1959-1996.

Sri Lanka's economy is still highly dependent on agriculture. In spite of all structural changes, still the focus on the export of primary products continues. Production for exports heavily depends on items, like tea, rubber, and coconut and production for home consumption consist of the production of (rice) paddy. The slow but steady sectoral change of the economy can be observed in table 4.7. It is obvious that the industrial (manufacturing) sector and since the later part of 1990s, the service sector have been growing at a slight higher rate than agriculture.

Table 4.7: Sectoral Growth and Growth Rates of GDP

Sector	1960-70	1970-80	1980-90	1990-95
Agriculture	3.0	2.8	2.2	2.4
Industry	6.6	4.0	4.6	6.5
Services	4.6	4.8	4.7	6.3
Average GDP growth rate	4.6	4.1	4.2	4.8

Source: World Bank, World Development Reports, 1960-1995.

Agriculture was strongly influenced by colonialism, which enhanced a structural change towards plantation farming and export crops. It is necessary to differentiate between production for exports, like tea, rubber, and coconut and those productions for home consumption, the subsistence crops of rice and other cereals. At the time of Independence, about 95 per cent of all foreign exchange was earned by the export of plantation crops. Share of tea was 60 per cent. The agricultural sector contributed 40 per cent to GDP. Half of this share was made-up of the plantation crops. Seventy-two percent of the population lived on subsistence agriculture and cultivated area was 85 per cent of the available. Nevertheless, food supply was not assured. Sri Lanka had to import paddy, sugar, wheat, flour, onions and chillies, whereby imports were regulated.

In spite of a per capita income of about 760 US$ in 1995, and looking at the Human Development Index (HDI), Sri Lanka showed the best performance of all South Asia economies occupying rank 91 out of 175 countries[1] (Werner, 1998: 131-151). In the

[1] Human Development Index (HDI) includes not only the per capita income but it also puts various indicators, for example education, real per capita income and life expectancy at birth together to form a composite indicators.

same year, India had a per capita income of only 340 US$, Pakistan of 460 US$, and Bangladesh of 240 US$. In 1996, Sri Lanka experienced a decline in the real growth rate of GNP from 6 per cent in 1995 to 3.1 per cent[2]. The depressed conditions at the beginning of 1996 were due to a severe drought and accompanying power cuts[3].

However, economic growth regained momentum during the second half of the year. In 1996 the manufacturing sector contributed a share of 36 per cent to the growth of GNP, services 77 per cent, and the mining and construction sector 6 per cent each, whereas the agricultural sector's contribution to real GDP growth came down by –25 per cent. This decline in the share of agriculture in GDP was mainly due to a reduction in domestic crops (paddy) by 27 per cent and in coconut production by 7.6 per cent.

Since the second half of 1996, Sri Lanka has experienced an improvement of its economic situation. Also in 1997 Sri Lanka's economy has undergone a strong recovery. The GDP growth rate for 1997 was above 6.3 per cent. Manufacturing output has gone up to 12 per cent during the first six months of 1997. Exports have increased by 20 per cent during the first five months of 1997. Even the tourists sector has begun to recover.

Considering some social indicators, however Sri Lanka's performance was better than that of some middle income economies. Since Independence in 1948, Sri Lanka governments followed a policy with a special focus on social concerns, not only in the field of medical services but also making provisions of subsidized food supply. While in 1995 the average life expectancy at birth was as low as 56 years in low-income

[2] Real GDP growth declined from 5.5% (1995) to 3.8% (1996).
[3] Due to its strong dependence on hydro power Sri Lanka's electricity generation declined during the drought.

economies (excluding Chine and India), and 68 years in middle-income economies, Sri Lanka could look at an average life expectancy (at birth) of 72.2 years (the same as South Korean). Infant mortality at a rate of 16 per thousand live births in 1995 was astonishingly low. In the same year, the average rate in low income economies was 89 per thousand live births, or 69 including China and India. The adult literacy rate was 90.1 per cent. As early as 1980, 90 per cent of the population was able to get medical care. Considering water supply, 57 per cent of the population had free access to drinking water, and 66 per cent to sanitary installations. Mother mortality (MMR) was at a rate of 30 per 100,000 live births in the years 1989-1995, and thus relatively low compared to China (115) and India (437).

After the establishment of British rule in Sri Lanka, the country had a population of 2.4 million in the year 1871, which gave a density of 37 persons per square km. By 1991, it had exceeded 17 million, with a corresponding density of about 241 persons/ square km. According to latest statistics, Sri Lanka has a population of 19 million in 2000, and this implies an average density of 278 persons per sq. km, which is the 21st highest in the world. Sri Lanka' s population growth was as high as 3 per cent per year in 1950s, but gradually has dipped close to 1.3 per cent in 1990s.

Due to the difficult political developments and the ongoing ethnic conflict, Sri Lanka's situation has worsened over the last decades. In 1991, for example, Sri Lanka's rank was 75 in the Human Development Report (HDR), which lately is falling.

Chapter – V

Climate Change in South and Central Sri Lanka: Special References to Trends in Rainfall and Temperature Changes

5. Introduction

The present chapter deals with the precipitation and temperature changes in Sri Lanka over the entire study area, represented by thirty three (33) rain-gauge stations and twelve (12) temperature recording stations (Map 3.2) over a period of four decades, i.e., from 1960 to 2002, principally at intervals of 10 years. The data was normalised for three-year cycles for each decade, starting, e.g., 1959-60, 1960-61 and 1961-62 with roughly the midpoint year in 1960-61 to even out extremities of climatic fluctuations from year to year.

5.1 Temperature Changes

For the period under study, temperature and rainfall analyses were carried out according to the rainfall yearly cycles in Sri Lanka, which begins in March and ends in February, next year. Temperature changes of annual average temperatures, mean maximum temperatures, mean minimum temperatures were calculated, at selected temperature stations under the study from 1959 to 2002. In addition, the decadal temperature changes were also examined with break points of decadal years, i.e., for 1960-61, 1970-71, 1980-81, 1990-91 and ending with 2000-01. Analyses were also carried out for Agro-Climatic Zones, for the rainfall seasonal cycles and corresponding temperature changes. Time series and Linear Trends were examined for the changes of temperature. Detailed discussions of methodology and techniques of data analysis were discussed in Chapter III. Table 5.1 shows, the names of the temperature stations, latitudes, longitudes as well as their elevations and Agro-climatic zones and Agro-ecological regions.

Table 5.1: Geographical distribution of temperature stations under the study

Temperature Stations	Agro-climatic Zone	Agro-ecological region	Latitudes (North)	Longitudes (Eeast)	Elevation (m) above MSL
1Annuradhapura	Dry zone	DL1	8° 21′	80° 23′	93
2 Maha Illuk pallama	Dry zone	DL1	8° 7′	80° 28′	138
3 Badulla	Intermediate zone	IM1	6° 59′	81° 3′	670
4 Diyathalawa	Intermediate zone	IU3	6° 49′	80° 58′	1248
5 Kurunegala	Intermediate zone	IL1	7° 28′	80° 22′	116
6 Nuwara Eliya	Wet zone	WU3	6° 58′	80° 46′	1895
7 Katunayake	Wet zone	WL3	7° 10′	79° 53′	9
8 Rathmalana	Wet zone	WL4	6° 49′	79° 53′	5
9 Colombo	Wet zone	WL4	6° 54′ 0"	79° 52′ 47"	2
10 Kandy	Wet zone	WM3	7° 20′	80° 38′	477
11 Rathnapura	Wet zone	WL1	6° 41′	80° 24′	34
12 Galle	Wet zone	WL4	6° 2′	80° 13′	13

Notes: DL: Dry zone Low country, IM: Intermediate zone Mid country, IU: Intermediate zone Up country, IL: Intermediate zone Low country, WU: Wet zone Up country, WL: Wet zone Low country, WM: Wet zone Mid country, MSL: Mean Sea Level.

Source: Somasekara et al, 1997 and Meteorology Department, Colombo.

5.1.1 Annual Average Temperature

Annual average of monthly average temperature have been estimated for each temperature station, for each of the sub-periods (decades) from 1959 to 2002 (Table 5.2). The time series of annual mean surface temperature changes, in related to the average of each sub period for 1959-2002 indicate, increasing trend when the more recent period was considered. However, it is found that the surface air temperature has been increasing at all the 12 stations, considered.

Table 5.2: Annual Average Temperature: 1959-2002 (In ^{0}C)

Years	Anuradh apura	Mahalllu kpallama	Badu lla	Diyatha lawa	Kurun egala	Nuwara eliya
1959-1962	27.3	27.1	23.4	20.3	27	15.8
1969-1972	27.4	27.3	23.4	20.1	27.2	15.9
1979-1982	28.1	27.8	23.8	20.5	27.6	15.7
1989-1992	28.2	27.5	24	20.4	27.4	16
1999-2002	28.3	27.6	24.4	20.8	27.6	16

Table 5.2 continued

Years	Katu nayake	Ratma lana	Colombo	Kandy	Ratna pura	Galle
1959-1962	n.a.	27.3	26.9	24.4	27.2	26.6
1969-1972	27.3	27.1	27.3	24.4	27.2	26.8
1979-1982	27.9	27.5	27.6	24.8	27.7	27.0
1989-1992	27.6	28.1	27.6	24.8	27.6	27.0
1999-2002	27.7	28.1	27.8	24.9	27.9	27.3

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.
Note: n.a.= not available.

Temperature increases have started as early as 1960 in the case of Anuradhapura, Badulla, Nuwara Eliya, Ratmalana, Colombo, Galle, and as late in 1980, at Kandy and Kurunegala. Increases in average annual temperature values at the other stations have been reported between 1960 and 1980. Annual mean temperature differences were calculated between the first sub period (ending 1960-61) and the last sub period (ending, 2000-01). All the stations indicate increase in temperature (Table 5.3).

Table 5.3: Annual average temperature increases 1959-2002 (In ^{0}C)

Temperature Stations	**Climatic Zones**	**Temperature increase, ^{0}C**
1 Anuradhapura	Dry zone	+1.0
2 Maha Illukpallama	Dry zone	+0.5
3 Badulla	Intermediate zone	+1.0
4 Diyathalawa	Intermediate zone	+0.5
5 Kurunegala	Intermediate zone	+0.6
6 Nuwara Eliya	Wet zone	+0.2
7 Katunayake	Wet zone	+0.4
8 Ratmalana	Wet zone	+0.8
9 Colombo	Wet zone	+0.8
10 Kandy	Wet zone	+0.5
11 Ratnapura	Wet zone	+0.7
12 Galle	Wet zone	+0.7

Source: Estimated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

As shown in table 5.3, almost all the stations show increases in annual temperature for the entire four-decade period 1960-61 to 2000-01 (Fig.5.1). Average annual temperature increased by more than 0.4 degrees Celsius for all the stations except Nuwaraeliya, which lie in the Central Highlands, at 1895m above mean sea level. The increases in temperature were 1.0 ^{0}C during the period 1960-61 to 2000-01 at Anuradhapura (Fig. 5.2) and Badulla. When compared across the entire period, it becomes clear that the greater increases (warming) were recorded over more recent periods than over the whole observation periods, especially after the 1970s.

Figure 5.1: Annual average temperature

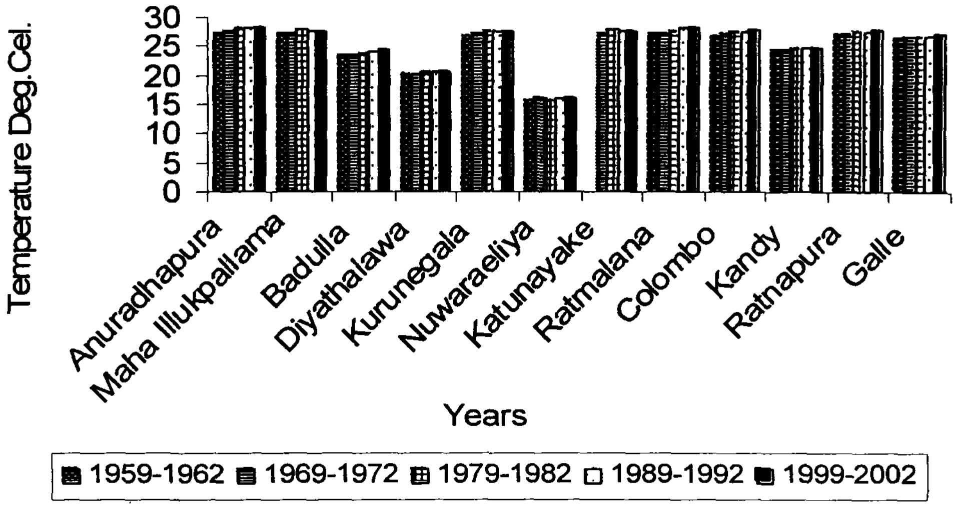
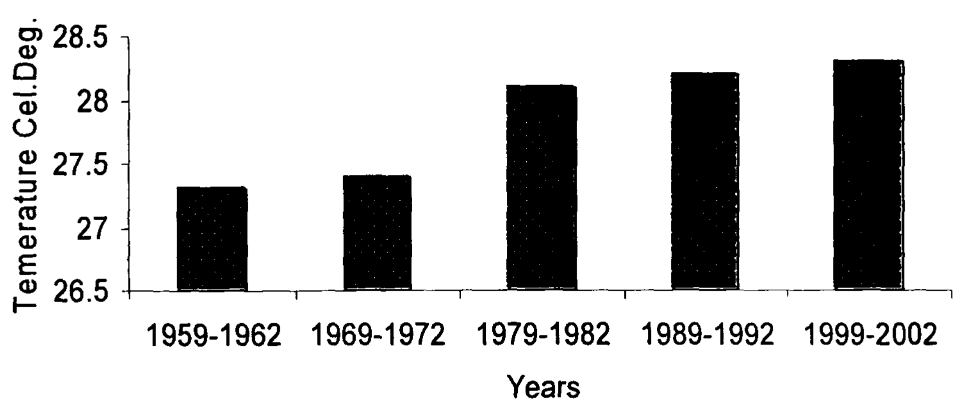


Figure 5.2: Annual average temperature at Anuradhapura



Linear trend analysis was carried out for computation of annual average temperature since 1960-61 to 2000-01. Positive trends of warming were noticed invariably for all the stations and with statistical significance of "t" values, for the slope "b" coefficient. Regression coefficient for annual average temperature is high at Badulla, Rathmalana and Colombo. When the entire period of study was split by 1970-71, it could be noticed that the warming trend is even more significant during the later decades that conforms some of the earlier studies and hypothesis on the subject. For the entire period (1960-61 to 2000-01), only two stations namely, Nuwara Eliya and Katunayake show a small positive trend ('b' below 0.3), whereas all the other stations indicate strong warming trends (Table 5.4). Slope values above 0.3 are considered significant. Increasing trend could be noticed almost all the stations since mid-1970s. Selected graphs have been shown in figure 5.3 and 5.4.

Table 5.4: Annual average temperature
Linear trends: 1959-2002

Temperature Stations	Climatic Zones	Slope	R^2 value
1 Anuradhapura	Dry zone	+0.03	0.879
2 Maha Illukpallama	Dry zone	+0.01	0.493
3 Badulla	Intermediate zone	+0.26	0.939
4 Diyathalawa	Intermediate zone	+0.14	0.703
5 Kurunegala	Intermediate zone	+0.14	0.721
6 Nuwara Eliya	Wet zone	+0.05	0.368
7 Katunayake	Wet zone	+0.09	0.216
8 Rathmalana	Wet zone	+0.26	0.797
9 Colombo	Wet zone	+0.21	0.896
10 Kandy	Wet zone	+0.14	0.845
11 Rathnapura	Wet zone	+0.18	0.835
12 Galle	Wet zone	+0.17	0.953

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

Figure 5.3 Trends of annual average temperature at Badulla

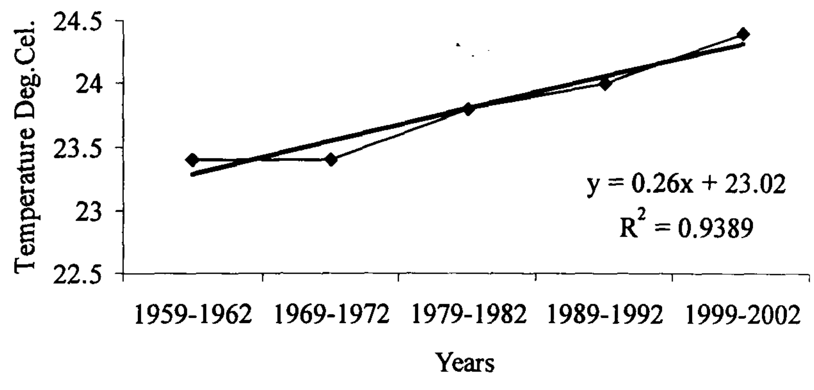
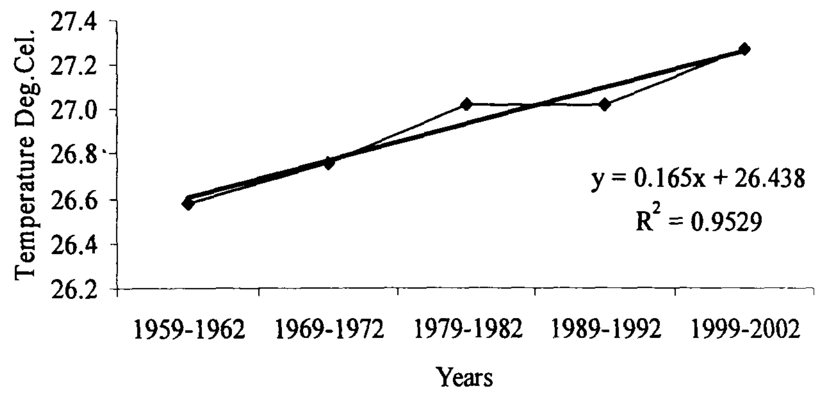
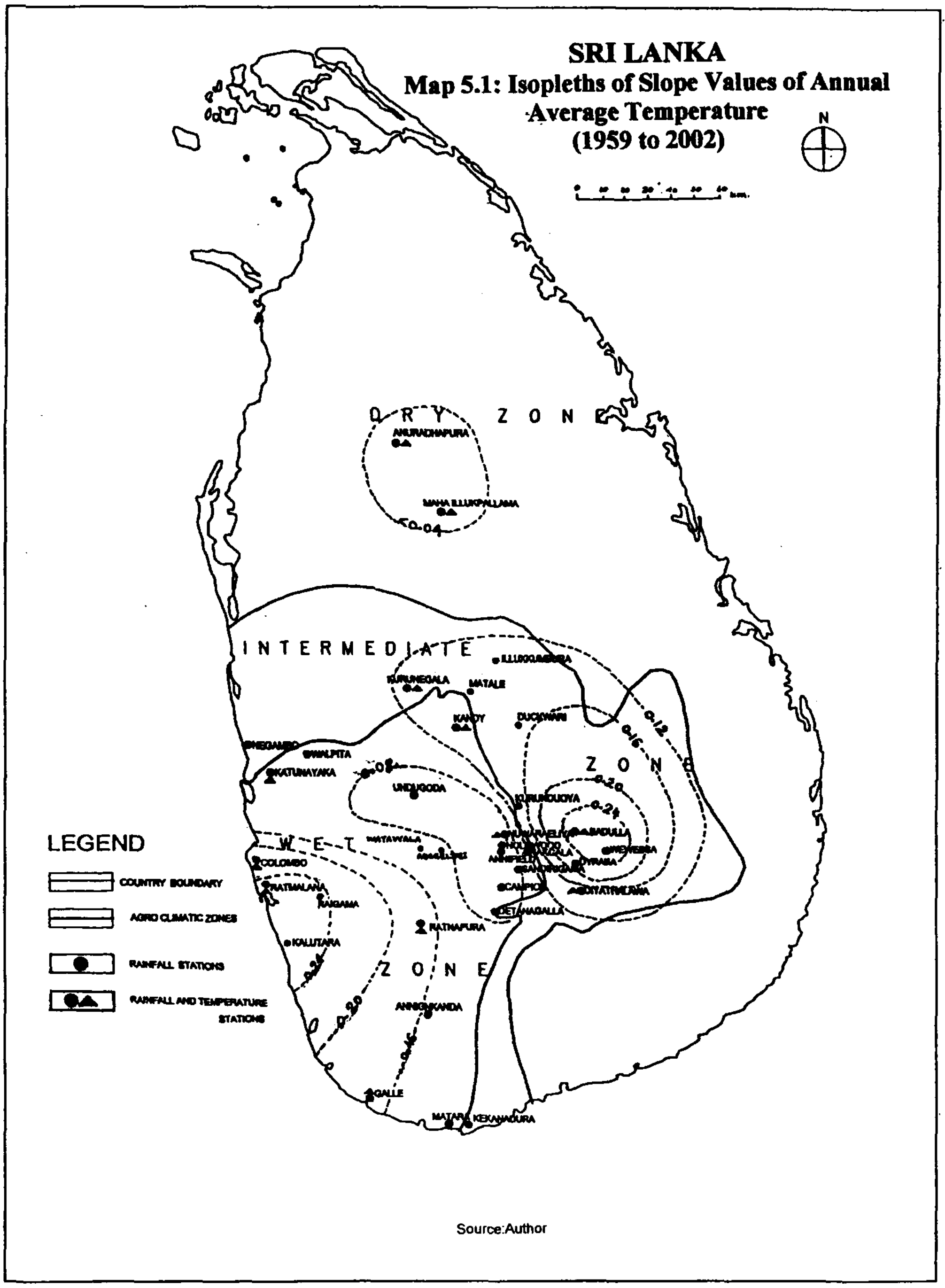


Figure 5.4: Trends of annual average temperature at Galle




SRI LANKA
Map 5.1: Isopleths of Slope Values of Annual Average Temperature (1959 to 2002)
N
DRY ZONE
INTERMEDIATE ZONE
WET ZONE
LEGEND
Source:Author

The map of Sri Lanka shows isopleth of the regression coefficient of increased annual surface air temperature for all the stations in Map 5.1.

5.1.2 Mean Maximum Temperature

Mean maximum temperature changes were examined from 1959-2002, representing each sub periods (Table 5.5). Time series data has showed that the mean maximum surface air temperature has also been increasing at all the 12 stations under the study.

Table 5.5: Mean maximum temperature, 1959-2002 (In ^{0}C)

Year	**Annura dhapura**	**Mahallluk pallama**	**Badulla**	**Diya thalawa**	**Kurune gala**	**Nuwara Eliya**
1959-62	29.1	28.6	24.8	21.5	28.6	17.1
1969-72	29.0	28.7	25.0	21.7	28.7	17.6
1979-82	29.7	29.4	25.4	22.1	29.5	17.4
1989-92	30.2	29.4	25.7	22.0	29.2	17.5
1999-2002	30.0	29.5	27.0	22.1	29.1	17.3

Table 5.5 continued

Year	**Katuna yake**	**Ratma lana**	**Colombo**	**Kandy**	**Ratnapura**	**Galle**
1959-62	n.a.	28.2	27.7	25.9	28.2	27.5
1969-72	28.4	28.3	28.5	26.1	28.3	27.8
1979-82	29.2	28.8	28.8	26.5	28.8	28.2
1989-92	28.5	29.1	28.6	26.6	29.1	28.2
1999-2002	28.7	29.0	28.7	26.1	29.0	28.2

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

Note: n.a.=not available.

The time series of mean maximum air temperature changes relative to the average for 1959-2002 indicate increases when the more recent periods were considered.

However, these increases have started as early as 1970s in the case of Annuradhapura, Maha Illukpallama, Badulla, Diyathalawa, Kurunegala Colombo, Kandy and Galle and as late as 1980s at Ratmalana, and Ratnapura. Increasing values at the other stations have commenced between 1980 and 1990. Increases of mean maximum temperature for all the stations are given in the table 5.6. Stations wise mean maximum temperature increasing values are shown in figure 5.5.

Table 5.6: Mean maximum Temperature Change: 1959-2002 (In ^{0}C)

Temperature Stations	Mean maximum temperature increase, ^{0}C
1 Annuradhapura	+0.9
2 Maha Illukpallama	+0.9
3 Badulla	+2.2
4 Diyathalawa	+0.7
5 Kurunegala	+0.5
6 Nuwara Eliya	+0.2
7 Katunayake	+0.3
8 Ratmalana	+0.8
9 Colombo	+1.0
10 Kandy	+0.2
11 Ratnapura	+0.8
12 Galle	+0.7

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

Observing the table 5.6, the higher warming trend of temperatures above 0.5° C are recorded at Annuradhapura, Maha Illukpallama, Diyathalawa, Kurunegala, Ratmalana, Colombo, Ratnapura and Galle (Fig. 5.5). The increase of mean maximum temperature was the highest at Badulla, where the increase has been by 2.2 ^{0}C during the period 1959-2002.

A linear regression analysis was also carried out for trends computation of mean maximum temperature since 1959-2002. Trends computation for mean maximum temperature shows a positive warming trend over the whole period under study, as well as sharp increases since 1970 s (Table 5.7).

Figure 5.5: Annual mean maximum temperature

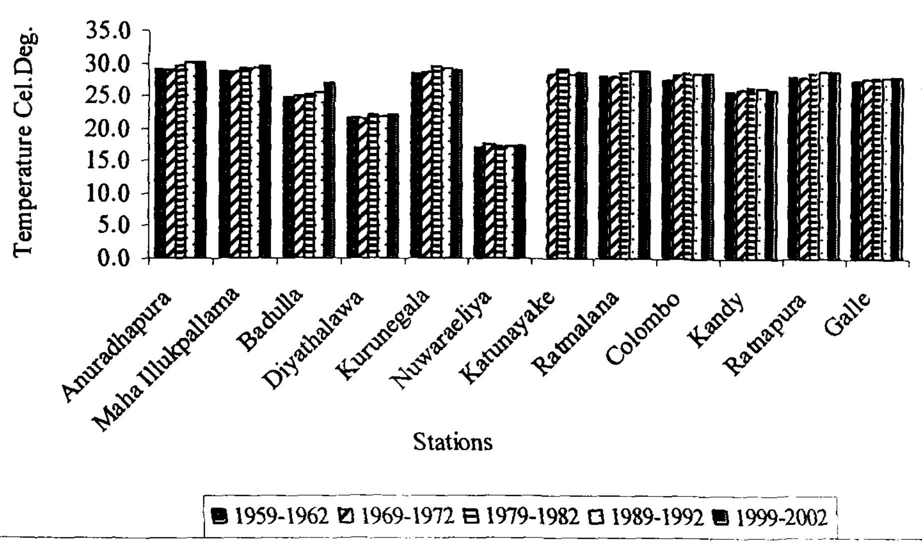
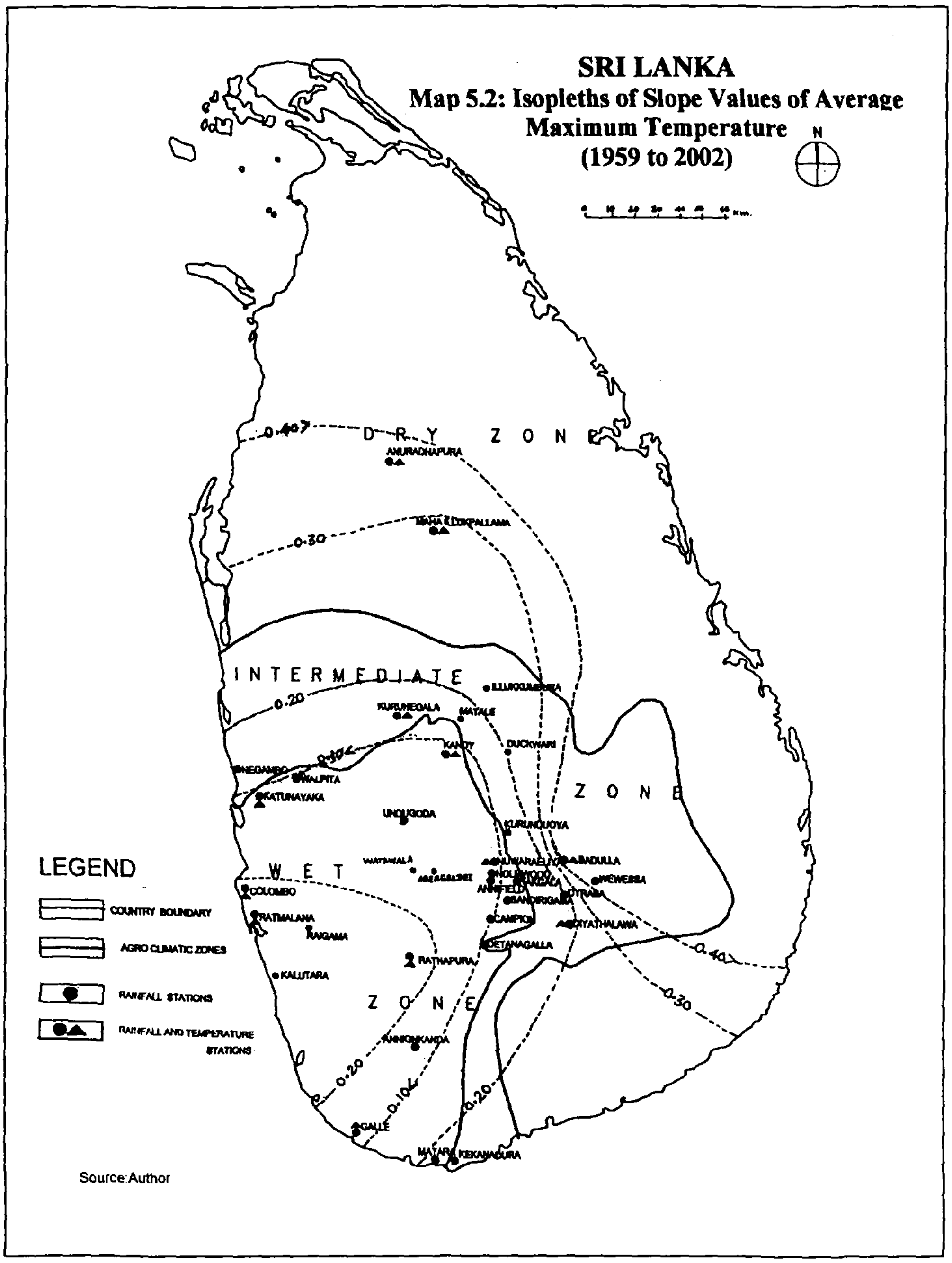


Table 5.7: Linear Trends for mean maximum temperature: 1959-2002

Temperature Stations	Climatic Zone	Slope	R^2 value
1 Annuradhapura	Dry zone	+0.317	0.802
2 Maha Illukpallama	Dry zone	+0.247	0.841
3 Badulla	Intermediate zone	+0.527	0.876
4 Diyathalawa	Intermediate zone	+0.143	0.746
5 Kurunegala	Intermediate zone	+0.157	0.408
6 Nuwara Eliya	Wet zone	+0.033	0.083
7 Katunayake	Wet zone	+0.010	0.001
8 Rathmalana	Wet zone	+0.243	0.842
9 Colombo	Wet zone	+0.217	0.595
10 Kandy	Wet zone	+0.090	0.262
11 Rathnapura	Wet zone	+0.243	0.842
12 Galle	Wet zone	+0.180	0.822

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

It is clear from the linear trend analysis the the temperature increases are particularly significant in more recent years (1999-2002) at almost all the stations. For the whole period (1959-2002) only three stations namely, Nuwara Eliya, Kandy and Katunayake show a light positive trend (slope below 0.3), while all other stations demonstrated an even more positive trends of warming (Table 5.7). The positive trends of warming were noticed invariably for all the stations and with statistical significance of "t" values for the slope, "b" coefficients. Regression coefficient is high at Anuradhapura, Maha Illukpallama, Badulla, Rathmalana, Ratnapura and Colombo. The map of Sri Lanka shows isopleth of the regression coefficient of increased maximum air temperature in Map 5.2.



Mean maximum temperature for months were also analysed to understand monthly fluctuation of temperatures. The month of April and May are the warmest months for almost all the stations. According to the rainfall seasons of Sri Lanka, the month of April is included in the First Inter Monsoon season and the month of May is included to the Southwest Monsoon season. Some of the stations, months of March, June, August, September and October were also recorded as warm months. The month of October is included in the Second Inter Monsoon season, which is prevails before arrival of Northeast Monsoon season during the winter months.

Table 5.8: Months of Maximum Recorded Temperature (In ^{0}C)

Stations	1959-62	1969-72	1979-82	1989-92	1999-2002
Anuradhapura	28.8 Aug./Sept.	29.0 April	29.5 May	30.0 April	29.7 May
Maha Illukpallama	28.5 August	28.6 April	29.3 May	29.1 April	29.3 May
Badulla	24.8 August	25.0 May	25.3 May	25.7 May	25.9 May/Oct.
Diyathalawa	21.4 May	21.7 May	22 May	21.9 May	22.1 May
Kurunegala	28.5 April	28.7 April	29.2 March	28.9 April	28.7 May
Nuwara Eliya	17.0 May	17.6 April	17.3 May	17.3 April	17.3 May
Katunayake	n.a.	28.2 May	29.0 May	28.4 April/May	28.5 May
Rathmalana	28.1 May	28.1 June	28.8 May	29.0 May	28.9 May
Colombo	27.6 May/April	28.3 June	28.8 May	28.6 May	28.7 May
Kandy	25.9 April	26.1 April	26.2 Apr./May	26.4 April	25.9 April/May
Rathnapura	28.2 Mar./April	28.3 April	28.7 March	28.7 March	28.8 March
Galle	27.5 April	27.7 April	28.0 May	28.0 May	27.9 April/May

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo. Note: n.a. = not available.

5.1.3 Mean Minimum Temperature

Mean minimum temperature changes were also analysed from 1959-2002 representing each sub periods. Time series data shows that the mean minimum surface air temperature has also been increasing at all the 12 stations. Observing the mean minimum temperature, Annuradhapura and Colombo show an increase of 1.1 ^{0}C and 1 ^{0}C respectively, during the period 1959-2002 (Table 5.9).

Table 5.9: Mean Minimum Temperature Change: 1959-62 to 1999-2002 (In ^{0}C)

Temperature Stations	**Climatic Zone**	**Mean minimum temperature increases, ° C**
1 Annuradhapura	Dry zone	+1.1
2 Maha Illukpallama	Dry zone	+.7
3 Badulla	Intermediate zone	+.7
4 Diyathalawa	Intermediate zone	+.5
5 Kurunegala	Intermediate zone	+.7
6 Nuwara Eliya	Wet zone	+.4
7 Katunayake	Wet zone	+.9
8 Ratmalana	Wet zone	+.7
9 Colombo	Wet zone	+1.0
10 Kandy	Wet zone	+.6
11 Ratnapura	Wet zone	+.7
12 Galle	Wet zone	+.8

Source: Calculated by the author, based on temperature records of Department of Meteorology,Government of Sri Lanka, Colombo.

A Linear regression analysis was also carried out, for computations of trend for mean minimum temperature between 1959-60 and 1999-2002. Trend computations for mean minimum temperatures show a positive development warming trend over the whole period 1959-2002 as well as significant increases were also noticed since the 1970s. Observing the table 5.10, the linear regression coefficients were higher at Anuradhapura, Rathmalana, Colombo, Rathnapura and Galle than other stations. Slope values are not significant at Nuwara Eliya, Diyathalawa, Katunayake and Kandy, indicating fluctuations.

Table 5.10: Linear Trends of Mean Minimum Temperature: 1959-2002

Temperature Stations	Climatic Zones	Slope	R^2 value
1 Annuradhapura	Dry zone	+0.323	0.816
2Maha Illukpallama	Dry zone	+0.153	0.577
3 Badulla	Intermediate zone	+0.173	0.450
4 Diyathalawa	Intermediate zone	+0.117	0.170
5 Kurunegala	Intermediate zone	+0.157	0.430
6 Nuwara Eliya	Wet zone	+0.090	0.087
7 Katunayake	Wet zone	+0.010	0.001
8 Rathmalana	Wet zone	+0.257	0.582
9 Colombo	Wet zone	+0.217	0.595
10 Kandy	Wet zone	+0.090	0.262
11Rathnapura	Wet zone	+0.257	0.582
12 Galle	Wet zone	+0.197	0.730

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

The monthly mean minimum temperatures were analysed for studying the monthly changes in pattern of temperature (Table 5.11). It is observed, that the month of November, December and January record the lowest temperatures for all most all the stations. According to the rainfall seasons of Sri Lanka, the month of November is included to the Second Inter Monsoon season and the month of December and January are included to the Northeast Monsoon season.

Table 5.11: Months of Minimum Recorded Temperatures (In ^{0}C)

Stations	1959-62	1969-72	1979-82	1989-92	1999-2002
1 Annuradha pura	25.1 January	24.7 December	25.4 January	25.7 January	26.2 Dec./Janua.
2 Maha Illukpallama	25.0 January	24.6 December	25.0 January	24.8 January	25.4 January
3 Badulla	21.5 January	21.3 January	21.0 January	21.6 January	22.1 January
4 Diyathalawa	18.6 January	18.2 January	18.0 January	18.2 January	19.1 January
5 Kurunegala	25.7 Decem.	25.4 December	25.8 January	25.5 January	26.3 December
6 Nuwara Eliya	15.0 January	14.9 February	13.8 January	14.8 January	15.3 January
7 Katunayake	n.a.	26.0 December	27.1 Decemb.	26.8 January	27.0 January
8 Rathmalana	26.6 February	25.9 December	26.3 January	27.1 January	27.2 January
9 Colombo	26.2 Novem.	26.1 December	26.7 Decemb.	26.8 January	27.1 January
10 Kandy	23.5 January	23.0 December	23.6 January	23.4 January	23.9 December
11 Rathnapura	26.7 Novem.	26.5 December	26.9 Septem.	26.9 July	26.8 January
12 Galle	25.9 January	25.8 January	26.0 January	26.1 January	26.7 January

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.
Notes: n. a. = not available.

5.1.4 Decadal Temperature Changes

Decadal temperature hss remarkably increased, from 1960 to 2000 specially, after mid of 1970s. Some of the stations clearly show the differences of trends lines with increased values (1970s) with significant R^2 values. Considering the overall situation, Sri Lanka had two warmest periods in the last 50s years under the study. The first period was in the 1970s and the other period was in the 1990s. Most of the stations, the variation of annual air temperature show the contrasts in variation, before and after 1975.

The variation of former period shows, steep changes and regional differences, while the variation in the latter period shows that the temperature has significantly increased. This increase had started as early as 1970 in the case of Anuradhapura, Badulla, Nuwara Eliya, Ratmalana, Colombo and Galle. Maha Illukpallama and Diyathalawa are remained almost in the same pattern since 1960s. Compared with the whole period under study, after 1970 s and the more recent decade from 1990s show strong positive trends of warming, e.g., at Anuradhapura, Badulla (Figure 5.6 and 5.7).

Figure 5.6: Decadel changes of average temperature at Anuradhapura

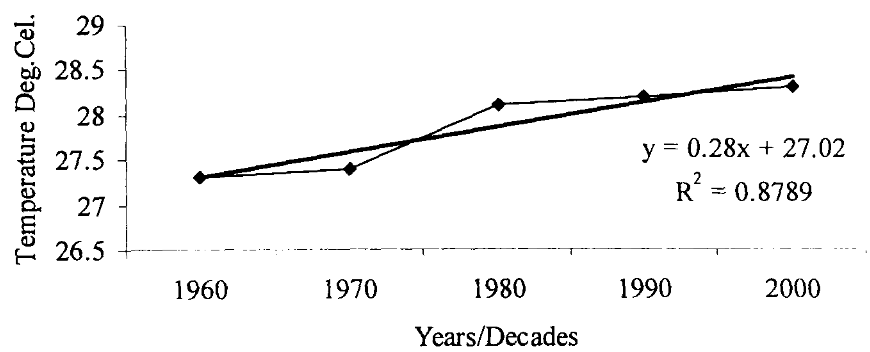
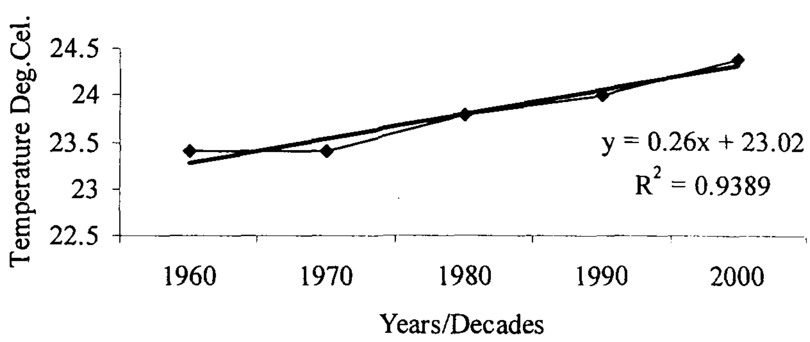
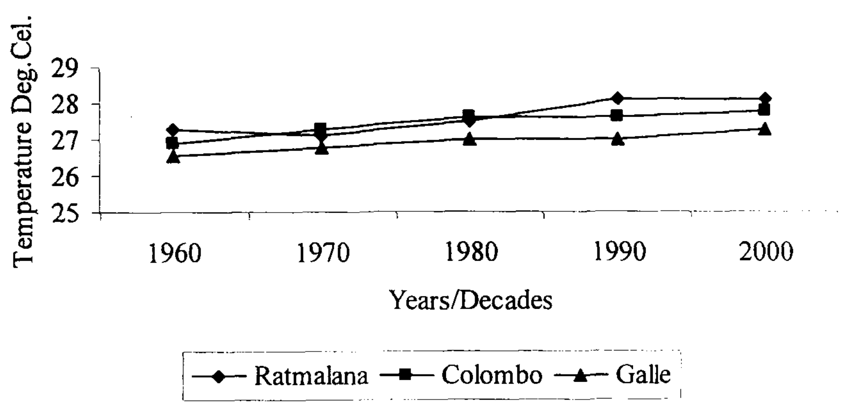


Figure 5.7: Decadel changes of average temperature at Badulla



Decadal temperature changes of mean maximum temperature show different pattern as compared with annual average temperatures. When the mean maximum temperature is considered, the decadal temperature changes are significant since 1970s. Ratmalana, Colombo and Galle recorded increasing temperature for 1970s, 1980s and 1990s decades (Figure 5.8).

Figure 5.8: Decadel temperature changes at selected stations



Maha Illukpallama and Diyathalawa show sluggish increases initially but these become marked after 1980s. There were no remarkable decadal increases at Nuwara Eliya and Katunayake. Decadal changes of mean minimum temperature were also studied for the same periods. There were differences in the pattern as compared with mean maximum temperatures. Increases in mean monthly temperatures were noticeable after the 1990s, i.e., Colombo, Kandy, Ratnapura and Galle stations.

5.1.5 Seasonal Temperature Changes and Significance

The detail discussion of the rainfall seasons of Sri Lanka has been discussed in Chapter IV. The monthly average temperature data were converted to seasonal average temperature data and examined seasonal temperature changes using the classification adapted in defining the rainfall year of Sri Lanka. Theses seasons are:

(a) First Inter-Monsoon season (FIM) - March to April

(b) South West-Monsoon season (SWM) - May to September

(c) Second Inter-Monsoon season (SIM) - October to November

(d) North East-Monsoon season (NEM) - December to February

Linear regression analyses were carried out for trends computations of mean seasonal temperature in between 1959-2002, with each sub periods. Positive warming trends were observed with significance. Trends for temperatures show increases over the whole period 1959-2002, as well as significant increases since 1970s, and again after the 1990s, for all most all the stations.

Increased warming trends could be noticed (for all the stations) during the First Inter-Monsoon as well as Southwest Monsoon seasons. Table 5.12 indicates the linear regression coefficients were higher at Anuradhapura, Badulla and Rathmalana as compared with other stations during the First Inter Monsoon season. The linear regression coefficients were higher, at Anuradhapura, Badulla, Colombo, Rathmalana and Ratnapura as compared with other stations, during the Southwest Monsoon season.

Table.5.12: Trend of Temperatures of First Inter Monsoon (FIM) and South West Monsoon (SWM) Seasons: 1959-2002

Temperature Stations	Climatic Zone	FIM Slope	FIM R^2 value	SWM Slope	SWM R^2 value
1 Annuradhapura	Dry zone	+0.292	0.703	+0.240	0.872
2 Maha Illukpallama	Dry zone	+0.090	0.148	+0.113	0.370
3 Badulla	Intermediate zone	+0.248	0.785	+0.249	0.976
4 Diyathalawa	Intermediate zone	+0.072	0.295	+0.133	0.635
5 Kurunegala	Intermediate zone	+0.042	0.066	+0.145	0.817
6 Colombo	Wet zone	+0.130	0.473	+0.215	0.732
7 Galle	Wet zone	+0.127	0.745	+0.130	0.838
8 Kandy	Wet zone	+0.075	0.230	+0.156	0.871
9 Katunayake	Wet zone	+0.110	0.146	+0.005	0.001
10 Nuwara Eliya	Wet zone	+0.137	0.220	+0.014	0.096
11 Rathmalana	Wet zone	+0.248	0.785	+0.265	0.834
12 Rathnapura.	Wet zone	+0.148	0.935	+0.213	0.861

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

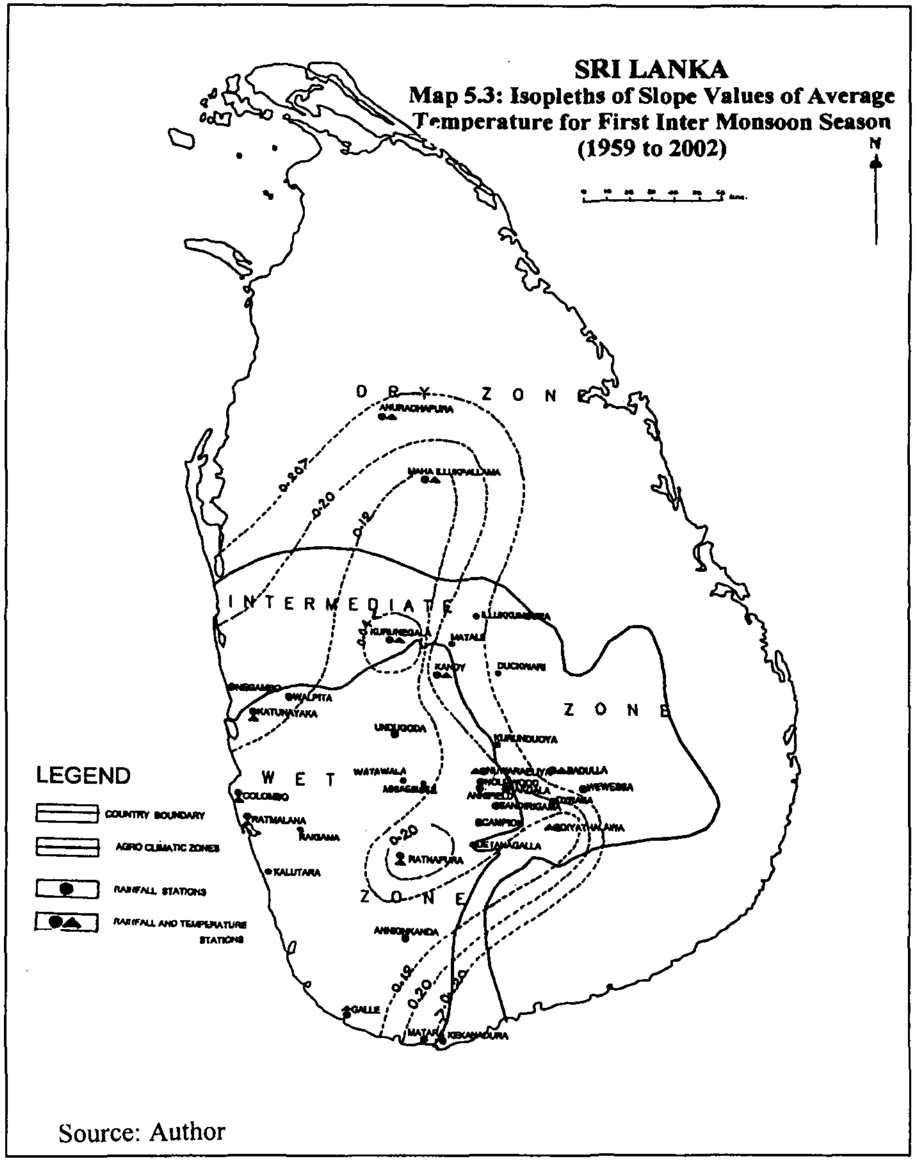
Increased warming trend could be observed for all the stations during the Second Inter Monsoon, as well as the Northeast Monsoon seasons. From Table 5.13 it could be ascertained that the trend slopes were higher at Anuradhapura, Badulla, Colombo, Galle and Rathmalana stations as compared with other stations during the Second Inter Monsoon season. The regression coefficients were higher at Anuradhapura, Badulla, Colombo, Galle and Katunayake as compared to other stations during the Northeast Monsoon season.

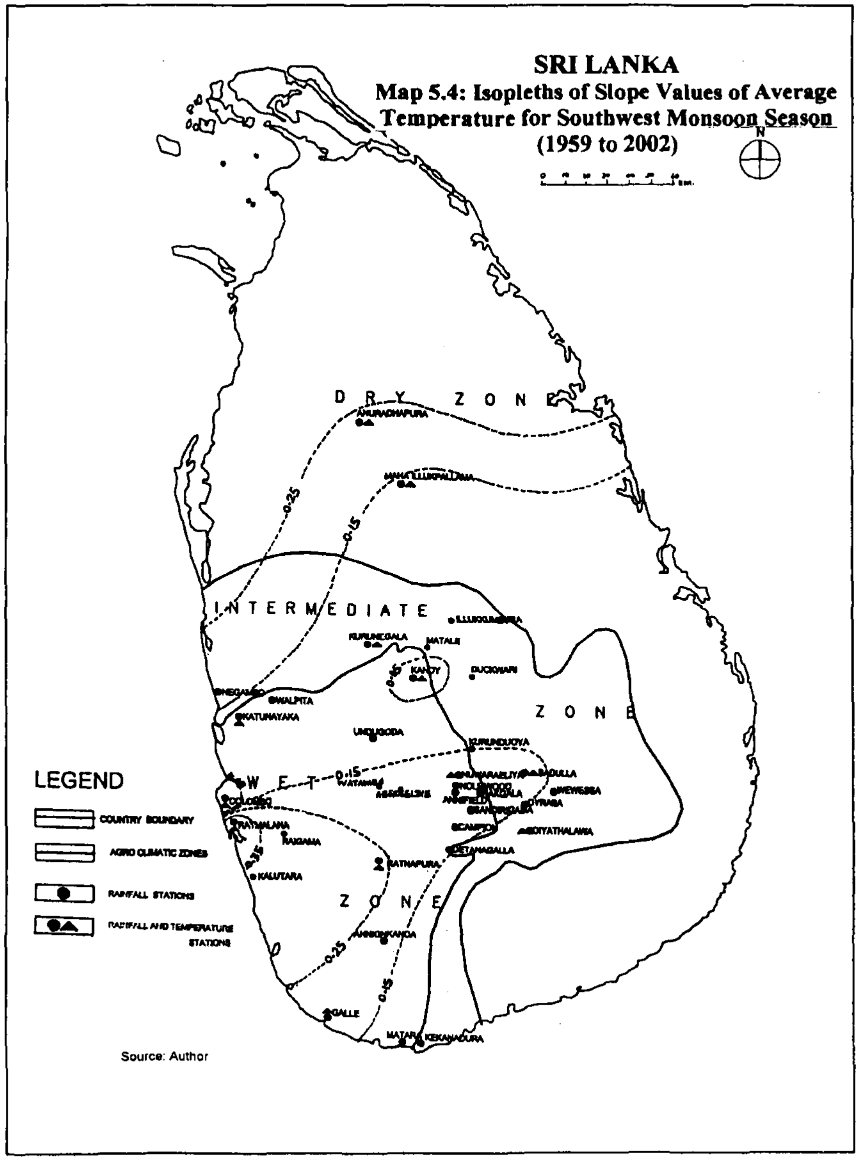
Table.5.13: Trend of Temperature of Second Inter Monsoon (SIM) and North East Monsoon (NEM) Season: 1959-2002

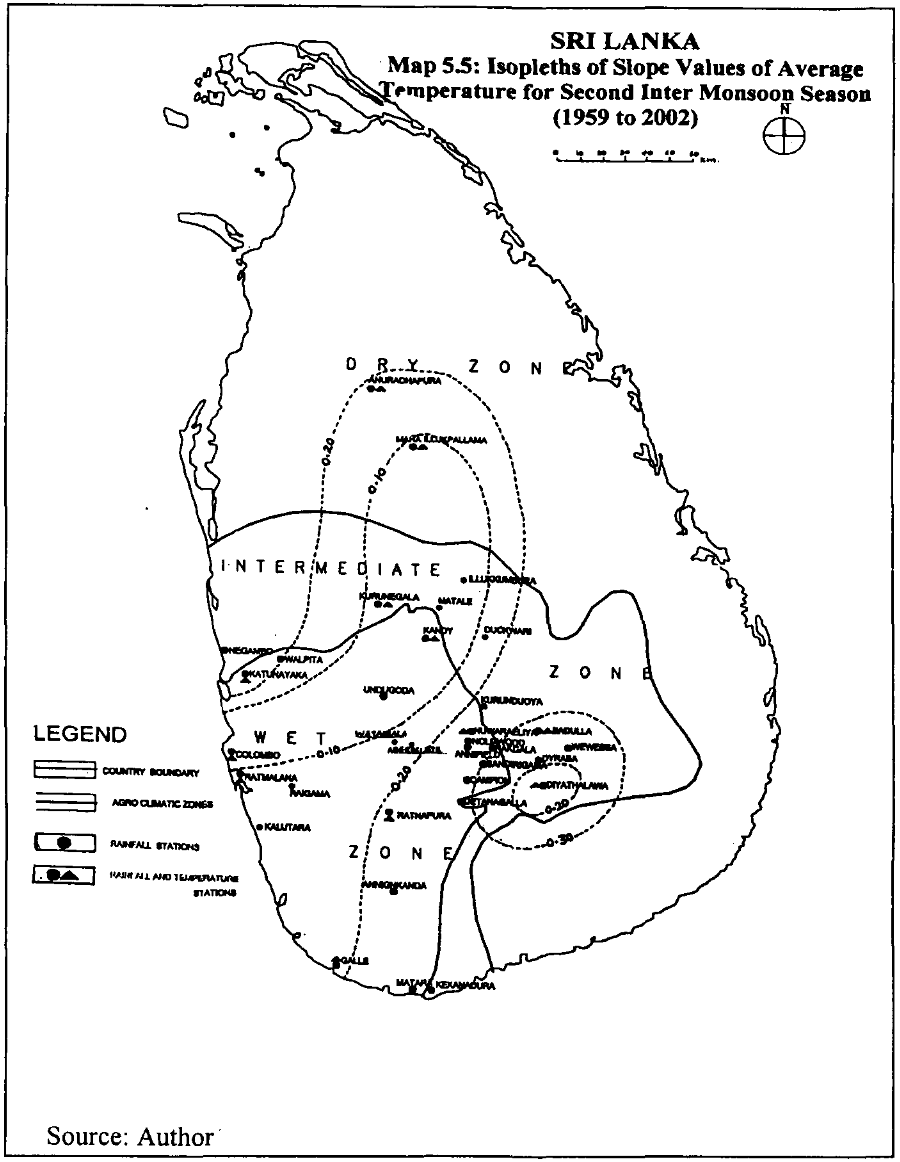
Temperature Stations	Climatc Zone	SIM Slope	SIM R^2 value	NEM Slope	NEM R^2 value
1 Annuradhapura	Dry zone	+0.165	0.540	+0.363	0.868
2 Maha Illukpallama	Dry zone	+0.093	0.577	+0.174	0.532
3 Badulla	Intermediate zone	+0.298	0.824	+0.210	0.748
4 Diyathalawa	Intermediate zone	+0.143	0.470	+0.174	0.509
5 Kurunegala	Intermediate zone	+0.087	0.977	+0.192	0.707
6 Colombo	Wet zone	+0.233	0.900	+0.228	0.901
7 Galle	Wet zone	+0.215	0.921	+0.217	0.857
8 Kandy	Wet zone	+0.130	0.860	+0.176	0.679
9 Katunayake	Wet zone	+0.020	0.015	+0.224	0.597
10 Nuwara Eliya	Wet zone	+0.013	0.044	+0.057	0.067
11 Rathmalana	Wet zone	+0.290	0.756	+0.267	0.546
12 Rathnapura	Wet zone	+0.183	0.902	+0.141	0.484

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

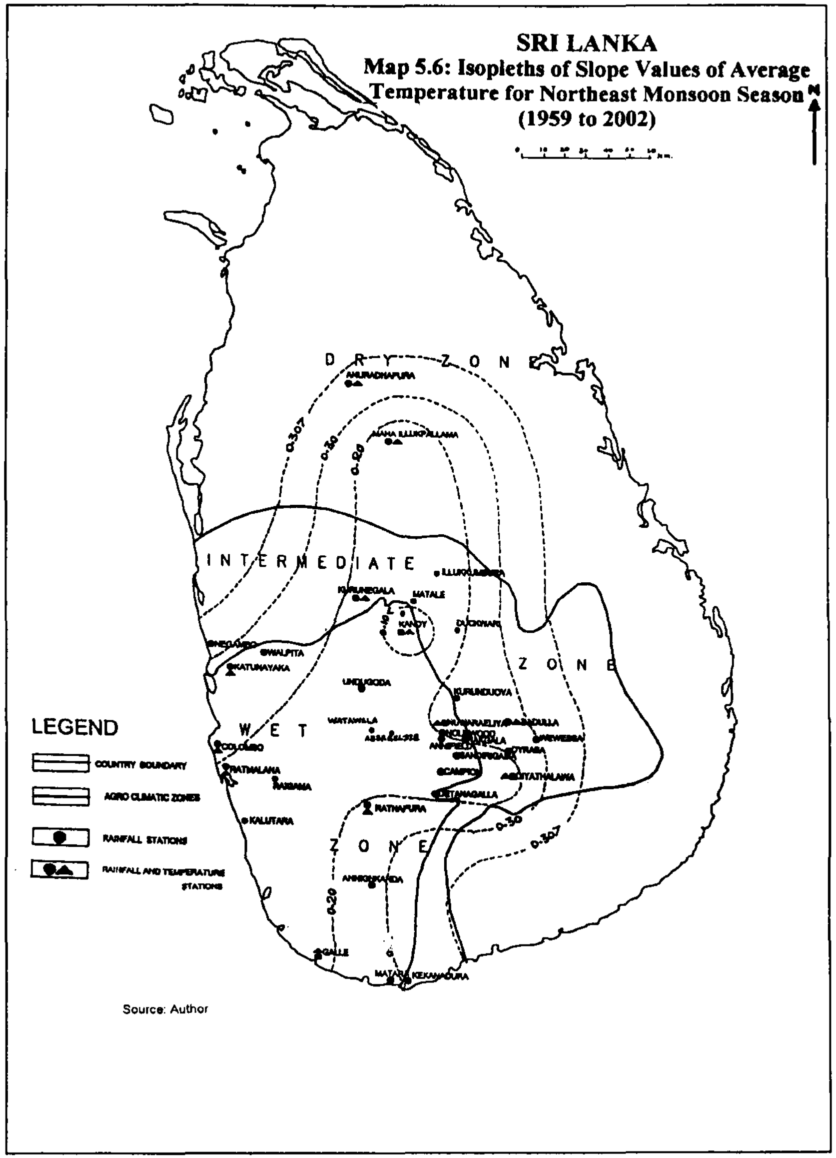
Much like the overall temperature trends, the seasonal temperature trends show a similar pattern of warming, especially after the 1970s and specifically, quite sharply after 1990s. The Map (5.3 to 5.6) of Sri Lanka shows isopleths of the regression coefficient of seasonal average temperature changes.


SRI LANKA
Map 5.3: Isopleths of Slope Values of Average Temperature for First Inter Monsoon Season
(1959 to 2002)
N
DRY ZONE
INTERMEDIATE ZONE
WET ZONE
ANURADHAPURA
MAHA ILLUPPALLAMA
KURUNEGALA
MATALE
KANDY
DUCKWARI
NEGAMBO
WALPITA
KATUNAYAKA
UNDUGODA
WATAWALA
KURUNDUOYA
BADULLA
WEWESSA
COLOMBO
RATMALANA
RAIGAMA
KALUTARA
RATHNAPURA
DIYATHALAWA
BANDARAWELA
ANNIEFIELD
CAMPION
PUSSELLAWA
GALLE
MATARA
KEKANADURA
0.20
0.12
LEGEND
COUNTRY BOUNDARY
AGRO CLIMATIC ZONES
RAINFALL STATIONS
RAINFALL AND TEMPERATURE STATIONS
Source: Author


SRI LANKA
Map 5.4: Isopleths of Slope Values of Average Temperature for Southwest Monsoon Season
(1959 to 2002)
N
DRY ZONE
INTERMEDIATE ZONE
WET ZONE
ANURADHAPURA
MAHA ILLUPPALLAMA
KURUNEGALA
MATALE
KANDY
DUCKWARI
NEGAMBO
WALPITA
KATUNAYAKA
UNDUGODA
WATAWALA
KURUNDUOYA
BADULLA
WEWESSA
COLOMBO
RATMALANA
RAIGAMA
KALUTARA
RATHNAPURA
DIYATHALAWA
ANNIEFIELD
CAMPION
GALLE
MATARA
KEKANADURA
0.25
0.15
LEGEND
COUNTRY BOUNDARY
AGRO CLIMATIC ZONES
RAINFALL STATIONS
RAINFALL AND TEMPERATURE STATIONS
Source: Author



SRI LANKA
Map 5.5: Isopleths of Slope Values of Average Temperature for Second Inter Monsoon Season (1959 to 2002)



SRI LANKA
Map 5.6: Isopleths of Slope Values of Average Temperature for Northeast Monsoon Season (1959 to 2002)

5.1.6 Prediction of Temperature Changes

Annual average of monthly average temperature has been forecast using linear regression model for each agro-climatic zone based on continuous data from 1950 to 2002. The zone-wise temperature forecasts from 2010 to 2050 have been summarised in table 5.13(a).

Table 5.13 (a): Forecast of Temperature (°C) for (2010-2050)

Agro Climatic Zone	2000	2010	2020	2030	2050
Dry Zone $Y=0.0193x-10.548$, $R^2=0.521$	27.95	28.25	28.44	28.63	29.02
Difference from 2000yr		0.30	0.49	0.68	1.07
Intermediate zone $Y=0.0193x-12.692$, $R^2=0.586$	25.84	26.10	26.29	26.49	26.87
Difference from 2000yr	.	0.26	0.45	0.65	1.03
Wet Zone $Y=0.0181x-9.0929$, $R^2=0.636$	27.18	27.29	27.47	27.65	28.02
Difference from 2000y.		0.11	0.29	0.47	0.84

Source: Calculated by the author, based on temperature records of Department of Meteorology, Government of Sri Lanka, Colombo.

Refering to table 5.13 (a) the temperature increases will be higher in the Dry zone than other two zones, Intermediate and Wet zone in Sri Lanka. Temperature will increase by 1.07^0 Celsius in the Dry zone, by 2050. In the year 2000, the monthly average temperature was 27.95 °C in the Dry zone, which will increase to 28.25 ^{0}C in 2010, to 28.44 ^{0}C in 2020, to 28.63 ^{0}C in 2030 and to 29.02 ^{0}C in 2050, respectively.

Temperature increases will be higher in the Intermediate zone than Wet zone. Temperature will increase by 1.03 ^{0}C in the Intermediate zone by 2050. Monthly average temperature was 25.84 ^{0}C in the Intermediate zone in the year 2000, which will increase

26.10 in 2010, to 26.29 ^{0}C in 2020, to 26.49 ^{0}C in 2030 and to 26.87 ^{0}C in 2050, respectively.

Temperature increases will be lower in the Wet zone than other two zones due to influence of higher pricipitation. Temperature will increase by 0.84 0C by 2050 in the Wet zone. Monthly average temperature was 27.18 °C in the Wet zone in the year 2000, which will increase to 27.29 ^{0}C in 2010, 27.47 ^{0}C in 2020, 27.65 ^{0}C in 2030 and 28.02 ^{0}C in 2050, respectively.

5.2 Changes in Precipitation

Table 5.14 shows name of the rainfall stations, their zones, regions, latitudes, longitudes and also elevations (above MSL) within the present study area.

Annual average rainfall changes were analysed at selected rainfall stations under the study area for the entire period from 1959 to 2002. In addition, the decadal rainfall changes were also examined, with significance break years. Agro-ecological zonal wise and season-wise rainfall changes and the trends with significance were also analysed. Time series data and trend analysis were carried out to examine the changes of rainfall. Detailed discussions on methodology and techniques of data analysis are indicated in Chapter III.

Table 5.14: Geographical distribution of precipitation stations under the study

Rainfall Stations	Agro-Climatic Zone	Agro-ecological region	Latitudes (Nort)	Longitudes (East)	Elevation (m)
1. Annuradhapura	Dry zone	DL1	8° 21′	80° 23′	93
2.Maha Illukpallama	Dry zone	DL1	8° 7′	80° 28′	138
3.Badulla	Intermediate zone	IM1	6° 59′	81° 3′	670
4.Diyathalawa	Intermediate zone	IU3	6° 49′	80° 58′	1248
5.Kurunegala	Intermediate zone	IL1	7° 28′	80° 22′	116
6. Illuk Kumbura	Intermediate zone	IM1+IM3	7° 33′ 0"	80° 46′ 0"	608
7. Kekanadura	Intermediate zone	IL1+IL3	5° 59′ 0"	80° 36′ 0"	50
8. Matale PWD	Intermediate zone	IM3	7° 28′	80° 37′	369
9. Negambo	Intermediate zone	IL1	7° 13′ 0"	79° 50′ 10"	3
10.Wewessa Estate	Intermediate zone	IU3	6° 58′ 8"	81° 6′ 18"	914
11. Kurundu Oya	Intermediate zone	IU2	7° 4′ 25"	80° 50′ 10"	1570
12. Duckwari	Intermediate zone	WU3+IU1	7° 3′ 5"	80° 8′	1667
13. Dyraaba	Intermediate zone	IU3	6° 8′ 7"	80° 9′	1220
14.Rathmalana	Wet zone	WL4	6° 49′	79° 53′	5
15.Colombo	Wet zone	WL4	6° 54′ 0"	79° 52′ 47"	2
16.Galle	Wet zone	WL4	6° 2′	80° 13′	13
17.Kandy	Wet zone	WM3	7° 20′	80° 38′	477
18.Katunayake	Wet zone	WL3	7° 10′	79° 53′	9
19.Nuwara Eliya	Wet zone	WU3	6° 58′	80° 46′	1895
20.Rathnapura	Wet zone	WL1	6° 41′	80° 24′	34
21. AbergeldieGr.	Wet zone	WU1	6° 54′ 30"	80° 35′ 20"	1098
22. Annifield Estate	Wet zone	WU2	6° 52′	80° 38′	1311
23. Campion Estate	Wet zone	WU2	6° 47′	80° 42′	1820
24. Holmwood	Wet zone	WU2	6° 51′ 15"	80° 42′ 37"	1585
25. Kalutara PWD	Wet zone	WL4	6° 40′ 0"	79° 57′ 0"	17
26. Raigam Estate	Wet zone	WL1	6° 46′ 0"	80° 11′ 0"	24
27. Sandirigama	Wet zone	WU3	6° 50′ 10"	80° 45′ 0"	1601
28. Hakgala Bot. Gr.	Wet zone	WU3	6° 55′ 30"	80° 9′ 0"	1701
29. Annignkanda	Wet zone	WM1	6° 20′ 50"	80° 36′ 10"	533
30. Undugoda	Wet zone	WM1	7° 8′ 0"	80° 22′ 0"	289
31. Detanagalla	Wet zone	WU2	6° 44′	80° 41′	315
32 .Walpita	Wet zone	WL3	7° 16′ 0"	80° 3′ 0"	47
33 .Watawala	Wet zone	WU1	6° 9′	80° 5′	995

Notes: **DL**: Dry zone Low country, **IM**: Intermediate zone Mid country, **IU**: Intermediate zone Up country, **IL**: Intermediate zone Low country, **WU**: Wet zone Up country, **WL**: Wet zone Low country, **WM**: Wet zone Mid country.

Source: Somasekara et al, 1997, and Meteorological Department, Colombo.

5.2.1. Annual Average Rainfall Changes

Table 5.15 shows annual average of monthly average rainfall changes since 1959 to 2002. When both the observation periods (1959-62 to 1999-2002 are compared, it is clear that decrease in pricipitation over the more recent period is more pronounced than over the whole observation period.

Table 5.15: Monthly Average Rainfall: 1959-2002

In mm

Year	Anura dhapu ra	Mahalll ukpalla ma	Bad ulla	Diyat alawa	Duck wari	Dyra aba	Illuk Kum bura	Kuru negala	Keka nadu ra
1959-62	124.6	136.3	158.7	137.3	229.4	142.0	238.4	176.4	148.6
1969-72	125.3	120.0	162.2	156.4	212.2	148.3	205.9	196.6	156.7
1979-82	97.7	100.2	131.8	116.1	160.2	111.8	152.3	152.6	135.5
1989-92	108.3	105.1	142.9	126.7	183.8	140.4	216.2	169.9	81.5
1999-02	99.3	111.1	128.4	108.6	173.4	96.0	207.1	148.4	139.3
1959-02 differences	-25.3	-25.2	-30.3	-28.7	-56.0	-46.0	-31.3	-28.0	-9.3

Table 5.15 continued

Year	Kurud u Oya	Matal ePWD	Nega mbo	Wewe ssa	Aber geldie	Annfi eldEs	Anni ngka	Cam pion	Colo mbo
1959-62	255.5	173.4	202.0	186.2	327.6	238.0	312.5	198.6	239.1
1969-72	253.3	171.3	191.9	183.8	355.5	234.3	331.5	205.4	208.8
1979-82	185.2	134.6	136.5	150.0	325.2	278.9	235.1	182.4	177.7
1989-92	239.4	169.9	90.0	132.0	264.4	227.5	372.9	177.4	185.7
1999-02	210.4	118.4	141.4	187.0	290.3	147.1	266.1	157.1	190.8
1959-02 differences	-45.1	-55.0	-60.6	+0.8	-37.3	-90.9	-46.4	-41.5	-48.3

Table 5.15 continued

Year	Detan agala	Galle	Holm wood	Kaluta raPW	Kǎn dy	Katu naya	Nuwa raEli	Raiga ma	Hakgal a-Bot.
1959-62	262.7	205.8	221.9	245.0	178.4	216.9	182.9	335.0	186.7
1969-72	246.7	197.3	236.6	232.9	166.1	204.3	170.1	338.3	196.7
1979-82	185.6	182.1	164.1	145.1	139.4	160.1	145.2	297.4	130.1
1989-92	217.6	173.7	137.4	219.9	144.3	146.4	159.3	319.5	155.3
1999-02	202.4	211.9	97.9	221.6	139.3	188.5	152.5	264.5	126.3
1959-02 differences	-60.3	+6.1	-124	-23.4	-39.1	-28.4	-30.4	-70.5	-60.4

Table 5.15 continued

Year	Watawala	Ratmala	Ratnapura	Sandirigam	Undugoda	Walpita
1959-62	431.6	227.7	306.1	194.0	277.4	190.3
1969-72	415.9	210.8	308.1	195.4	302.6	186.1
1979-82	423.9	184.4	268.6	218.5	277.0	123.7
1989-92	414.6	180.4	289.0	164.1	293.7	139.7
1999-02	456.1	219.6	312.1	143.3	196.2	168.7
1959-02 differences	+24.5	-8.1	+5.9	-50.7	-81.2	-21.6

Source: Calculated by the author, based on rainfall records of Department of Meteorology, Government of Sri Lanka, Colombo.

Linear trend analysis between 1959 and 2002 indicates negative trends of rainfall in majority of stations with statistical significance. Results of the linear trend analysis are reported in the table 5.16. Trends of incidence of average annual rainfall show decreasing trend over the whole period 1959-2002. The declines are significant for periods after 1970s, and again since the 1990s. Trend of rainfall is positive only at Watawala station.

Almost all the stations show sharp decreases in pricipitation in 1970s, and again from 1980s as well as 1990s. It can be clearly observed at Campion, Holmwood, Kandy, Anuradhapura and Badulla stations (Fig.5.9 and 5.10). The map of Sri Lanka shows isopleths of slope values of Annual average rainfall for 1959 to 2002 for all the rainfall stations in Map 5.7.

Table 5.16: Trends of Monthly Average Rainfall: 1959-2002

Rainfall Stations	Climatic Zone	Slope	R^2 value
1 Annuradhapura	Dry zone	-6.75	0.643
2 Maha Illukpallama	Dry zone	-6.53	0.527
3 Badulla	Intermediate zone	-8.00	0.681
4 Diyathalawa	Intermediate zone	-8.71	0.540
5 Kurunegala	Intermediate zone	-8.27	0.452
6 Illuk Kumbura	Intermediate zone	-5.24	0.068
7 Kekanadura	Intermediate zone	-9.38	0.251
8 Matale PWD	Intermediate zone	-11.2	0.482
9 Negambo	Intermediate zone	-22.3	0.601
10 Wewessa Estate	Intermediate zone	-5.02	0.098
11 Kurundu Oya	Intermediate zone	-10.40	0.296
12 Duckwari	Intermediate zone	-14.03	0.609
13 Dyraaba	Intermediate zone	-9.98	0.486
14 Ratmalana	Wet zone	-4.67	0.122
15 Colombo	Wet zone	-11.96	0.599
16 Galle	Wet zone	-1.14	0.013
17 Kandy	Wet zone	-10.00	0.793
18 Katunayake	Wet zone	-11.47	0.376
19 Nuwara Eliya,	Wet zone	-7.15	0.580
20 Ratnapura	Wet zone	-0.71	0.004
21 Abergeldie Group	Wet zone	-16.58	0.544
22 Annifield Estate	Wet zone	-18.85	0.385
23 Campion Estate	Wet zone	-11.09	0.855
24 Holmwood Estate	Wet zone	-34.7	0.899
25 Kalutara PWD	Wet zone	-5.98	0.058
26 Raigam Estate	Wet zone	-15.9	0.684
27 Sandirigama Estate	Wet zone	-13.28	0.508
28 Hakgala Bot.Gr.	Wet zone	-16.21	0.641
29 Annignkanda	Wet zone	-5.14	0.023
30 Undugoda	Wet zone	-17.14	0.410
31 Detanagalla	Wet zone	-14.97	0.562
32 Walpita	Wet zone	-8.98	0.237
33 Watawala	Wet zone	+4.77	0.199

Source: Calculated by the author, based on rainfall records of Department of Meteorology, Government of Sri Lanka, Colombo.

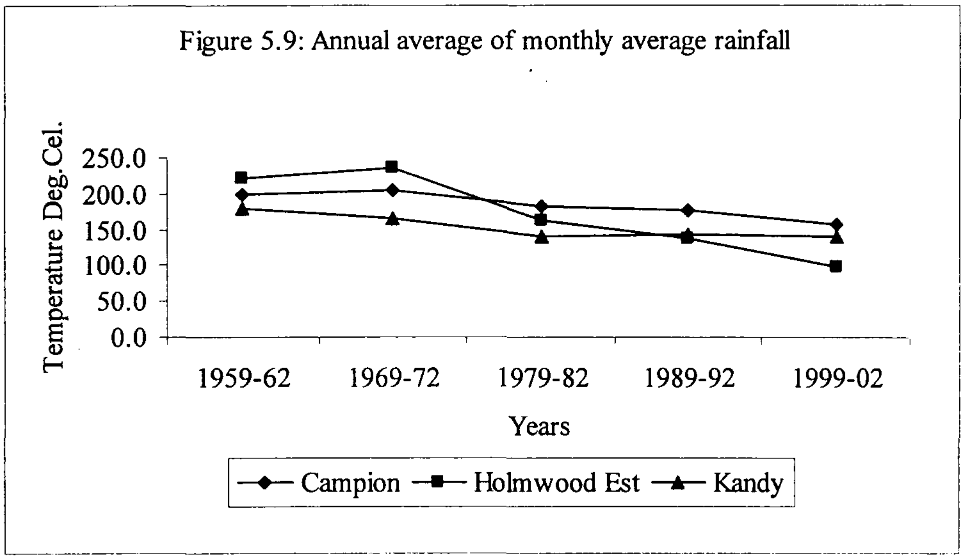


Figure 5.9: Annual average of monthly average rainfall
Temperature Deg.Cel.
250.0
200.0
150.0
100.0
50.0
0.0
1959-62
1969-72
1979-82
1989-92
1999-02
Years
Campion
Holmwood Est
Kandy

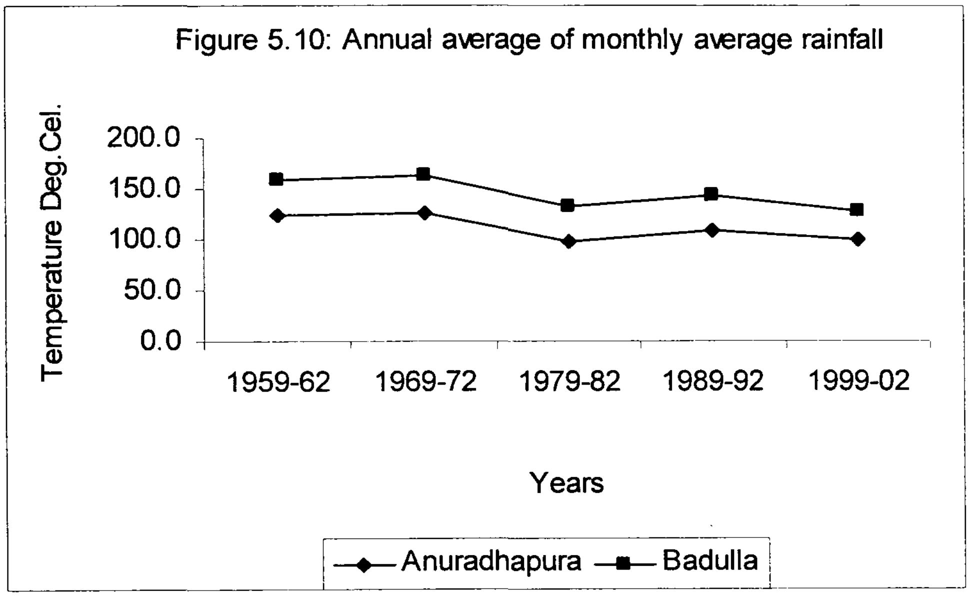
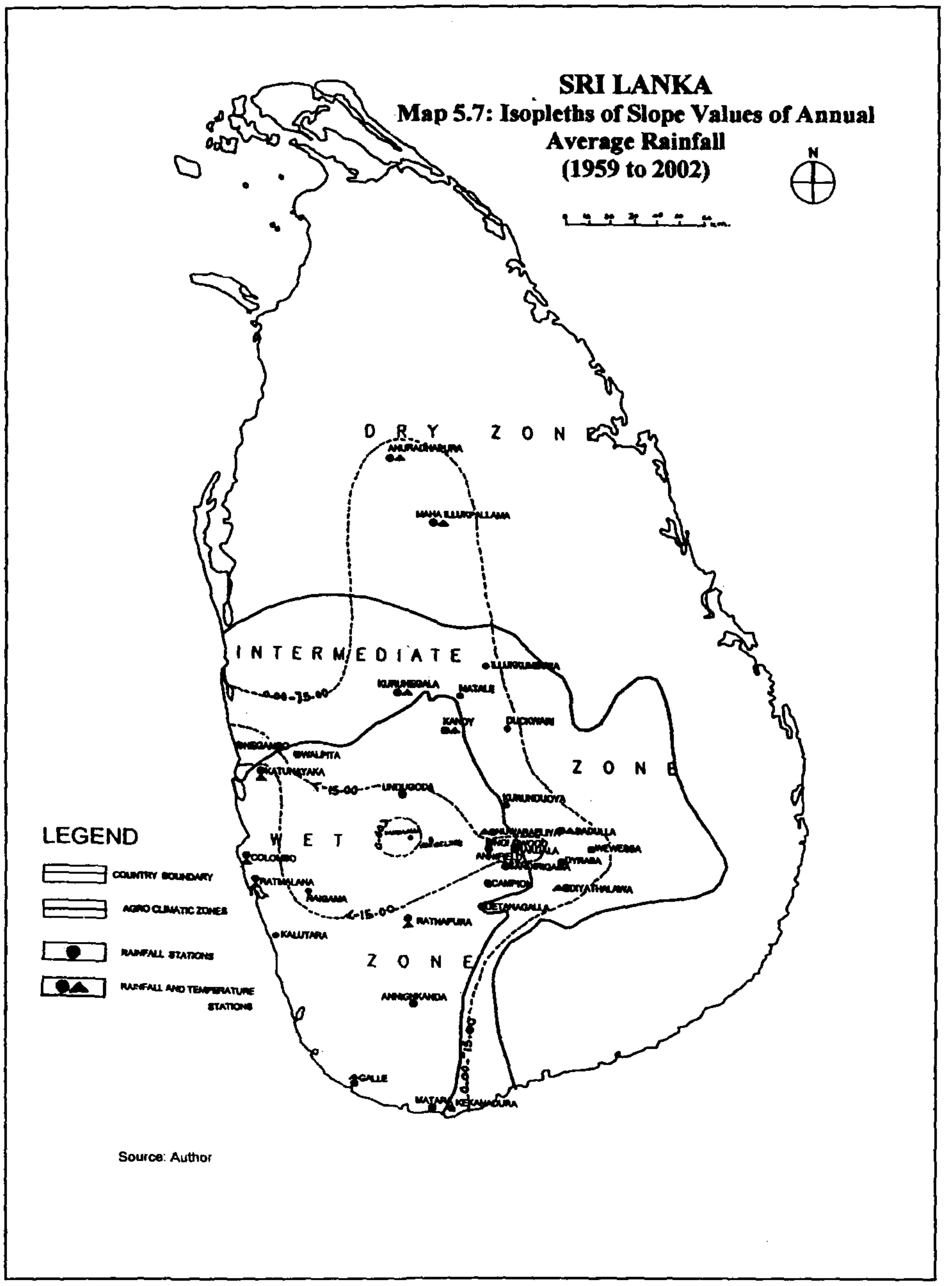


Figure 5.10: Annual average of monthly average rainfall
Temperature Deg.Cel.
200.0
150.0
100.0
50.0
0.0
1959-62
1969-72
1979-82
1989-92
1999-02
Years
Anuradhapura
Badulla

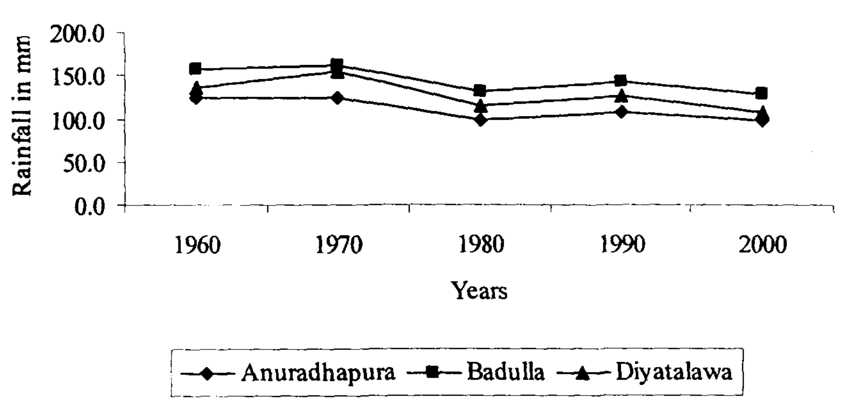


SRI LANKA
Map 5.7: Isopleths of Slope Values of Annual Average Rainfall (1959 to 2002)

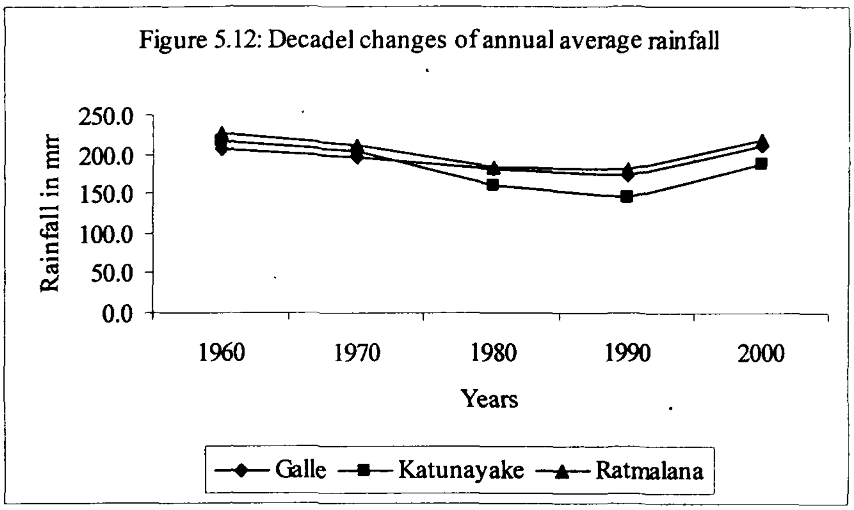
5.2.2 Decadal Precipitation Changes

Rainfall figures from 1960-2000 show decreasing trends at decadal break points of 1970s, 1980s and again 1990s. Some of the stations clearly indicate the differences in decreasing trends lines for decadal points with significant R^2 values for the slopes. Considering the overall situation, Sri Lanka had two warmest periods in the last 50 years. The first period was in the 1970s and the other period was in the 1990s. Moreover, rainfall consistently decreased in most of the stations during the same decades. Theses decreases are very remarkable for Anuradhapura, Badulla, Diyathalawa (Fig.5.11) and Kurunegala, Kurundu Oya, Matale, Duckwari, Dyrabba and Illukkumbura in 1970s and 1990s.

Figure 5.11: Decadel changes of annual average rainfall



Kandy, Nuwara Eliya, Raigama, Hakgala Bot. Gr., Detanagalla, Holmwood and Undugoda rainfall stations also show decreasing deacdel changes for 1970s and again 1990s. In some stations (Katunayaka, Galle, Ratmalana (Fig. 5.12) and Kekanadura, Negambo, Wewessa, Abergilde, and Annifield) after a decreasing trend during the 1970s and 1980s, there has been a minor increase towards the 1990s.



5.2.3 Seasonal Changes of Rainfall

Seasonal pricipitation shows decreasing (significant) trends; out 33 stations 26 stations in FIM, 30 stations in SWM, 24 stations in SIM, and 24 stations in NEM seasons reassert the trends (Table 5.17). Some stations, however, indicate both decreasing as well as increasing trends during the First Inter Monsoon as well as Southwest Monsoon seasons. Table 5.17 indicates, decreasing higher trends at Badulla, Kurunduoya, Nuwaraeliya, Abergeldie, Annifield, Campion, Homwood, Hakgala and Detanagalla as compared to other stations during the First Inter Monson season. Only Rathmalana and Galle show positive significant increasing trends in this season. Similarly, the linear trends (slopes) were higher at Kekanadura, Negambo, Ratmalana, Colombo, Abergeldie, Annifield, Holmwood, Kalutara, Raigama, Undugoda and Walpita as compared with other station during the Southwest Monsoon season. Some of the station shows positive slopes but none of them is significant.

Table 5.17: Linear Trends of Rainfall for First Inter Monsoon (FIM) and South West Monsoon (SWM) Seasons: 1959-2002

Rainfall Stations	Climatic Zone	FIM Slope	FIM R^2 values	SWMSlope	SWM R^2 values
1 Annuradhapura	Dry zone	-6.43	0.742	-1.24	0.055
2 Maha Illukpallama	Dry zone	-14.98	0.684	-2.68	0.185
3 Badulla	Intermediate zone	-21.57	0.702	+3.97	0.284
4 Diyathalawa	Intermediate zone	-15.75	0.459	+1.92	0.050
5 Kurunegala	Intermediate zone	-6.28	0.052	-16.64	0.844
6 Illuk Kumbura	Intermediate zone	-11.13	0.636	-9.46	0.280
7 Kekanadura	Intermediate zone	+9.35	0.070	-21.76	0.512
8 Matale PWD	Intermediate zone	-7.98	0.093	-11.47	0.678
9 Negambo	Intermediate zone	-18.19	0.187	-32.78	0.769
10 Wewessa Estate	Intermediate zone	-3.80	0.028	-1.45	0.037
11 Kurundu Oya	Intermediate zone	-24.87	0.624	+7.75	0.514
12 Duckwari	Intermediate zone	-14.85	0.622	-14.07	0.883
13 Dyraaba	Intermediate zone	-18.93	0.767	-2.62	0.036
14 Ratmalana	Wet zone	+23.58	0.423	-23.01	0.786
15 Colombo	Wet zone	-10.47	0.184	-20.54	0.772
16 Galle	Wet zone	+29.38	0.431	-18.06	0.671
17 Kandy	Wet zone	-9.17	0.423	-12.16	0.729
18 Katunayake	Wet zone	-19.62	0.319	-17.04	0.541
19 Nuwara Eliya	Wet zone	-25.10	0.865	-3.13	0.058
20 Ratnapura	Wet zone	+9.07	0.223	-19.94	0.688
21Abergeldie Gr.	Wet zone	-35.68	0.412	-38.43	0.842
22 Annifield Estate	Wet zone	-22.58	0.374	-23.49	0.333
23 Campion Estate	Wet zone	-23.12	0.722	-5.24	0.119
24 Holmwood Est.	Wet zone	-49.83	0.630	-32.33	0.970
25 Kalutara PWD	Wet zone	+16.95	0.167	-21.65	0.583
26 Raigam Estate	Wet zone	-17.47	0.820	-23.77	0.714
27 Sandirigama Est.	Wet zone	-16.25	0.311	-17.2	0.428
28 Hakgala Bot.gr.	Wet zone	-24.6	0.533	-12.83	0.557
29 Annignkanda Est.	Wet zone	+8.84	0.126	-12.66	0.091
30 Undugoda	Wet zone	-16.51	0.400	-27.76	0.499
31 Detanagalla	Wet zone	-43.55	0.947	-10.32	0.309
32 Walpita	Wet zone	-0.45	0.0003	-20.97	0.576
33 Watawala	Wet zone	+5.62	0.043	-8.30	0.264

Source: Calculated by the author, based on rainfall records of Department of Meteorology, Government of Sri Lanka., Colombo.

Table 5.18: Linear Trends of Rainfall during Second Inter Monsoon (SIM) and North East Monsoon (NEM) Seasons: 1959-2002

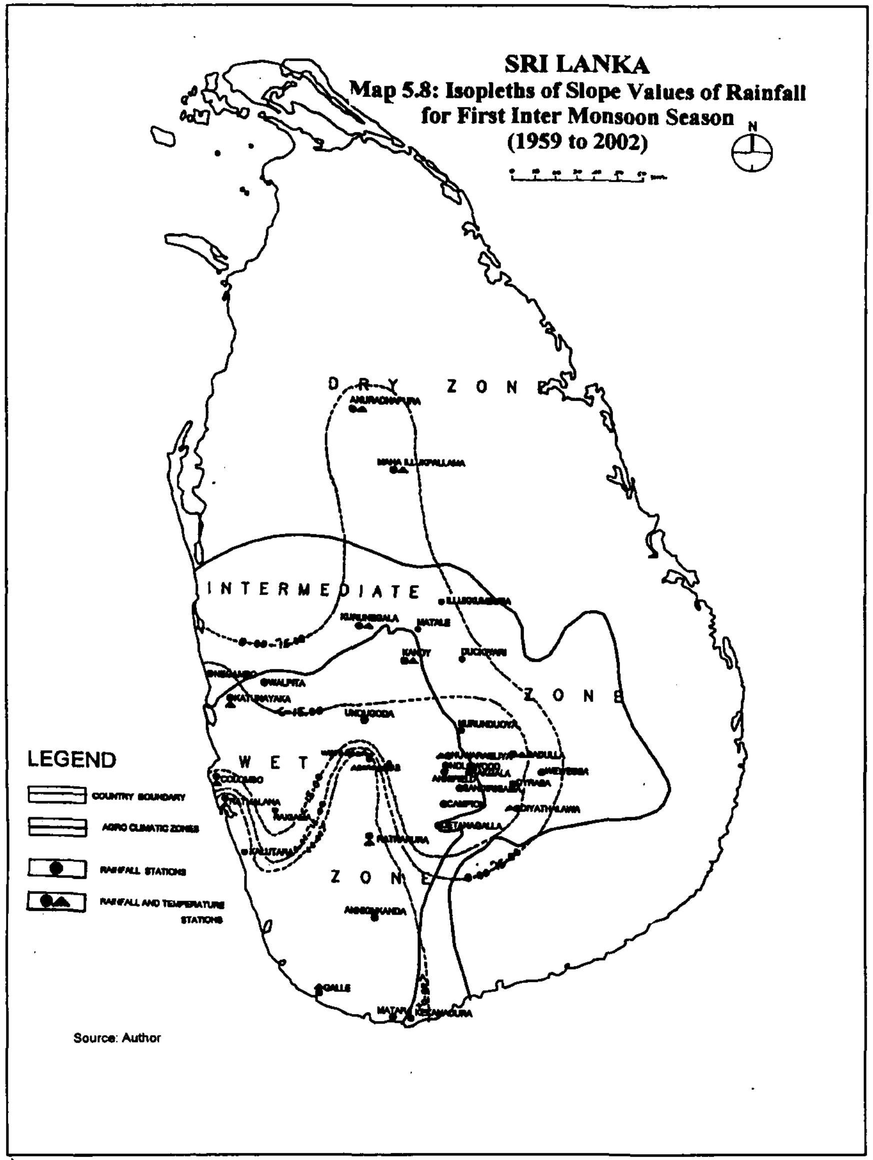
Rainfall Stations	Climatic Zone	SIM Slope	SIM R^2 value	NEM Slope	NEM R^2 value
1 Annuradhapura	Dry zone	-7.49	0.360	-15.65	0.246
2 Maha Illukpallama	Dry zone	-6.37	0.097	-7.42	0.053
3 Badulla	Intermediate zone	-5.50	0.045	-20.58	0.254
4 Diyathalawa	Intermediate zone	-22.5	0.506	-12.52	0.135
5 Kurunegala	Intermediate zone	-12.1	0.076	+6.90	0.037
6 Illuk Kumbura	Intermediate zone	+3.30	0.015	+0.02	1E-07
7 Kekanadura	Intermediate zone	+10.43	0.129	-10.36	0.188
8 Matale PWD	Intermediate zone	-15.05	0.122	-8.64	0.072
9 Negambo	Intermediate zone	-25.51	0.551	-7.70	0.077
10 Wewessa Estate	Intermediate zone	-5.35	0.022	-7.01	0.021
11 Kurundu Oya	Intermediate zone	-17.80	0.276	-26.08	0.114
12 Duckwari	Intermediate zone	-20.52	0.411	-9.10	0.048
13 Dyraaba	Intermediate zone	-6.15	0.103	-18.84	0.331
14 Ratmalana	Wet zone	+8.9	0.694	-1.96	0.011
15 Colombo	Wet zone	-18.1	0.869	+0.97	0.005
16 Galle	Wet zone	+11.5	0.359	-1.70	0.011
17 Kandy	Wet zone	-18.3	0.853	-1.43	0.003
18 Katunayake	Wet zone	-12.9	0.664	+4.27	0.061
19 Nuwara Eliya	Wet zone	-3.20	0.032	-7.45	0.065
20 Ratnapura	Wet zone	+17.9	0.538	+12.3	0.224
21 Abergeldie Gr.	Wet zone	+44.98	0.509	-8.47	0.187
22 Annifield Estate	Wet zone	-10.38	0.042	-14.26	0.675
23 Camoion Estate	Wet zone	-19.48	0.419	-7.22	0.102
24 Holmwood Est.	Wet zone	-27.12	0.892	-22.96	0.562
25 Kalutara PWD	Wet zone	+9.85	0.074	-5.71	0.060
26 Raigam Estate	Wet zone	-16.47	0.089	+0.88	0.002
27 Sandirigama Est.	Wet zone	-7.58	0.058	-8.51	0.197
28 Hakgala Bot.gr.	Wet zone	-9.25	0.712	-20.90	0.220
29 Annignkanda Est.	Wet zone	+4.05	0.002	-5.63	0.011
30 Undugoda	Wet zone	-18.66	0.096	-3.72	0.077
31 Detanagalla	Wet zone	-15.38	0.112	+2.33	0.003
32 Walpita	Wet zone	-5.29	0.123	+2.87	0.022
33 Watawala	Wet zone	+27.57	0.714	+22.7	0.174

Source: Calculated by the author, based on rainfall records of Department of Meteorology, Government of Sri Lanka, Colombo.

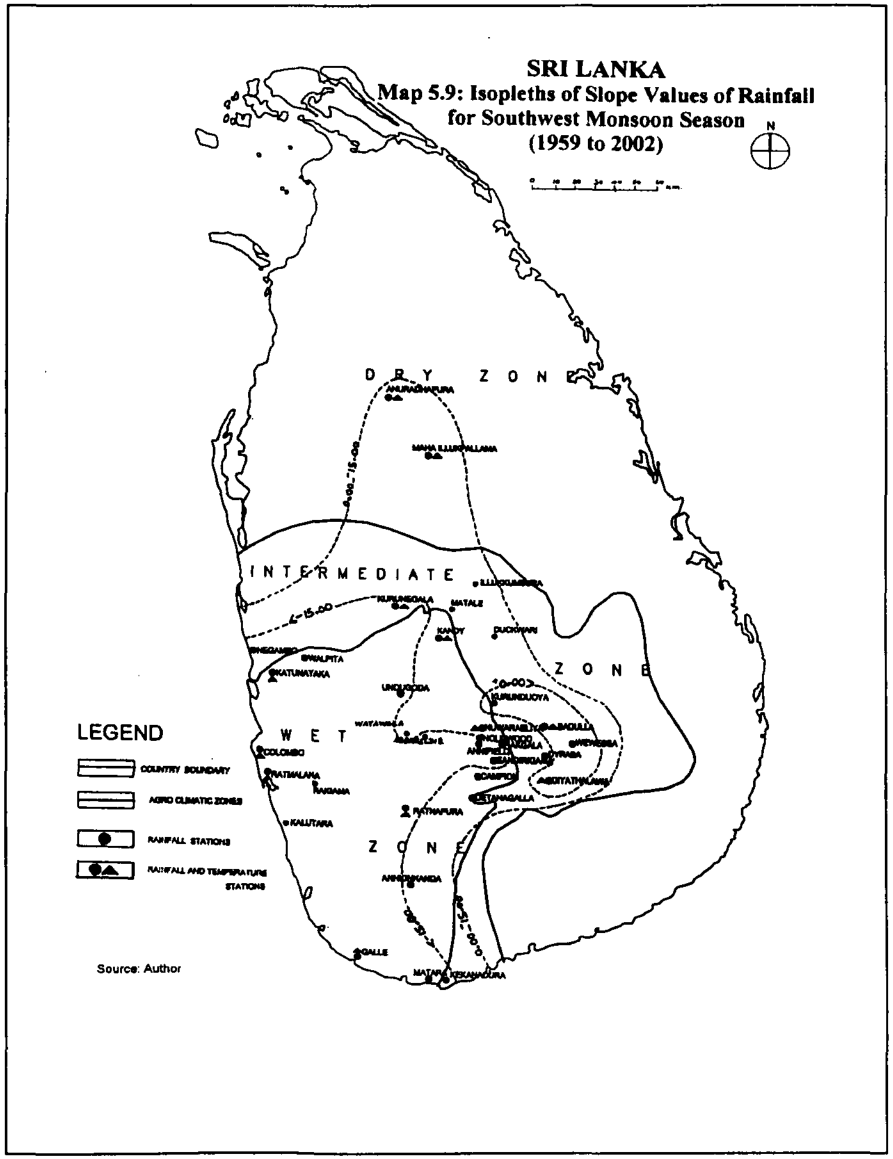
A mix of decreasing as well as increasing trends of rainfall can be noticed in the Second Inter Monsoon and the Northeast Monsoon seasons too. Out of 33 stations 24 stations show decreasing negative trends of rainfall during the Second Inter Monsoon season. Table 5.18 indicates decreasing trends that were higher at Diyathalawa, Negambo, Duckwari and Holmwood as compared to other station in the Second Inter Monsoon season. Only Abrgeldie and Watawala stations show positive significant increasing trends in this season, as deviations from the general trend. Out of 33 stations, 24 stations have shown negative trends of rainfall in the Northeast Monsoon season. The linear negative trends were higher at Badulla, Kurundu Oya, Holmwood, and Hakgala as compared with the other stations during the Northeast Monsoon season. Some of the stations show positive slopes but none of them are significant, except Watawala station.

5.2.4 Prediction of Rainfall Changes (2010-2050)

Annual average of monthly average rainfall has been forecast using linear trend rates for each agro-climatic zone based on decadal moving (three-year) averages of monthly average pricipitation for 1960, 1970, 1980, 1990 and 2000, covering four decades for all the 33 rain-gauge stations representing the three major Agro-Climatic Zones in the study area. The pricipitation forecasts are for 2010, 2020, 2030 and 2050 based on (stations') average zonal precipitations for the decades as above (Table 5.19).



SRI LANKA
Map 5.8: Isopleths of Slope Values of Rainfall for First Inter Monsoon Season (1959 to 2002)



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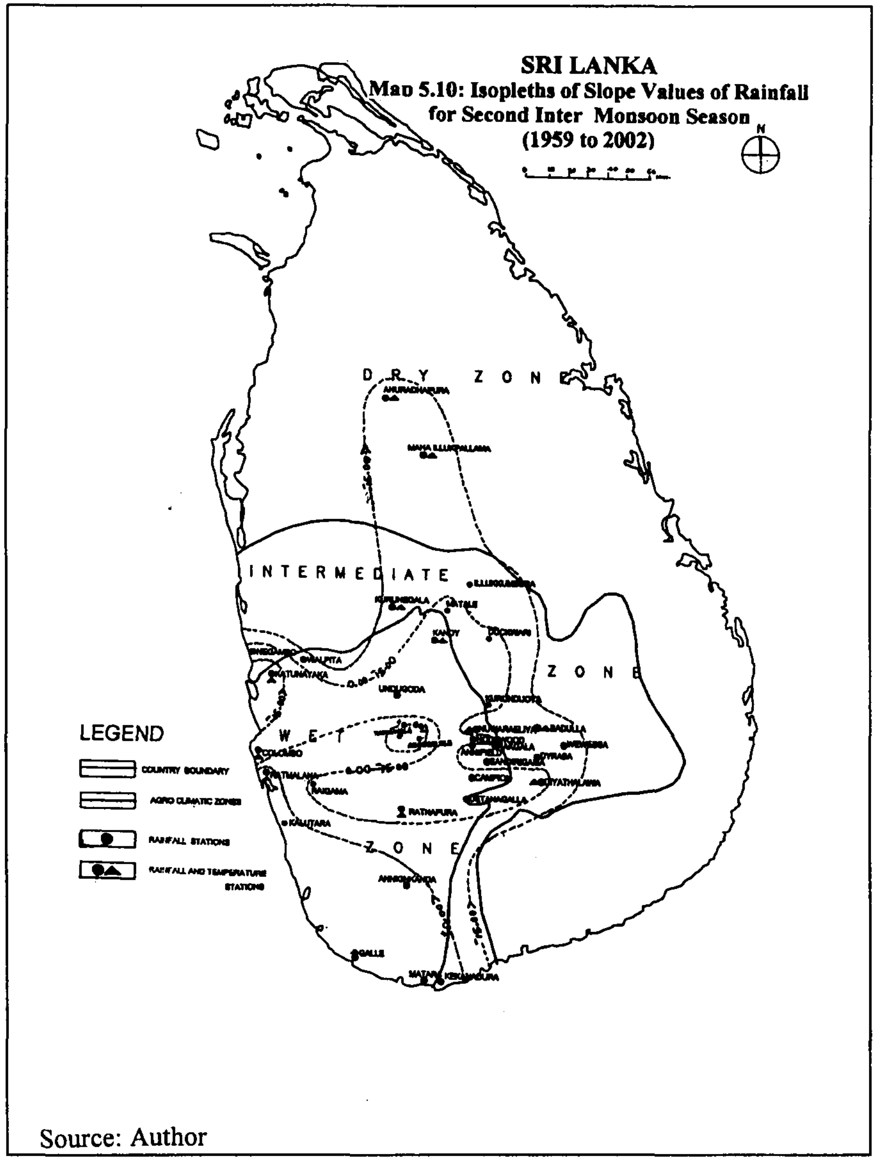
Map 5.9: Isopleths of Slope Values of Rainfall for Southwest Monsoon Season (1959 to 2002)



Source: Author

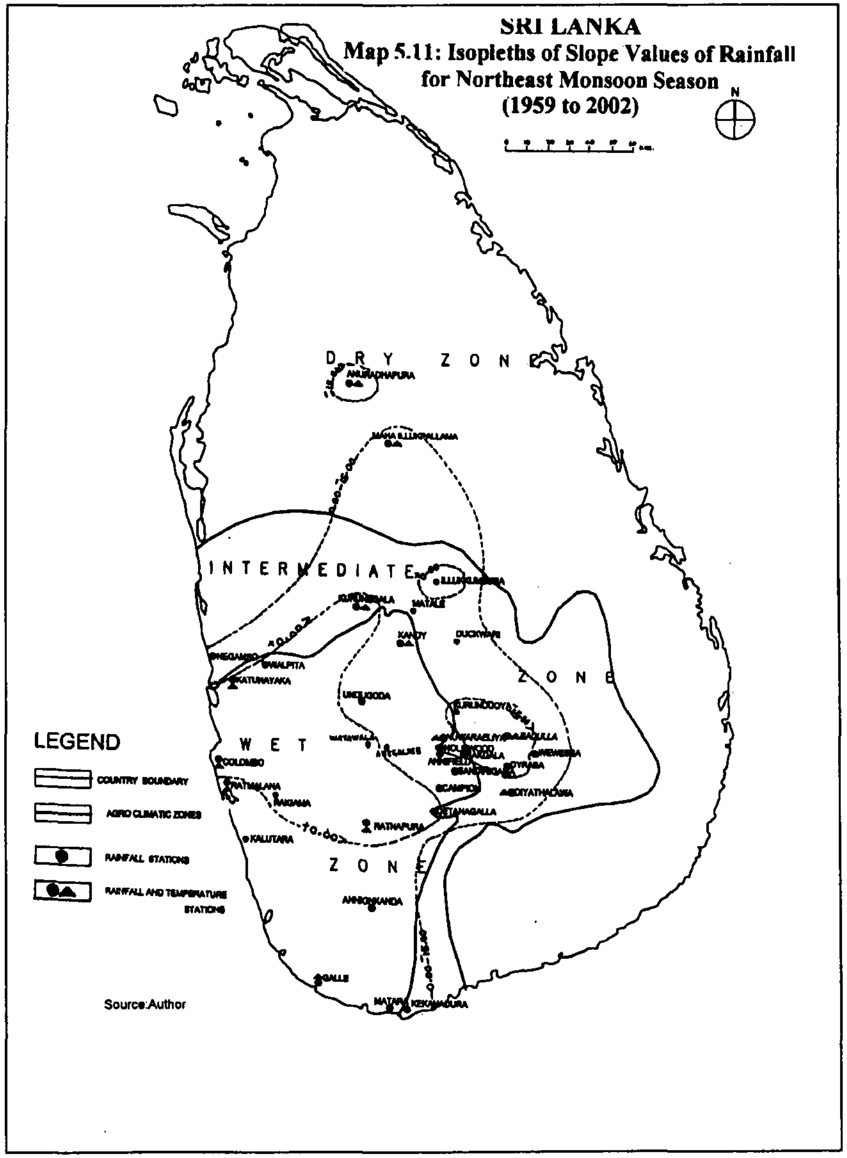


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Table 5.19: Forecast Rainfall (mm) for (2010-2050)

In mm.

Agro Climatic Zone	2000	2010	2020	2030	2050
Dry Zone Y=0.6641x+1427.6, R^2=0.636	105.2	92.96	86.32	79.68	66.4
Difference (monthly average)		-12.24	-18.88	-25.52	-38.8
Per year decline	**-14.69**				
Intermediate Zone Y=-1.0228x+2188.8, R^2=0.619	150.8	132.97	122.74	112.52	92.06
Difference (monthly average)		-17.83	-28.06	-38.28	-58.74
Per year decline	**-21.40**				
Wet Zone Y=-1.0535x+2302, R^2=0.793	197.73	184.67	174.13	112.52	92.06
Difference (monthly average)		-13.07	-23.6	-38.28	-58.74
Per year decline	**-15.68**				

Source: Calculated by the author, based on rainfall records of Department of Meteorology, Government of Sri Lanka, Colombo.

On the basis of the pricipitation forecasts, all the three ago-climatic zones indicate consistent decline in average monthly rainfall. The slopes for all the three linear trends are highly significant (see, table 5.19). The rainfall decline will be somewhat sharper in the Intermediate zone as compared to the other two zones.

In the Intermediate zone, the monthly average rainfall will decrease by -58.74 mm in 2050 as compared with 2000 level, i.e., 150.8 mm. The average yearly decline will be 21.40 mm, which is the highest predicted decline among the three zones. The forecasts for average monthly pricipitation for the zone, decline by –17.83, -28.06, and -38.28 mm for the years 2010, 2020 and 2030, respectively.

In the Wet Zone, the average monthly rainfall will decline by -55.21 mm. by 2050, as compared to the monthly averages for 2000, i.e. 197.73 mm. Rainfall is predicted to decline by –15.68 mm./per year in the Wet zone. The forecasts for other years will be decline by –13.07 mm, -23.6 mm and -34.14 mm for 2010, 2020 and 2030, respectively.

The Dry zone appears to be relatively less affected by the predicted decline in average monthly rainfall as compared with the other two zones. The rainfall will decline by –14.69 mm. /per year in the Dry zone, resulting in an average monthly decrease of –38.08 mm. in 2050, as compared with the figures of 2000 (105.2 mm), which could have devastating impact in the largely rainfed and water deficit area. Monthly average decline in rainfall will be by –12.24 mm, -18.88 mm and -25.52 mm for 2010, 2020 and 2030, respectively.

5.3 Main Findings

(a) Temperature Changes:

1. It is found that, annual average of monthly average temperature, mean maximum temperature and mean minimum temperature has been increasing in almost all the stations, since 1959 to 2002 and increases are quite pronounced recent times.
2. Average annuals temperature increased by more than 0.4 ^{0}C at all the stations except, Nuwaraeliya that lies in the Central Highland at 1895m above mean sea level. The increases in temperature were +1.0° C during the period 1959-2002 at Anuradhapura (Dry zone) and Badulla (Intermediate zone).
3. When compared across the entire period, it become clear that greater increases in temperature (warming) were recorded over more recent periods than over the

whole observation period, especially after the 1970s. Almost all the stations show annual average temperature increases, for the entire four decades periods since 1960 to 2000. Increasing trends of annual temperature could be noticed at almost all the stations, since mid 1970s. Linear trends (slopes) are particularly high at Badulla, Rathmalana and Colombo.

4. Trend computation for mean maximum temperature also shows positive warming trends over the whole period, especially significant since the 1970s. Slopes are high at Anuradhapura, Maha Illukpallama, Badulla, Rathmalana, Rathnapura and Colombo.
5. For most of the stations, the month of the May and April are recorded as the warmest months of mean maximum temperature. Mean minimum temperature months are recorded in November, December and January.
6. Mean minimum temperature also has been increasing at all the stations. Slopes of mean minimum temperature are particularly high at Anuradhapura, Rathmalana, Colombo, Rathnapura and Galle.
7. Decadal temperature changes indicate consistent increase over the entire period especially after the mid 1970s. Considering overall situation, Sri Lanka had two warmest periods during the last 50 years. The first period was in the 1970s and other period was in the 1990s. Compared with the whole period, after 1970s and the more recent decades from 1990 show, stronger positive trends of warming.

8. Increasing trend of temperature can be noticed for all the seasons and stations in the First Inter Monsoon season, Southwest Monsoon season, Second Inter Monsoon and Northeast Monsoon seasons

9. The slopes for temperature increases are high at Anuradhapura, Badulla, and Rathmalana during the First Inter Monsoon season; and similarly, at Anuradhapura, Badulla, Colombo, Rathmalana and Rathnapura for the Southwest Monsoon season. Slopes are high at Anuradhapura, Badulla, Colombo, Galle and Rathmalana during the Second Inter Monsoon season; and similarly, at Anuradhapura, Badulla, Colombo, Galle and Katunayake during the Northeast Monsoon season. Seasonal temperature increases have been particularly significant after 1970 and recently, since 90s, for all the stations, with small variations here and there.

10. The temperature increases will be higher in the Dry zone than other two zones, Intermediate and Wet zone in Sri Lanka. Temperature will increase by 1.07^0 Celsius in the Dry zone, by 2050. In the year 2000, the monthly average temperature was 27.95 °C in the Dry zone, which will increase to 28.25 ^{0}C in 2010, to 28.44 ^{0}C in 2020, to 28.63 ^{0}C in 2030 and to 29.02 ^{0}C in 2050, respectively. Temperature increases will be higher in the Intermediate zone than Wet zone. Temperature will increase by 1.03 ^{0}C in the Intermediate zone by 2050. Monthly average temperature was 25.84 ^{0}C in the Intermediate zone in the year 2000, which will increase 26.10 in 2010, to 26.29 ^{0}C in 2020, to 26.49 ^{0}C in 2030 and to 26.87 ^{0}C in 2050, respectively. Temperature increases will be lower in the

Wet zone than other two zones due to influence of higher pricipitation. Temperature will increase by 0.84 0C by 2050 in the Wet zone. Monthly average temperature was 27.18 °C in the Wet zone in the year 2000, which will increase to 27.29 ^{0}C in 2010, 27.47 ^{0}C in 2020, 27.65 ^{0}C in 2030 and 28.02 ^{0}C in 2050, respectively.

(b) Rainfall Changes:

11. From the foregoing analyses of precipitation conditions in the study area for the past four decades, it is clear that there has been a consistent decline in the quantum of rainfall over the area, especially during the recent decades. Out of 33 stations, 32 stations show, negative trends of annual average rainfall (exception is, positive trend only at Watawala station).
12. Almost all the stations with negative trends show sharp decreases in 1970 and again from 1980 to 1990s.
13. Considering overall situation, the rainfall declines appear to be associated with the warmest periods, i.e., the 1970s and the 1990s. in Sri Lanka. This appears somewhat unusual in the sense warmer periods are associated with increased precipitation. This does not happen in the instant case, for reasons associated with global circulation issues, much beyond the scope of the present study.
14. Slopes of linear trends show, out of 35 stations, 26 stations in First Inter Monsoon season, 30 stations in Southwest Monsoon season, 24 stations in Second Inter

Monsoon season, and 24 stations in Northeast Monsoon seasons have shown decreasing trends in precipitation.

15. Sharp decreasing trends in precipitation are noticeable at Badull, Kurunduoya, Nuwaraeliya, Abergeldie, Annifield, Campion, Holmwood, Hakgala and Detanagalla during the First Inter Monsoon season. Sharp decreasing trends in precipitation are noticeable at Kekanadura, Negambo, Ratmalana, Colombo, Abergeldie, Anifield, Holmwood, Kalutara, Raigama, Undugoda and Walpita during the Southwest Monsoon. Out of 33 stations, 24 stations show decreasing trends of rainfall in Second Inter Monsoon season; slopes were particularly high at Diyathalawa, Negambo, Duckwari, and Holmwood. Out of 33 stations 24 shows negative trend of rainfall in the Northeast Monsoon season. The sloes were particularly high at Badulla, Kurunduoya, Holmwood and Hakgla during the Northeast Monsoon season.
16. On the basis of the pricipitation forecasts, all the three ago-climatic zones indicate consistent decline in average monthly rainfall. The slopes for all the three linear trends are highly significant. The rainfall decline will be somewhat sharper in the Intermediate zone as compared to the other two zones. In the Intermediate zone, the monthly average rainfall will decrease by -58.74 mm in 2050 as compared with 2000 level, i.e., 150.8 mm. The average yearly decline will be 21.40 mm, which is the highest predicted decline among the three zones. The forecasts for average monthly pricipitation for the zone, decline by –17.83, -28.06, and -38.28 mm for the years 2010, 2020 and 2030, respectively. In the Wet Zone, the average

monthly rainfall will decline by -55.21 mm. by 2050, as compared to the monthly averages for 2000, i.e. 197.73 mm. Rainfall is predicted to decline by –15.68 mm./per year in the Wet zone. The forecasts for other years will be decline by –13.07 mm, -23.6 mm and -34.14 mm for 2010, 2020 and 2030, respectively. The Dry zone appears to be relatively less affected by the predicted decline in average monthly rainfall as compared with the other two zones. The rainfall will decline by –14.69 mm. /per year in the Dry zone, resulting in an average monthly decrease of –38.08 mm. in 2050, as compared with the figures of 2000 (105.2 mm), which could have devastating impact in the largely rainfed and water deficit area. Monthly average decline in rainfall will be by –12.24 mm, -18.88 mm and -25.52 mm for 2010, 2020 and 2030, respectively.

Chapter – VI

Analyses of Production, Coverage and Yield of Principal Crops in Sri Lanka: 1969-70 to 2000-2001

This chapter is devoted to the study of production, area and yield of selected principal crops, Rice, tea, coconut and rubber as outlined in respect of the designated districts under the study, representing major Agro-Climatic zones, for the past few decades (1969-70 to 2000-2001). This chapter contains two major parts: Part I includes analyses of trend of rice production, area coverage and yield. Growth rates of rice production, area coverage and yield are also analysed in this section. Part II examines the trend of production, area extent and yield of selected major plantation crops, tea, coconut and rubber.

6. Introduction

The agricultural economy of Sri Lanka is made up of a basic duality: export oriented plantation sector with tea, rubber and coconut as the main crops and a local consumption (market) oriented subsistence food crop sector, with rice as its mainstay. Over 90 per cent of the area under plantation crops and the other permanent crops are concentrated in the Wet zone, which represents only 30 per cent of the total geographical area of Sri Lanka. The subsistence rice sector is distributed widespread, with 57 per cent of the land area devoted to rice and seasonal crops and in the Dry zone, the coverage is

70 per cent of the total land area and in the Wet zone, 43 per cent. Nevertheless, even in the subsistence sector, differences between the Wet and Dry zones are quite considerable; the Wet zone has a year round dependable supply of water from rainfall, whereas in the Dry zone, the dependence on irrigation for most of the year, is of paramount significance through out the year. It, therefore, can be said that the spatial distributions of the two agricultural sectors conform to the basic zonal arrangements, i.e., according to rainfall conditions. The spatial distribution of the main crop types can be arranged according to administrative districts. Nearly 47 per cent of the agricultural land is devoted to plantation crops (Tea: 12%, Rubber: 12%, Coconut: 23%), and 33 per cent is under rice cultivation, 11 per cent to permanent crops other than plantation crops, and the balance 9 per cent under temporary (other seasonal) crops.

Table 6.1: Districts-wise Percentage Distribution of Principal Crops in Sri Lanka :1980-81

Districts	Tea	Rubber	Coconut	Rice	Other permanent crops	Temporary Crops
Colombo	0.14	11.35	17.13	4.26	9.18	5.09
Kalutara	2.09	22.36	2.62	3.43	6.13	1.35
Kandy	32.10	2.89	3.00	2.98	10.73	5.04
Nuwaraeliya	17.50	0.03	0.09	1.16	1.21	4.25
Kegalle	5.09	23.02	4.61	1.73	7.76	3.00
Galle	5.80	9.92	4.02	3.83	4.86	2.66
Matara	6.24	4.01	3.62	3.24	7.10	1.78
Ratnapura	11.96	17.28	2.77	2.52	7.54	6.24
Matale	3.20	3.54	2.84	2.16	6.81	4.05
Badulla	15.55	0.85	0.50	2.65	4.02	8.21
Kurunegala	0.15	2.65	35.72	10.41	3.03	7.83
Anuradhapura	0.00	0.00	1.33	13.06	4.07	13.89
Puttalama	0.00	0.02	12.79	2.80	1.64	3.74

Source: Department of Census and Statistics, 1983, Government of Sri Lanka, Colombo.

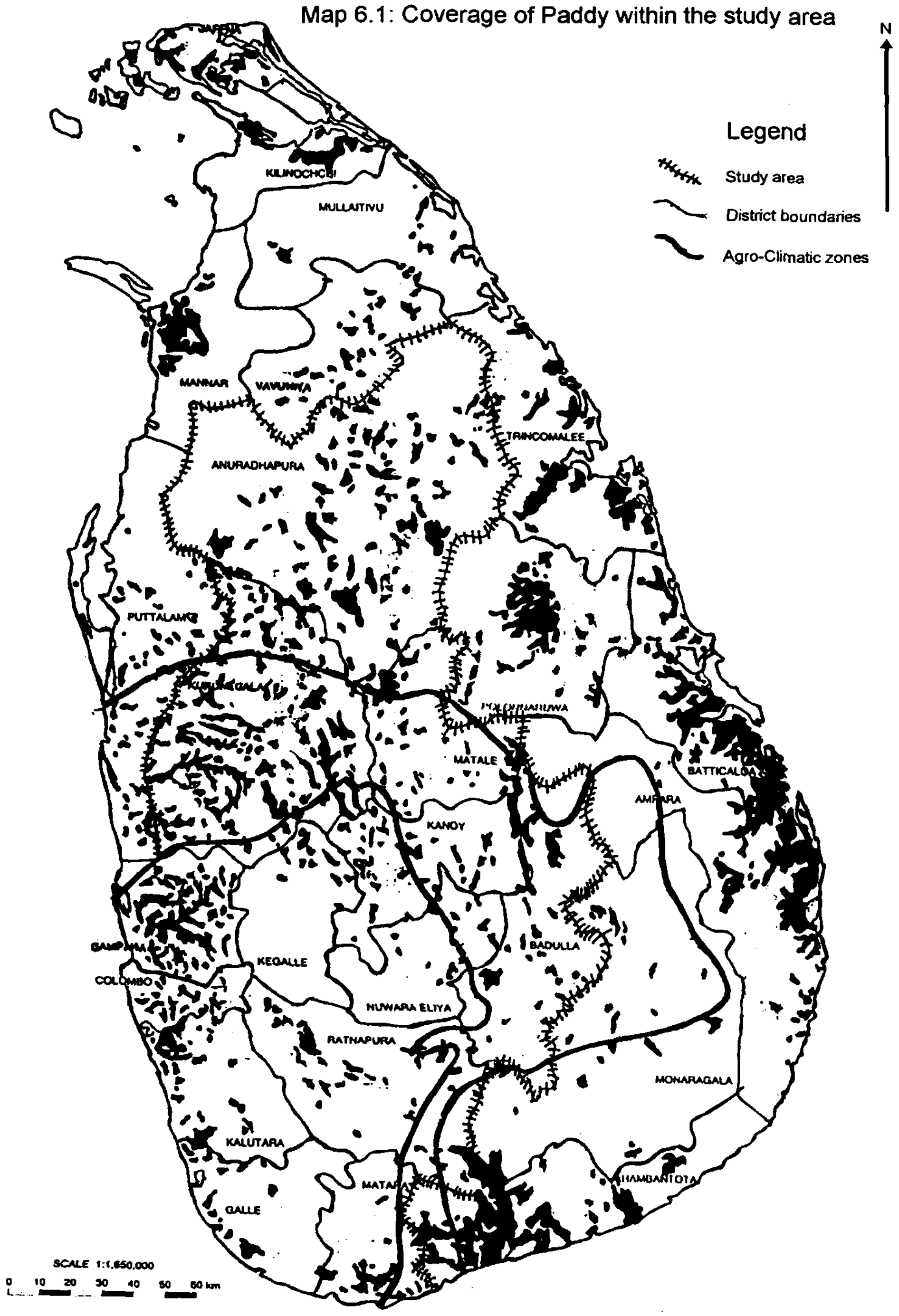
Productivity in the agriculture sector has in the recent past shown decreasing trend. This is evident, in both the plantation and the non-plantation sector, including that of rice, as well as of some of the other major agricultural crops, despite the fact that initially yields were rising since the introduction of *Green Revolution* technology. The low level of productivity of plantations is evident from their low yield. Since the 1970s, the yield of tea has remained more or less constant, with production fluctuating between 200 and 240 million Kg. per year. In the case of rubber, the yield has fallen with production decreasing by around one third, and in the case of coconut, the yield has been subject to wide fluctuations (mainly due to weather condition) without any discernible trend (Ranaweera, 1998:85-102).

Part I: Analyses of Rice Production, Coverage and Yield

6.1 Introduction

Rice is cultivated in Sri Lanka under a wide range of rainfall and other environmental conditions, which explain its rather more even distribution (Map 6.1), compared to that of plantation crops. Rice cultivation in Sri Lanka is strongly influenced by topographical and climatic factors that cause considerable regional variations. Sri Lanka is under the influence of both the Southwest Monsoon (from May to September) and the Northeast Monsoon (from December to February). Rice is cultivated in Sri Lanka under rain-fed as well as irrigated conditions. Rice is cultivated under different water supply systems. Nearly, 38 per cent of the rice acreage is cultivated under rain-fed conditions, 33 under major irrigation works, and the balance 29 per cent in minor irrigation schemes (Department of Census and Statistics, 1981a).

Map 6.1: Coverage of Paddy within the study area



Source: Somasekaram et al, 1997

In fact, it is reported that the Wet zone in mid-country areas is optimal for rice cultivation, if the very high yields and stable production levels are any indication (Department of Census and Statistics, 1981a). In the low land Wet zone, flooding and poor drainage are serious hazards, whereas in much of the Dry zone outside the major irrigation schemes, drought is a perennial problem. The low yield in the Wet zone lowland areas is indicative of poor water supply conditions, partly resulting from, either too much rainfall, and partly, lack of sufficient water control and management system. On the other hand, in the Dry zone, in irrigated areas, the yield is found to be relatively high, compared to the Wet zone lowlands, but there is a lot of room for improvement, if the level of discipline in water use and management can be stepped up. The extension of the area of the cultivation and by bridging the wide differences between the cultivated areas during Wet and Dry seasons can be done by providing more assured supplies of irrigation water.

The intensity of cultivation (cropping intensity) of rice and other seasonal crops, during the respective seasons is primarily a function of water availability, although institutional and management factors may have a role to play. Normally, except for areas with adequate irrigated water supplies, the percentage of cultivable land that is cultivated in any one season, is influenced by the distribution of rainfall. During 'Maha' season cropping coverage is high, all over the country. On the other hand, in the 'Yala' season, it is generally low except in the Wet zone and in areas of irrigated agriculture. Cropping intensity varies with the nature of water supply too. Under rain-fed conditions, the coverage is very low in the Dry zone, during the 'Yala' season. Even during the rainy seasons, some areas have relatively low intensities presumably due to rainfall variability as well as due to farmers` attitudes. Sometime, as a guarantee against possible crop failure, or due to their preference for *"slash and burn"* farming in forested tracts, they do not make use of much of the rain water directly, and wait for the tanks to fill before rice cultivation operations are set in motion; often they may start too late or leave the fields to fallow. The cropping coverage under minor irrigation works is not much better during the dry seasons. Almost everywhere in the Dry zone, cropping intensity under major irrigation works is relatively high in both the seasons, although the intensity is still far lower than in areas of the Wet zone.

(a) Analyses of Rice Production

The intent of this part is to study the trends of rice production with a comparison of districts that represent major Agro-Climatic zones. The discussion deals with the changes that have occurred in production since 1969, for which reliable and comparable data is available. In addition to the analyses of current trends, it attempts to look for their associated causes too.

Trend of rice production was examined during the period 1969 to 2001. The 'Maha' and 'Yala' cultivation seasons were studied separately and the trend of rice production was examined for each of the selected district. As outlined earlier, 13 districts were selected covering all the major Agro-Climatic zones. Rice production for both the seasons ('Maha' season: October to February and 'Yala' season: March to September) are shown in the table 6.1a.

Table 6.1a: Rice production ('Maha' and 'Yala') 000' bushels*: 1968/69 to 2000/2001

District	1968/69 Maha	1969 Yala	1969/70 Maha	1970 Yala	1970/71 Maha	1971 Yala
Annuradhapura	4793	926	6531	2860	4022	2134
Badulla	2065	419	1881	534	1553	495
Kurunegala	5534	1446	6172	3289	4269	3311
Colombo	2148	1127	1907	1005	1726	771
Gampaha	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Galle	1098	754	819	1117	898	1019
Kalutara	1350	913	1226	1107	1161	1034
Kandy	2698	1769	3225	1876	2253	1709
Kegalle	1749	973	1564	1092	1327	965
Matale	1666	417	1136	740	1458	542
Matara	1418	1056	602	1293	896	1405
Nuwara Eliya	764	444	943	460	846	510
Ratnapura	1359	1187	1364	1050	1360	7776

Table 6.1a continued

District	1978/79 Maha	1979 Yala	1979/80 Maha	1980 Yala	1980/81 Maha	1981 Yala
Annuradhapura	9905	2182	10564	1229	5894	1127
Badulla	2027	490	2116	486	2061	424
Kurunegala	8113	1273	9600	5117	11066	5516
Colombo	586	293	774	494	759	575
Gampaha	1647	612	1644	1222	1918	1092
Galle	1185	927	1211	1077	1545	1260
Kalutara	1386	1223	1485	1266	1788	1515
Kandy	2686	1605	2653	1771	2714	1562
Kegalle	1571	784	1451	1412	1704	1429
Matale	1859	681	1762	533	2072	521
Matara	1506	1503	1702	1345	1590	1735
Nuwara Eliya	507	190	465	158	511	280
Ratnapura	1403	1055	1439	1274	1462	1446

Table 6.1a continued

District	1988/89 Maha	1989 Yala	1989/90 Maha	1990 Yala	1990/91 Maha	1991 Yala
Annuradhapura	1761	146	1761	1761	4714	1084
Badulla	3078	1706	3078	1645	3283	1477
Kurunegala	10762	3199	10762	4702	11938	5664
Colombo	884	325	884	486	768	390
Gampaha	36630	759	36630	1220	1502	946
Galle	1945	1337	1945	1745	1932	1260
Kalutara	2068	1708	2068	1741	2163	1416
Kandy	2355	1824	2355	1956	2450	1651
Kegall	1792	1195	1792	1284	1713	1229
Matale	2589	544	2589	768	2772	554
Matara	2365	1652	2365	2129	1850	1278
Nuwara Eliya	622	348	622	252	651	334
Ratnapura	2094	1210	2094	1608	1774	1353

Table 6.1a continued

District	1998/99 Maha	1999 Yala	1999/00 Maha	2000 Yala	2000/01 Maha	2001 Yala
Annuradhapura	8755	8755	9205	3246	7000	2969
Badulla	3200	1430	3469	1910	3795	1953
Kurunegala	10347	6906	11377	2671	7660	3949
Colombo	688	347	596	120	593	105
Gampaha	1334	456	1326	215	1184	154
Galle	1938	1341	1918	1120	1712	639
Kalutara	2083	1372	1915	1507	1943	1574
Kandy	1797	1455	2019	1104	2319	1447
Kegalle	1525	1215	1633	690	1096	827
Matale	2143	1015	2302	956	2462	971
Matara	2226	2176	2253	2255	2211	1853
Nuwara Eliya	574	195	548	180	578	230
Ratnapura	1859	1415	2008	1533	1972	1457

Source: Compiled by author from 'Rice Statistics of Sri Lanka', Department of Census and Statistics, 1968-2001.

Notes: n.a. = not available. * - 1Bushel = 8 gallons or 36.4 litres, a measure of volume, a British measure still in current use in Sri Lanka. By weight, 1 bushel will be about 30-32 Kg., depending on the SG of a given mass.

(i) Trend of Rice Production in 'Maha' Season

Trend of rice production has been examined, using linear trend analyses. Analyses show that the trend of rice production was positive for Anuradhapura, Kurunegala, Kalutara, Badulla, Galle, Matale, Ratnapura and Matara during 'Maha' season from 1969 to 2001 (Table 6.1b). Linear trend is much stronger, at Kalutara, Badulla, Galle, Matale, Ratnapura and Matara. The rice production declined at Colombo (Figure 6.1a), Kandy, Nuwaraeliya, Gampaha and Kegalle during the 'Maha' season in the concerned period. The negative trend is stronger at Colombo, Kandy (Figure 6.1b), Nuwaraeliya and Gampaha.

(ii) Trend of Rice Production on 'Yala' Season

Analyses show, that the trend of Rice production was positive, at Anuradhapura, Kurunegala, Kalutara, Badulla, Matale and Matara during 'Yala' cultivation season from period 1969 to 2001 (Table 6.1b). Positive trends are much stronger at Kalutara, Badulla, Mathale and Matara.

Table 6.1b: Linear regression equations for 'Maha' and 'Yala' Season Rice production: 1969/70 to 2000/2001

Districts	'Maha'	'Yala'
Anuradhapura	Y= 118.764x+5984.7 R^2= 0.0152	Y= 77.643x+1701.9 R^2= 0.0462
Kurunegala	Y= 626.98x+6284.1 R^2= 0.3052	Y= 26.75x+4157 R^2= 0.0034
Kalutara	Y= 132.18x+1123.8 ***R^2= 0.7184***	Y= 75.119x+1057 ***R^2= 0.5794***
Badulla	Y= 327.33x+1181.5 ***R^2= 0.9014***	Y= 252.4x-20.321 ***R^2= 0.8008***
Colombo	Y= -175.49x+1790.6 ***R^2= 0.6973***	Y=-118.52x+1026.6 ***R^2= 0.9126***
Galle	Y= 165.64x+752.11 ***R^2= 0.7602***	Y= -21.512x+1251.4 R^2= 0.0293
Kandy	Y= -100.95x+2952.8 ***R^2= 0.4537***	Y= -71.357x+1955.6 ***R^2= 0.421***
Matale	Y= 202.96x+1155.8 ***R^2= 0.7485***	Y= 47.583x+484 ***R^2= 0.3783***
Nuwareeliya	Y= -40.19x+826.36 R^2= 0.3497	Y= -32.857x+48.36 ***R^2= 0.4012***
Ratnapura	Y= 114.18x+1227.6 ***R^2= 0.4416***	Y= -332.94x+3685.4 R^2= 0.1297
Matara	Y=229.37x+651.46 *R^2=0.7636	Y=99.56x+1213.6 *R^2=0.3921
Gampaha	Y=-129.54x+2301.5 *R^2=0.5997	Y=-332.94x+3685.4 R^2=0.1297
Kegalle	*Y=-10.381x+1581.7* *R^2=0.0119*	Y=-46.79x+1326.7 R^2=0.1786

Source: Calculated by the author from 'Rice Statistics of Sri Lanka', Department of Census and Statistics, 1969-2001.

Note: * = Significant.

The trends of rice production were negative, at Colombo, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle during 'Yala' in concerned period. The negative trends are stronger at Colombo, Kandy and Nuwaraeliya (Table 6.1b).

Figure 6.1a: Rice production at Colombo : Maha season

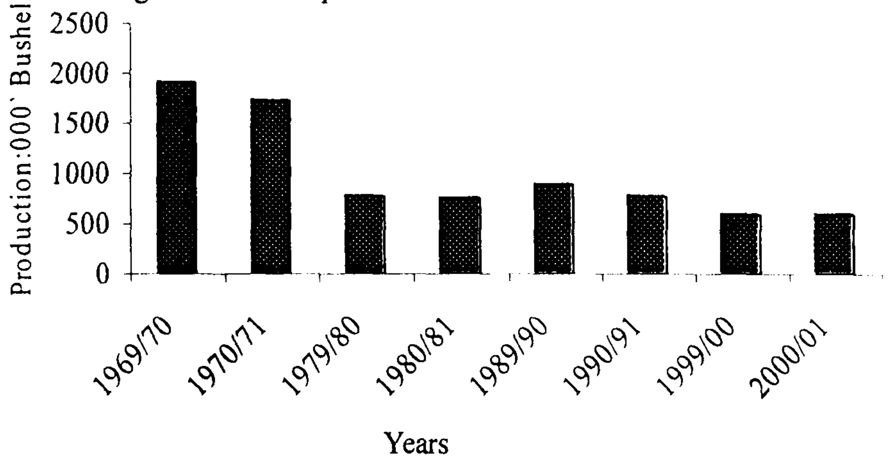
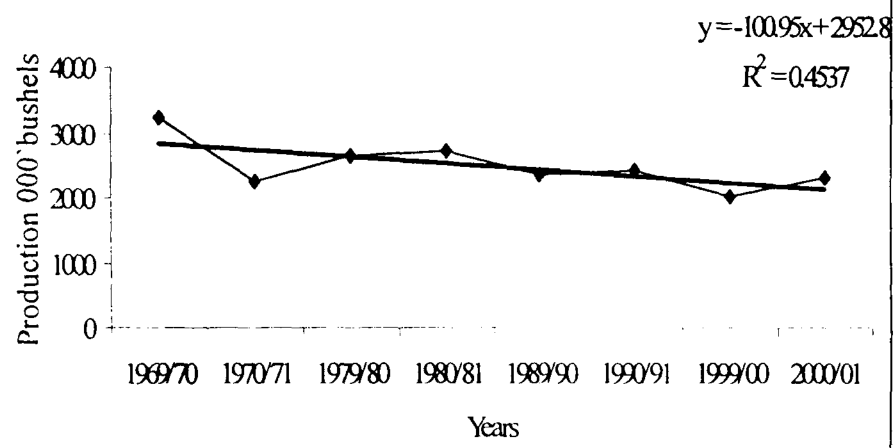


Figure 6.1b: Trend of Rice production at Kandy : Maha Season



(b) Analysis of Rice Coverage

Trend of gross extent harvested of rice has been examined for the period 1969 to 2001. 'Maha' and 'Yala' seasons are concerned separately for each district. Gross extent harvested of rice from 1968 to 2001 has been shown in the following table 6.1c.

Table 6.1c: Rice gross extent harvested (Acres): 'Maha' and 'Yala'

District	1968/69 Maha	1969 Yala	1969/70 Maha	1970 Yala	1970/71 Maha	1971 Yala	1978/79 Maha	1979 Yala
Annuradhapura	107249	19828	139288	60659	104659	51291	180051	45811
Badulla	32006	11173	33320	11613	28946	12431	39784	11295
Kurunegala	148505	44278	149254	90637	127248	86375	160239	28177
Colombo	58279	34513	57749	35878	55116	27170	17442	8771
Gampaha	n.a	n.a.	n.a.	n.a.	n.a.	n.a.	40362	16666
Galle	42552	36537	36737	46417	42403	44690	46142	44399
Kalutara	40812	34549	40082	39852	40584	38325	45379	40457
Kandy	46555	35603	47432	37008	47277	38747	54711	37448
Kegalle	27230	21221	27010	22408	27246	21939	21203	21460
Matale	27168	9109	25649	16210	24801	13458	32851	37448
Matara	41894	31206	25585	40108	32430	43584	46552	43886
Nuwara Eliya	17439	9735	17832	11155	17938	11395	11293	4850
Ratnapura	35756	30888	35783	30903	37727	35177	37080	30138

Table 6.1c continued

District	1979/80 Maha	1980 Yala	1980/81 Maha	1981 Yala	1988/89 Maha	1989 Yala	1989/90 Maha	1990 Yala
Annuradhapura	180949	26911	145929	21963	12192	3620	70829	33902
Badulla	39616	13808	39609	11989	45438	26268	36462	25503
Kurunegala	163657	82969	174489	86589	138860	50613	161496	90896
Colombo	17313	14004	17120	15088	15445	8752	15880	11907
Gampaha	40309	22127	41253	25809	34667	17119	36462	27769
Galle	44944	41004	47673	47685	49577	40746	47945	45316
Kalutara	45379	41998	47084	44351	43975	39473	44052	39989
Kandy	55074	40257	55164	34432	47006	35802	47233	39789
Kegalle	27459	24283	27359	26016	27496	23655	27459	26957
Matale	26597	11738	35331	10429	30344	10631	36226	15115
Matara	48793	41346	48941	46379	46487	39650	47477	44195
Nuwara Eliya	11435	5075	11678	8771	15767	9231	15105	8216
Ratnapura	37896	34599	38868	36081	37364	25813	37923	33849

Table 6.1c continued

District	1990/91 Maha	1991 Yala	1998/99 Maha	1999 Yala	1999/00 Maha	2000 Yala	2000/01 Maha	2001 Yala
Annuradhapura	73795	20545	130716	46367	134132	48992	100311	43181
Badulla	49809	24880	52329	23405	51563	25349	53122	25588
Kurunegala	170094	103749	168214	106313	162310	43832	109694	65649
Colombo	15676	11757	12120	8351	11265	2658	10220	2359
Gampaha	34407	26231	26650	8859	24761	4706	22082	3329
Galle	48296	43448	41989	33143	40960	28132	38871	16089
Kalutara	44276	37555	37990	30814	37427	31646	37209	32178
Kandy	47303	36598	39412	26599	37501	20607	38549	24875
Kegalle	27296	26965	25030	30814	24226	13353	15532	14623
Matale	35279	10283	33602	15374	34248	15117	31352	15252
Matara	44816	36175	42371	37479	41563	40468	42236	36221
Nuwara Eliya	15233	7768	16169	5433	15455	5218	14789	5562
Ratnapura	36638	33943	38537	29664	36956	30074	35743	27312

Source: Compiled by the author from 'Rice Statistics of Sri Lanka' Department of Census and Statistics, 1968-2001.

Note: n.a. = not available; The 'Maha' season spills over two years (from Oct to March), whereas the 'Yala' seasons falls within the same calendar year. Therefore, the data format refers to two years in case of Maha and one calendar year for Yala season.

(i) Trend of Rice Gross Extent Harvested on 'Maha' Season

Trends of rice coverage were examined, using linear trend analyses (Table 6.1d). Analyses show that the trend of rice gross extent harvested was positive at Badulla, Galle Matale and Matara during 'Maha' cultivation season since 1969 to 2001. The positive trend is significant only at Badulla and Matale. The trends of rice gross extent harvested were negative at Anuradhapura, Kurunegala, Kalutara, Colombo, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle during 'Maha' in the concerned period. The negative trends are very significant at Colombo, Kandy, Gampaha and Kegalle during the 'Maha' season.

Table 6.1d: Linear trend equations for 'Maha' and 'Yala' Seasons for Rice gross extent harvested: 1969/70 to 2000/2001

Districts	'Maha'	'Yala'
Anuradhapura	Y= -6214.7x+146703 R^2= 0.1603	Y= -1678.6x+45984 R^2= 0.0769
Kurunegala	Y= -1134.4x+157385 R^2= 0.0151	Y= -3817.1x+98520 R^2= 0.2564
Kalutara	Y= -502.82x+44274 R^2= 0.1104	Y= -1247.7x+43851 ***R^2= 0.4744***
Badulla	Y=3323x+26602 **R^2= 0.8247*	Y= 2489.8x+7690.9 ***R^2= 0.7788***
Colombo	Y= -6644.2x+54941 ***R^2= 0.6924***	Y= -4528.6x+35149 ***R^2= 0.8705***
Galle	Y= 214.84x+425.2 R^2= 0.0141	Y= -3453.8x+54640 **R^2= 0.5762*
Kandy	Y= -1694.1x+54565 ***R^2= 0.4102***	Y= -2178.8x+43812 ***R^2= 0.5268***
Matale	Y= 1358.3x+25073 ***R^2= 0.4806***	Y=1770.2x+8105.7 R^2= 0.2638
Nuwareeliya	Y= -224.9x+15945 R^2= 0.0522	Y= -744.19x+11244 ***R^2= 0.5248***
Ratnapura	Y= -105.4x+37666 R^2= 0.0544	Y= -653x+35681 R^2= 0.2835
Gampaha	Y=-4076.2x+55631 **R^2=0.9021*	Y=-4535.2x+43289 **R^2=0.5698*
Kegalle	Y=-1140.9x+30582 **R^2=0.4531*	Y=-1000.4x+26649 R^2=0.2202
Matara	Y=1771.8x+33507 R^2=0.2683	Y=-720.07x+44300 R^2=0.2339

Source: Calculated by the author from 'Rice Statistics of Sri Lanka', Department of Census and Statistics, 1969-2001.
Note: *= Significant.

(ii) Trend of Rice Gross Extent Harvested on 'Yala' Season

Linear trend was estimated for 'Yala' season too. Analyses show that the trend of Rice gross extent harvested was positive only at Badulla and Matale during the 'Yala' cultivation season from 1969 to 2001. The positive trend is significant only at Badulla. The trends of Rice gross extent harvested were negative at Anuradhapura, Kurunegala, Kalutara, Colombo, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha, Kegalla and Matara during 'Yala' during the concerned period. The trends are very significant at Kalutara, Colombo, Galle, Kandy and Nuwaraeliya and Gampaha during the 'Yala' season (Table 6.1d).

(c) Average Yield of Rice

Average yield of rice by districts, according to the rice cultivation seasons have been shown in the table 6.1e.

Table 6.1e: Rice average yield in bushels* (Per. net acre): Maha and Yala Season: 1970-71 to 2000-2001

District	1970/71 Maha	1971 Yala	1980/81 Maha	1981 Yala	1990/91 Maha	1991 Yala	2000/01 Maha	2001 Yala
Annura.pura	47.8	51.8	50.2	63.8	79.5	65.6	86.8	85.5
Badulla	63.1	46.9	61.2	41.6	77.6	69.8	84.1	89.8
Kurunegala	37.0	45.1	63.4	63.7	70.2	54.6	69.8	60.2
Colombo	36.9	33.4	52.2	44.8	57.6	39.0	68.2	52.3
Gampaha	n.a.	n.a.	54.7	49.8	51.4	42.4	63.1	54.5
Galle	27.1	29.2	41.4	33.8	51.1	37.1	56.3	50.8
Kalutara	31.0	29.3	41.2	37.0	53.0	40.9	56.6	53.0
Kandy	60.3	55.8	62.2	57.4	65.5	57.1	76.1	73.6
Kegalle	52.0	47.0	66.5	58.6	67.0	48.6	75.4	60.4
Matale	51.0	44.9	65.2	55.5	87.4	59.9	87.3	70.8
Matara	35.0	40.9	41.2	47.4	52.3	44.8	66.3	64.8
Nuwara Eliya	83.8	79.6	77.6	56.7	75.8	76.3	69.3	73.4
Ratnapura	42.4	39.4	44.2	47.1	57.0	46.9	64.9	62.8

Source: Calculated by the author from 'Rice Statistics of Sri Lanka', Department of Census and Statistics, 1970-2001.

* Bushel is the traditional British measure still in use in agricultural statistics of Sri Lanka. Since, it is a measure of volume, the net weight would vary with a given substance. For paddy the approximate equivalence will be between 30-35 Kg./ bushel.

Average yield of rice has been increasing continuously, almost in all the districts in the 'Maha' and 'Yala' seasons, since 1970-71 to 2000-2001. These increases are be due to other factors such as, use of fertiliser, different types high yielding seeds and improved cultivation techniques and farm management practices, well beyond the scope of present research. However, in some of the districts, the average yield is still lower (below 60 b/acre), especially in the Wet zone areas.

Anuradhapura, Badulla and Mathale recorded higher yields in the 'Maha' season than other districts, which is over 80 bushels per net acre in the 2000-01. The lowest yields were recorded at Galle and Kalutara, which is below 60 bushels per net acre in the Maha season, 2000/01. Anuradhapura and Badulla recorded the highest yields in the 'Yala' season, i.e., over 80 bushels per net acres in the 2001. The lowest yields were recorded at Colombo, Gampaha, Galle and Kalutara i.e., below 60 bushels per net acres in the Yala season, 2001.

(d) (i) Analysis of Growth rates of rice production, coverage and yield: Maha season

Growth rate of rice coverage is negative at Anuradhapura, Colombo, and Nuwaraeliya since 1970 to 1981 during the 'Maha' season (Table 6.1f & Map 6.1a). Negative growth rate of area extent can be seen at Anuradhapura, Kurunegala, Colombo, Gampaha, Galle, Kalutara, Kandy, Kegalla, Matale, Ratnapura and Matara since 1980-2001 (Map 6.1b) during 'Maha' season. Negative growth rates can be observed in the above districts, except Matale and Matara from 1970 to 2001. Growth rate of rice yield is negative at Badulla, and Nuwaraeliya during 1970 to 81. The growth rate is negative only at Nuwaraeliya and Colombo during 1980 to 2001. Negative growth rates can be observed at Kurunegala, Colombo, Kandy and Kegalle from 1980 to 2001, during the Maha season.

Table 6.1f: Growth Rate (GR) of Rice extent (acres), Yield (bushels per net acre) and Production (000` bushels): Maha season

Districts	1970/71	1980/81	2000-2001	1970-1981	1980/81-2000/01	1970/71-2000/01
				Growth Rates in %/ year		
1.Anuradhapura:Extent	104659	1459	100311	-9.9	-1.6	-0.1
Yield/ acre	48	50	87	+0.5	+3.6	+2.7
Production	4022	5894	7000	+4.7	+0.9	+2.5
2.Badulla : Extent	28946	39609	53122	+3.7	+1.7	+2.8
Yield	63	61	84	-0.3	+1.9	+1.1
Production	1553	2061	3795	+3.3	+4.2	+4.8
3.Kurunegala: Extent	127248	174489	109694	+3.7	-1.9	-0.5
Yield	37	63	70	+7.1	+0.5	+3.0
Production	4269	11066	7660	+15.9	-1.5	+2.6
4.Colombo:Extent	55116	17120	10220	-6.9	-2.0	-2.7
Yield	37	52	68	+4.1	+1.5	+2.8
Production	1726	759	593	-5.6	-1.1	-2.2
5.Gampah: Extent	n.a	41253	22082	n.a	-2.3	n.a
Yield	n.a	55	63	n.a	+0.8	n.a
Production	n.a	1918	118	n.a	-4.7	n.a
6.Galle: Extent	42403	47673	38871	+1.2	-0.9	-0.3
Yield	27	41	56	+5.3	+1.8	+3.6
Production	898	1545	1712	+7.2	+0.5	+3.0
7.Kalutara: Extent	40584	47084	37209	+1.6	-1.0	-0.3
Yield	31	41	57	+3.3	+1.9	+2.8
Production	1161	1788	1943	+5.4	+0.4	+2.2
8.Kandy:Extent	47277	55164	38549	+1.7	-1.5	-0.6
Yield	60	62	76	+0.3	+1.1	+0.9
Production	2253	2714	2319	+2.0	-0.7	+0.1
9.Kegalle :Extent	27246	27359	15532	+0.04	-2.2	-1.4
Yield	52	67	75	+2.8	+0.7	+1.5
Production	1327	1704	1096	+2.8	-1.8	-0.6
10.Matale :Extent	24801	35331	31352	+4.2	-0.6	+0.9
Yield	51	65	87	+2.8	+1.7	+2.4
Production	146	207	2462	+4.2	+54.4	+53.0
11.Nuwaraeliya:Extent	17938	11678	14789	-3.5	+1.3	-0.6
Yield	84	78	69	-0.7	-0.5	-0.6
Production	846	511	578	-4.0	+0.7	-1.1
12.Ratnapura :Extent	37727	38868	35743	+0.3	-0.4	-0.2
Yield	42	44	65	+0.4	+2.3	+1.8
Production	1360	1462	1972	+0.8	+1.7	+1.5
13.Matara: Extent	32430	48941	42236	+5.1	-0.7	+1.0
Yield	35	41	66	+1.8	+3.0	+3.0
Production	896	1590	2211	+7.7	+2.0	+4.9

Source: Calculated by the author from 'Rice Statistics of Sri Lanka', Department of Census and Statistics, 1970-2001. Note: n.a. = not available.

Rice (total) production in the districts of Colombo, Kegalle and Nuwaraeliya are negative from 1970 to 2001 during the 'Maha' season (Table 6.1f). Negative Growth rate of rice coverage is higher (less than -1.5 per year), during the Maha season, in the districts of Anuradhapura, Kurunegala, Colombo, Gampaha, Kandy and Kegalle from 1980-81 to 2000-2001 (Map 6.1b). Negative Growth rates of rice production are higher (less than -1.5/per year), during Maha season, in the districts of Kurunegala, Gampaha and Kegalle from 1980-81 to 2000-2001. Negative Growth rates of rice coverage and production are higher (less than -1.0 per year), during Maha season, in the district of Colombo and Kegalle from 1970-71 to 2000-2001.

(ii) Growth rates of rice production, coverage and yield: 'Yala' season

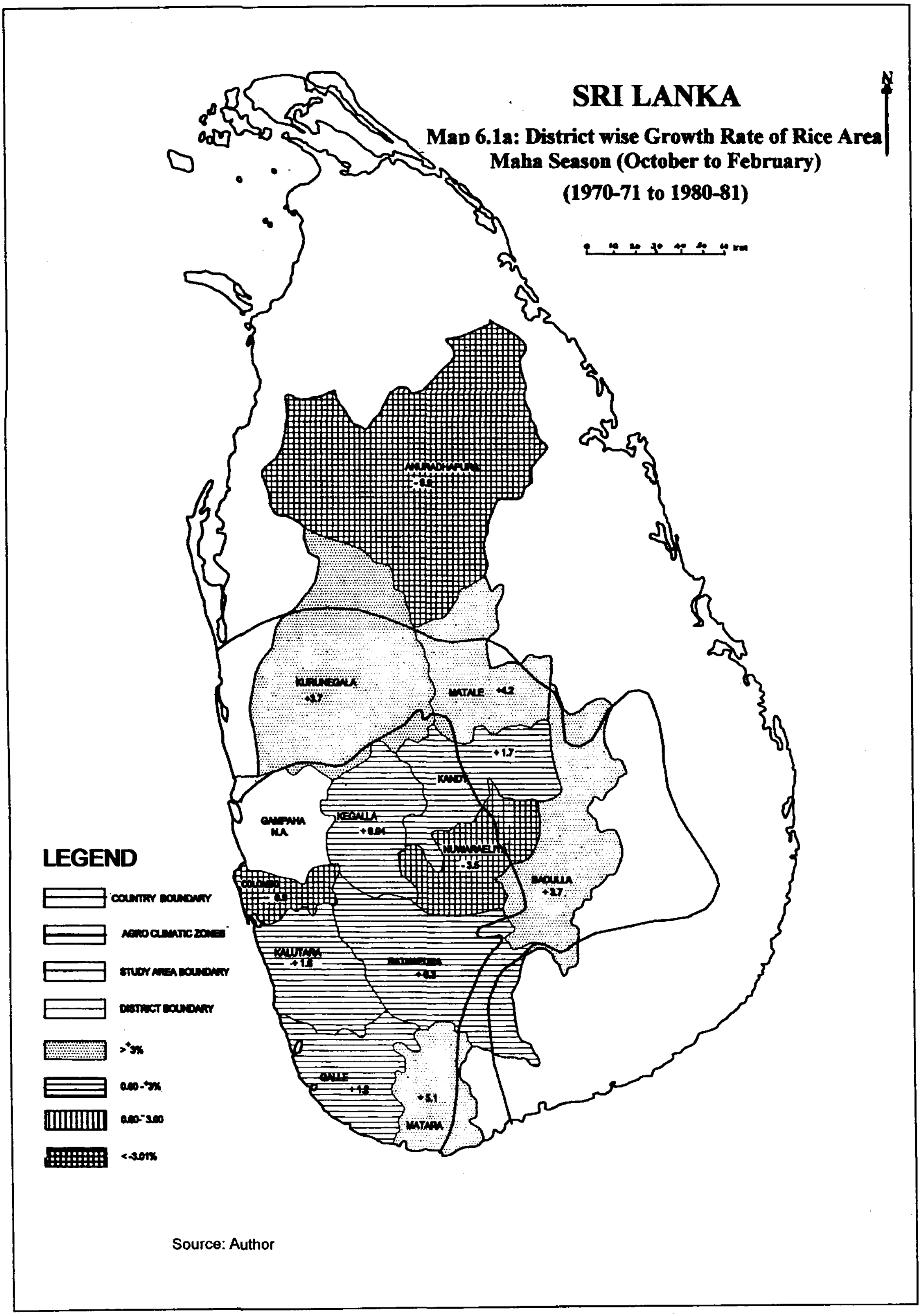
Growth rates of rice coverage are negative at Anuradhapura, Badulla, Colombo, Kandy, Matale, Nuwaraeliya, from 1970 to1981 during the 'Yala' season (Table 6.1g & Map 6.1c). Negative growth rates of area coverage of rice during the 'Yala' season can be observed at Kurunegala, Colombo, Gampaha, Galle, Kalutara, Kandy, Kegalle, Nuwaraeliya, Ratnapura, and Matara between 1980 and 2001 (Map 6.d). Anuradhapura, Kurunegala, Colombo, Galle, Kalutara, Kandy, Kegalle, Nuwaraeliya, Ratnapura and Matara show negative growth rates for the entire study period of 1970-2001. Growth rates of rice yield are negative at Badulla, and Nuwaraeliya during 1970-81 (Map 6.1e) in the 'Yala' season too. The growth rate is negative only at Nuwaraeliya during 1980-2001 (Map 6.1f) in the 'Yala' season. Anuradhapura, Badulla, Colombo, Kandy, Matale, Nuwaraeliya and Ratnapura report negative growth rates of rice production for 1970-81 period during the 'Yala' season. Negative growth rate can be observed at Kurunegala, Colombo, Gampaha, Galle, Kandy, Kegalle and Nuwaraeliya for 1980-2001 during the same season.

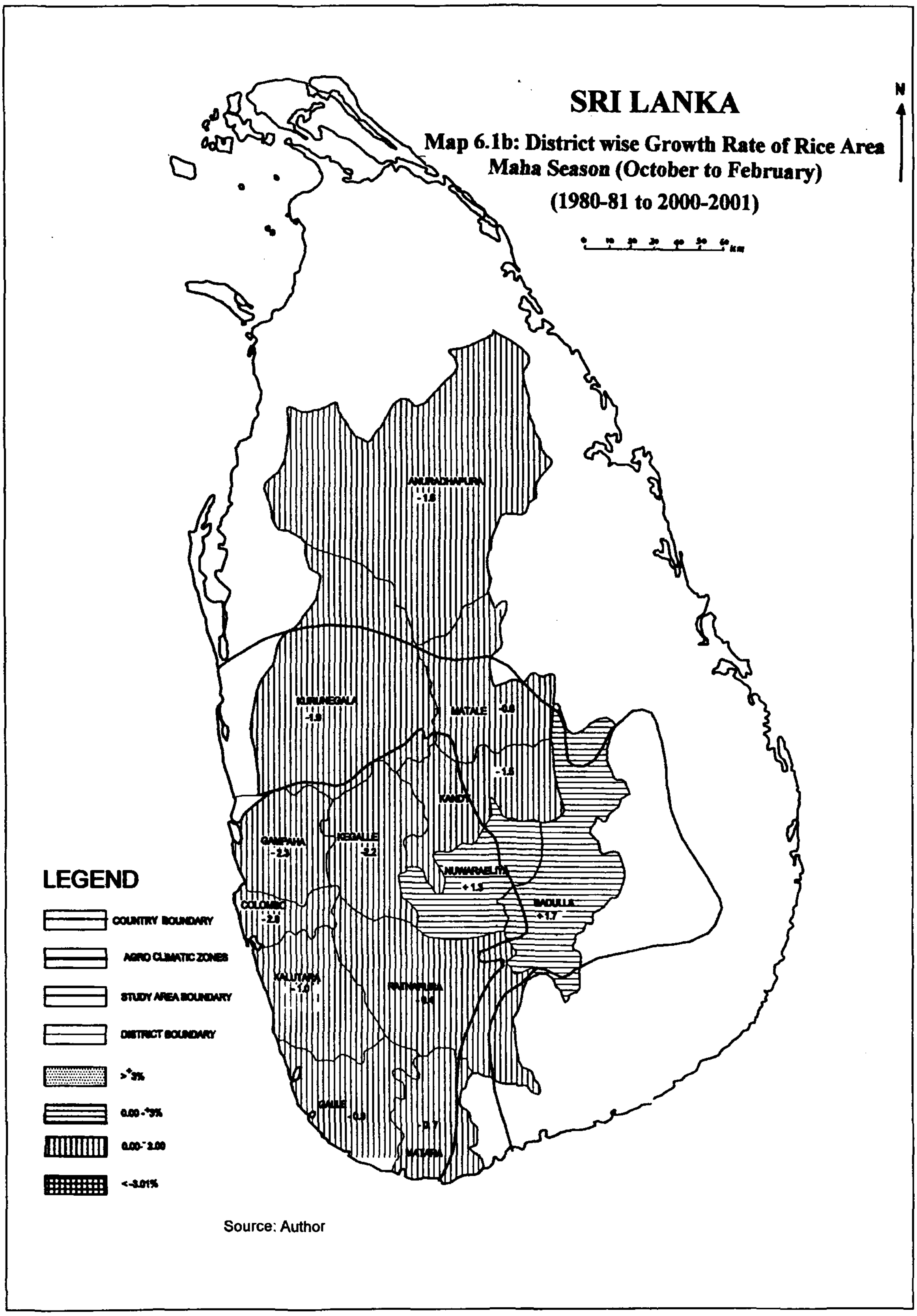
Table 6.1g: Growth Rate (GR) of Rice extent (acres), Yield (bushels per net acres) and Production (000' bushels): Yala season

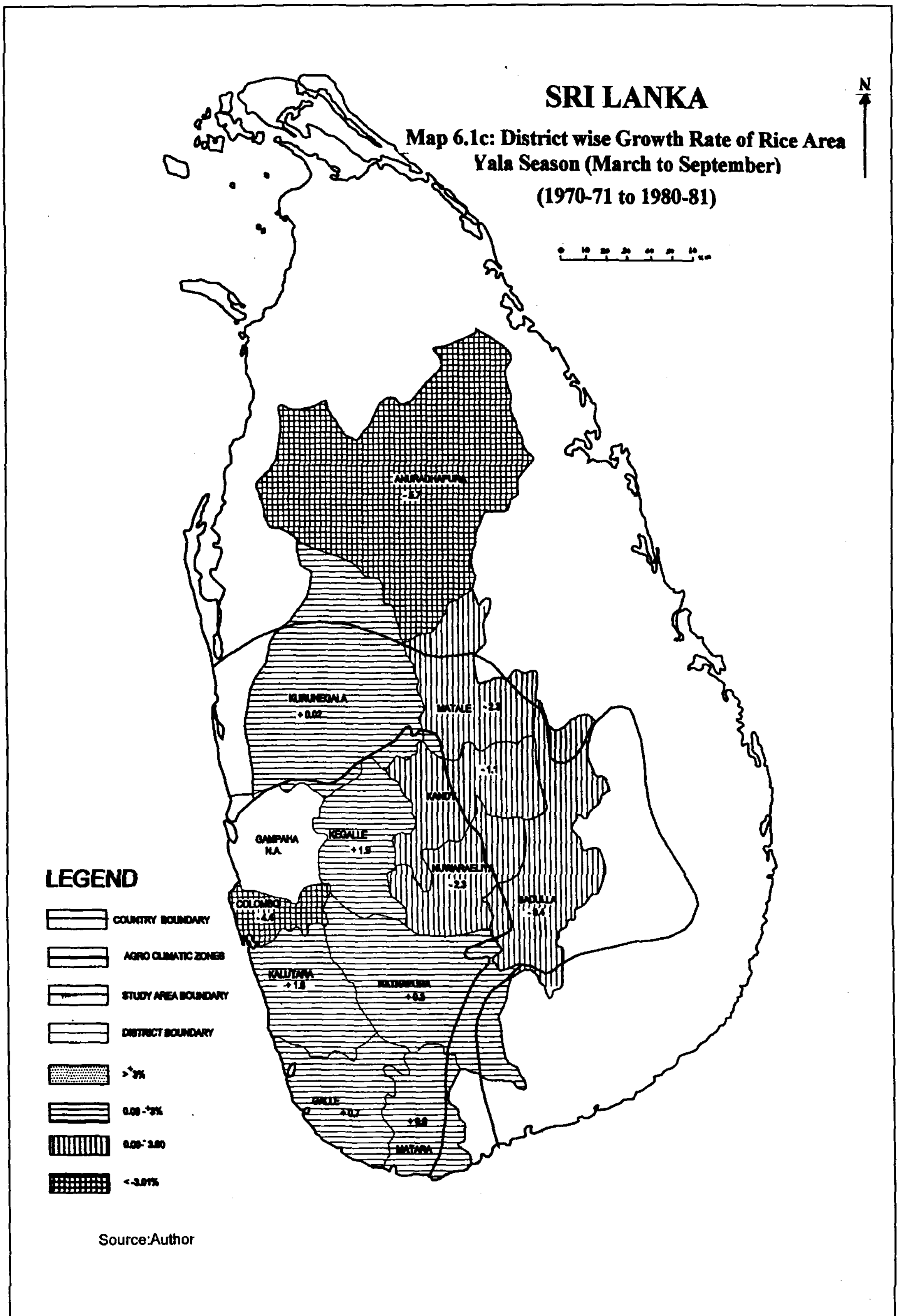
Districts	1970/71	1980/81	2000-2001	1970-71 to 1980-81	1980/81-2000/01	1970/71-2000/01
				Growth Rates in %/ year		
1.Anuradhapura: Extent	51291	21963	43181	-5.7	+4.8	-0.5
Yield	52	64	86	+2.3	+1.7	+2.2
Production	2134	1127	2969	-4.7	+8.2	+1.3
2.Badulla :Extent	12431	11989	25588	-0.4	+5.7	+3.5
Yield	47	42	90	-1.1	+5.8	+3.0
Production	495	424	1953	-1.4	+18.0	+9.8
3.Kurunegala: Extent	86375	86589	65649	+0.02	-1.2	-0.8
Yield	45	64	60	+4.1	-0.3	+1.1
Production	3311	5516	3949	+6.7	-1.4	+0.6
4.Colombo:Extent	27170	15088	2359	-4.4	-4.2	-3.0
Yield	33	45	52	+3.4	+0.8	+1.9
Production	771	575	105	-2.5	-4.1	-2.9
5.Gampaha: Extent	n.a	25809	3329	n.a	-4.4	n.a
Yield	n.a	50	55	n.a	+0.5	n.a
Production	n.a	1092	154	n.a	-4.3	n.a
6.Galle: Extent	44690	47685	16089	+0.7	-3.3	-2.1
Yield	29	34	51	+1.6	+2.5	+2.5
Production	1019	1260	639	+2.4	-2.5	-1.2
7.Kalutara: Extent	38325	44351	32178	+1.6	-1.4	-0.5
Yield	29	37	53	+2.6	+2.2	+2.7
Production	1034	1515	1574	+4.7	+0.2	+1.7
8.Kandy: Extent	38747	34432	24875	-1.1	-1.4	-1.2
Yield	56	57	74	+0.3	+1.4	+1.1
Production	1709	1562	1447	-0.9	-0.4	-0.5
9.Kegalle :Extent	21939	26016	14623	+1.9	-2.2	-1.1
Yield	47	59	60	+2.5	+0.2	+1.0
Production	965	1429	827	+4.8	-2.1	-0.5
10.Matale :Extent	13458	10429	15252	-2.3	+2.3	+0.4
Yield	45	56	71	+2.4	+1.4	+1.9
Production	542	521	971	-0.4	+4.3	+2.6
11.Nuwaraeliya:Extent	11395	8771	5562	-2.3	-1.8	-1.7
Yield	80	57	73	-2.9	+1.5	-0.3
Production	510	280	230	-4.5	-0.9	-1.8
12.Ratnapura: Extent	35177	36081	27312	+0.3	-1.2	-0.7
Yield	39	47	63	+2.0	+1.7	+2.0
Production	7776	1446	1457	-8.1	+0.04	-2.7
13.Matara: Extent	43584	46379	36221	+0.6	-1.1	-0.6
Yield	41	47	65	+1.6	+1.8	+1.9
Production	1405	1735	1853	+2.3	+0.3	+1.1

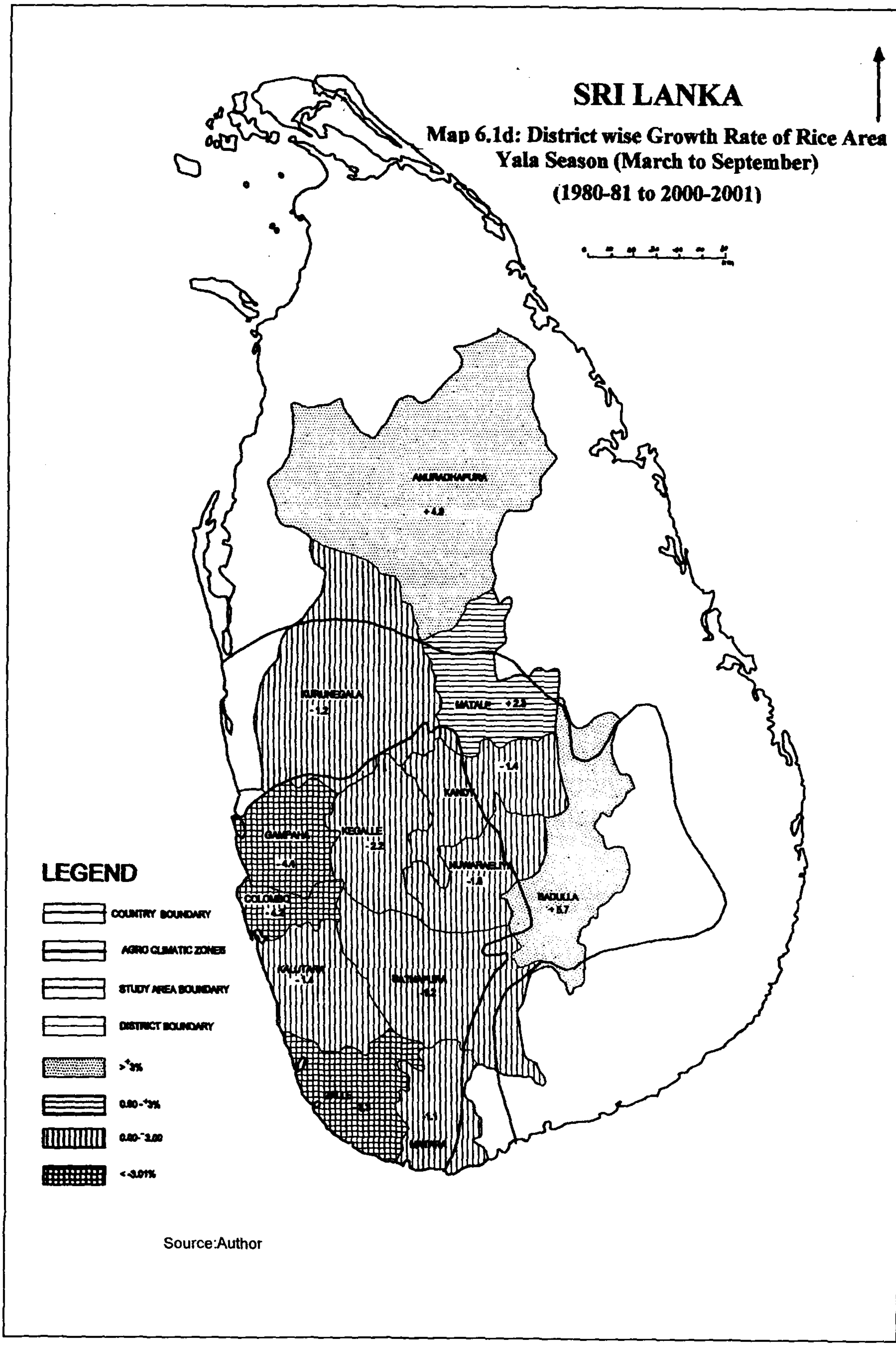
Source: Calculated by the author from 'Rice Statistics of Sri Lanka', Department of Census and Statistics, 1970-2001. Note: n.a. = not available.

Colombo, Galle, Kandy, Kegalle, Nuwaraeliya and Ratnapura districts indicate negative growth rates for rice coverage for the entire period of 1970-2001 for the 'Yala' season (Table 6.1g), i.e., negative Growth rate of rice coverage during Yala season, is higher (less than –2.0%/per year) in the districts of Colombo, Gampaha, Galle and Kegalle from 1980-81 to 2000-2001 (Map 6.1d). Negative growth rates of rice production are higher (less than –2.0%/per year), during Yala season, in the districts of Colombo, Gampaha, Galle and Kegalle from 1980-81 to 2000-2001. Negative Growth rate of rice coverage as well as production is higher during Yala season (less than –1.5%/per year), in the districts of Colombo, Galle, Nuwaraeliya and Ratnapura from 1970-71 to 2000-2001.


SRI LANKA
Map 6.1a: District wise Growth Rate of Rice Area
Maha Season (October to February)
(1970-71 to 1980-81)
ANURADHAPURA
KURUNEGALA
MATALE
KANDY
GAMPAHA
N.A.
KEGALLA
NUWARAELIYA
BADULLA
COLOMBO
KALUTARA
RATNAPURA
GALLE
+5.1
MATARA
LEGEND
COUNTRY BOUNDARY
AGRO CLIMATIC ZONES
STUDY AREA BOUNDARY
DISTRICT BOUNDARY
Source: Author


SRI LANKA
Map 6.1b: District wise Growth Rate of Rice Area
Maha Season (October to February)
(1980-81 to 2000-2001)
N
LEGEND
COUNTRY BOUNDARY
AGRO CLIMATIC ZONES
STUDY AREA BOUNDARY
DISTRICT BOUNDARY
ANURADHAPURA
KURUNEGALA
MATALE
KANDY
GAMPAHA
KEGALLE
NUWARAELIYA
+1.5
BADULLA
+1.7
COLOMBO
KALUTARA
RATNAPURA
GALLE
MATARA
Source: Author

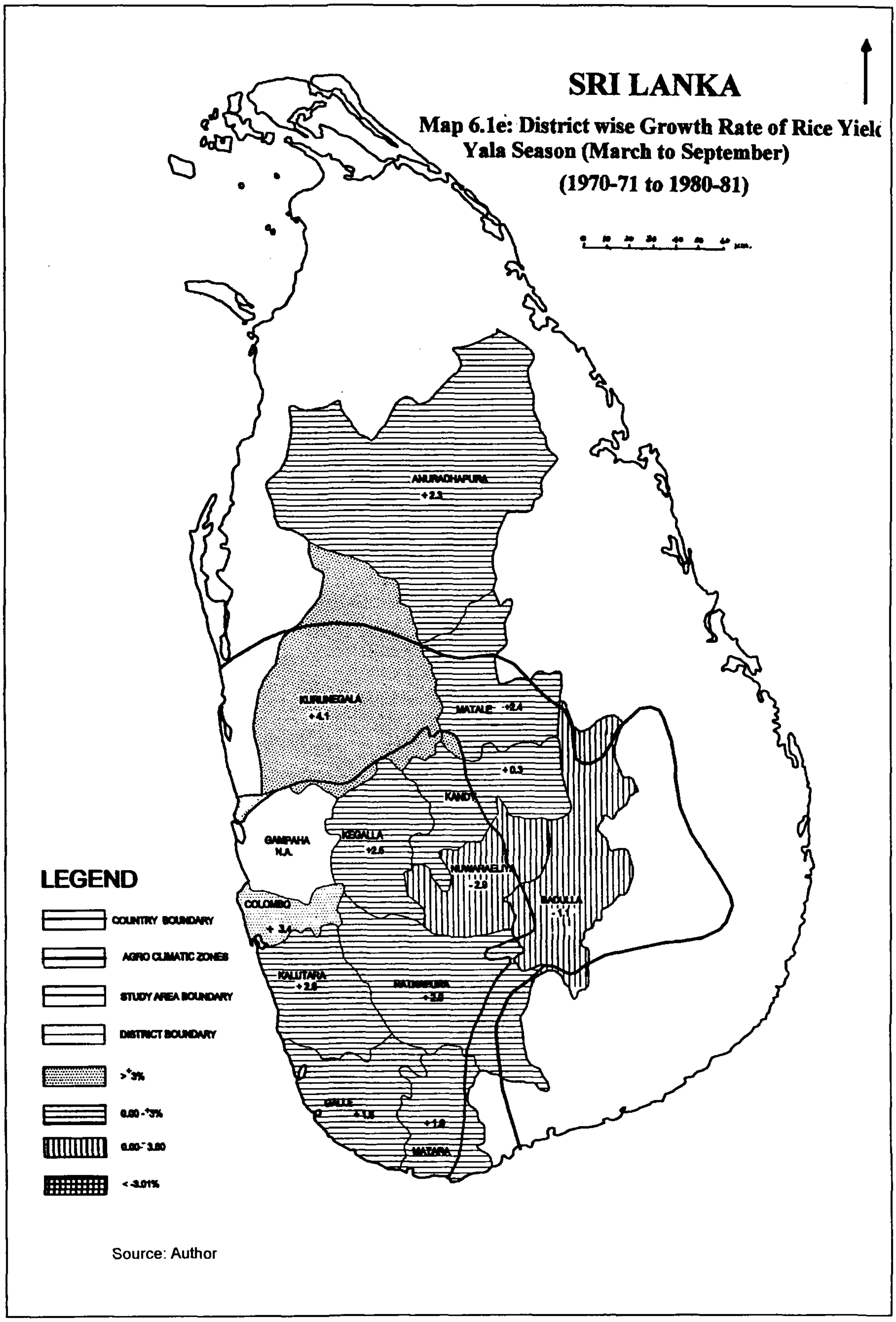

SRI LANKA
Map 6.1c: District wise Growth Rate of Rice Area
Yala Season (March to September)
(1970-71 to 1980-81)
N
ANURADHAPURA
KURUNEGALA
+ 0.02
MATALE
KANDY
GAMPAHA
N.A.
KEGALLE
NUWARAELIYA
-2.3
BADULLA
COLOMBO
KALUTARA
GALLE
MATARA
LEGEND
COUNTRY BOUNDARY
AGRO CLIMATIC ZONES
STUDY AREA BOUNDARY
DISTRICT BOUNDARY
<-3.01%
Source:Author



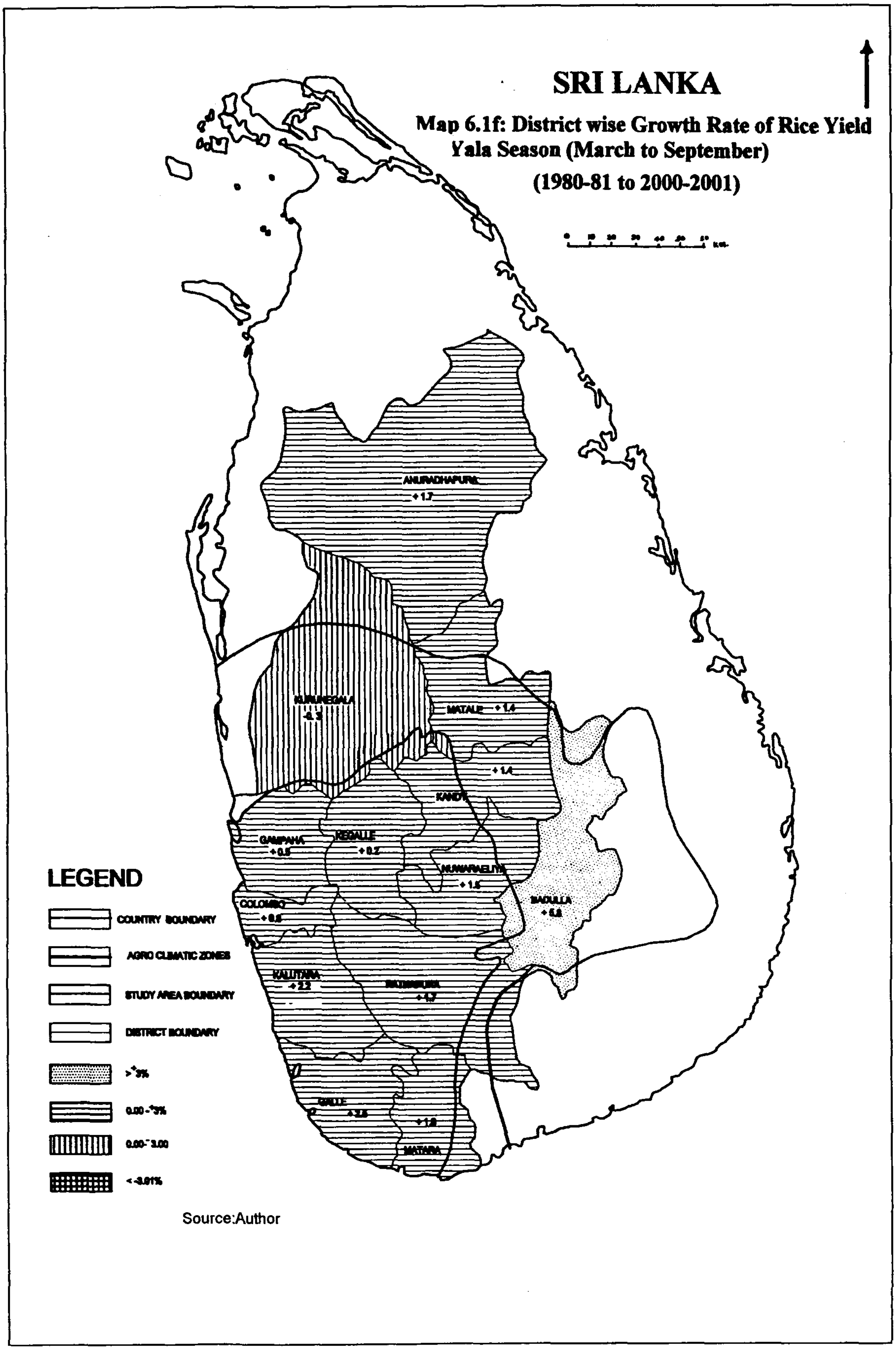
SRI LANKA

Map 6.1d: District wise Growth Rate of Rice Area Yala Season (March to September) (1980-81 to 2000-2001)

Source:Author



Map 6.1e: District wise Growth Rate of Rice Yielc
Yala Season (March to September)
(1970-71 to 1980-81)



SRI LANKA

Map 6.1f: District wise Growth Rate of Rice Yield Yala Season (March to September) (1980-81 to 2000-2001)

Part II: Analyses of Plantation Crops: Production, coverage and Yield

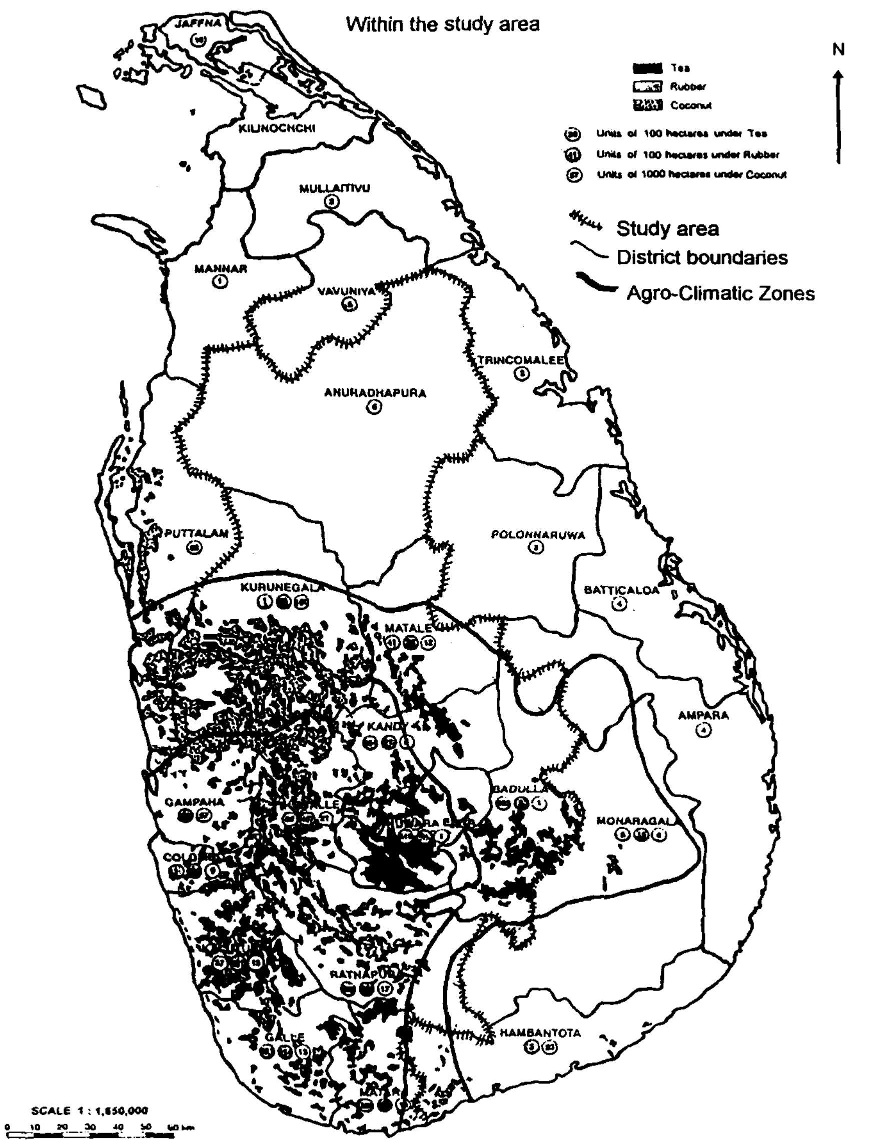
6.2 Introduction

The plantation crops, particularly tea and rubber need very high minimum rainfall requirements (more than 1500mm of evenly distributed annual rainfall), generally found in the Wet zone and in the moist parts of the Intermediate zone. The optimal rainfall for tea appears to be over 2500mm per annum and at least 500mm during the Southwest Monsoon season. Therefore, the districts in the central hill country, Kandy, Nuwara-eliya, Badulla and to a lesser extent, Ratnapura are tea regions par excellence having more than 75 per cent of the total coverage of the crop (Table 6.1). Much of the balance under tea is in the districts of Matara, Galle, Kegalle and Matale districts (Map 6.2). Tea yields are recorded to get affected adversely when dry conditions (less than 50mm of monthly rainfall) persist for more than a month.

Rubber is mainly a Wet zone mid-country crop, with over 60 per cent of the total planted areas concentrated in the Kegalle, Kalutara, and Ratnapura districts (Map 6.2). Colombo and Galle account for another 20 per cent of the rubber coverage and the balance is dispersed over other areas in the Wet zone or in the Intermediate zone with at least 1500mm annual and 400mm Southwest Monsoon rainfall, and free from more than two months of relative dry conditions. Due to other Agro-ecological requirements, rubber occupies the undulating terrain generally sandwiched between an upper tier of tea and a lower tier of coconut/Rice.

The spatial distribution of tea and rubber are thus more or less conditioned by rainfall regimes. Coconut on the other hand, due to its greater tolerance, (of a wide range of rainfall and other environmental conditions) is more widespread in its distribution (Map 6.2).

Map 6.2: Coverage of Tea, Coconut and Rubber Within the study area



Source: Somasekaram et al, 1997

It requires, even under the driest condition, well-distributed rainfall of over 2000mm, with no prolonged droughts. Hence, the importance of the coastal areas of the Wet zone and the Intermediate zone as the major habitat of the coconut palm with Kurunegala, Colombo and Puttalam districts accounting for more than 65 per cent of the total acreage. The rest of the Wet zone and areas in the Intermediate zone have around 20 per cent of the crop and the balance, scattered over the Dry zone in places where ground water availability partly makes up for lower or uneven rainfall. The optimal area of coconut cultivation, in term of coverage and yields is the coconut triangle formed by Colombo, Chillaw, and Kurunegala. Out side this region, one or more climatic constraints, mainly rainfall make for sub optimal conditions.

(A) Analyses of Tea Production, coverage and Yield

The optimal rainfall for tea appears to be over 2500mm per annum and at least, 500mm during the Southwest Monsoon season. Therefore, the district in the Central Highlands, i.e., districts of Kandy, Nuwaraeliya, Badulla (Map 6.2) and to a lesser extent, Ratnapura, are tea regions par excellence, having more than 75 per cent of the total coverage of the crop (Table 6.2a). The rest of the balance areas under tea are in the districts of Matara, Galle, Kegalle and Matale. The high sensitivity to drought explains the location of the prime tea areas in the rain swept up-country and mid-country localities of the Central Highlands of Sri Lanka.

(a) Analyses of Tea Production

Three major tea cultivation areas have been identified in Sri Lanka according to the elevation, which is as follows:

(i) High Grown Area: Tea lands average elevation of which is 4000ft (1220m) and above, above mean sea level : Districts of Kandy, Nuwaraeliya, Badulla).

(ii) Medium Grown Area: Tea land average elevation of which is above 2000ft (610m) but below 4000ft (1220m): Districts of Kandy, Nuwaraeliya, Badulla, Matale, Matara, Ratnapura, Kegalle, Kurunegala

(iii) Low Grown Area: Tea lands average elevation of which is below 2000ft. (610m): Districts of Kandy, Nuwaraeliya, Badulla, Mathale, Matara, Ratnapura, Kegalle, Kurunegala, Colombo, Kalutara, Galle, Hambantota

The steady increase in Sri Lanka`s total tea production in the early 1950`s reached a peak in 1965 with a maximum level of 228 million Kg. But tea production has progressively declined thereafter to a minimum of 179 million Kg. in 1983, which was a severely drought year. However, this declining trend in production reversed in 1984 and 1985, when 208 million Kg. and 214 million Kg were produced in the country. Tea production within the observation period reached a peak in 2000. Table 6.2a shows that high and medium grown tea production has been decreasing, while low grown tea production has been increasing.

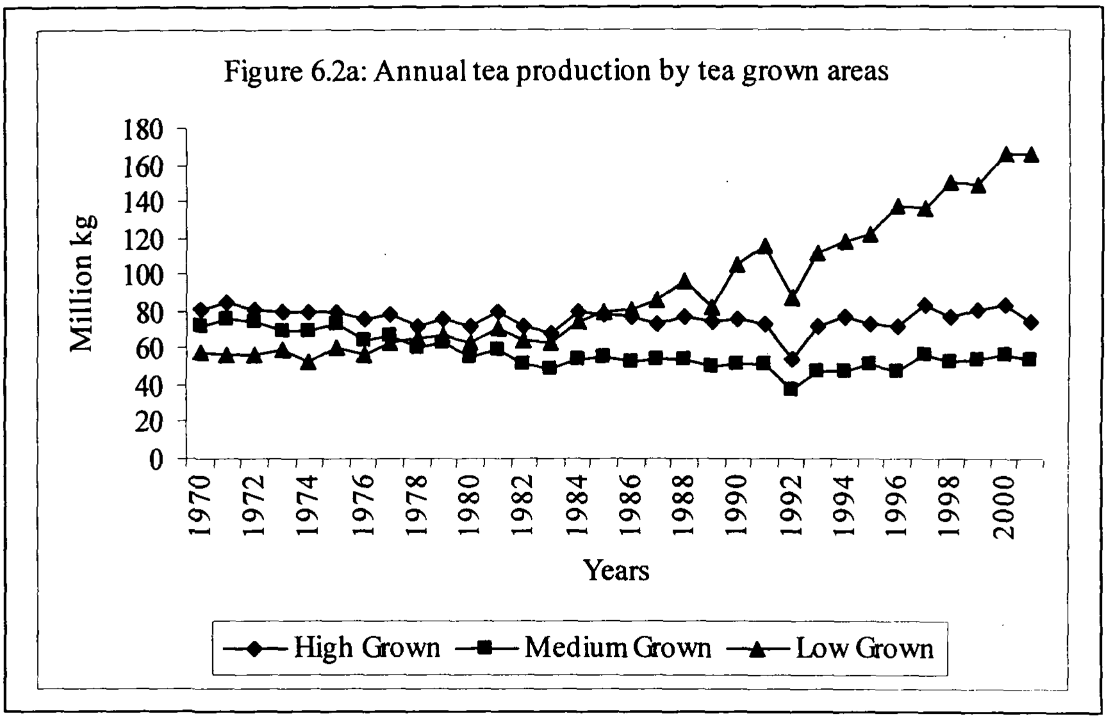
Table 6.2a: Annual tea production by tea grown areas: Million kg.

Years	H.G	M.G	L.G	T.P.	Years	H.G	M.G	L.G	T.P.
1970	81	71.6	58.2	210.8	1986	77	53.2	80.7	210.9
1971	84.3	75.4	56.5	216.2	1987	73.5	53.5	86.3	213.3
1972	80.9	74.3	56.5	211.7	1988	76.9	54.3	95.8	227
1973	79.9	69.7	59.6	209.2	1989	74	50.2	82.8	207
1974	79.4	70	52.5	201.9	1990	76.1	51.8	105.2	233.1
1975	80	73	60.4	213.4	1991	73.3	51.4	116.2	240.9
1976	75.8	64.3	56.1	196.2	1992	53.7	37.7	87.3	178.7
1977	78.7	66.5	63.2	208.4	1993	72.6	47.3	112.2	232.1
1978	71.5	60.9	65.9	198.3	1994	76.7	47.4	118	242.1
1979	76.4	62.4	67.1	205.9	1995	73.5	50.8	121.8	246.1
1980	72.4	55.5	63.1	191	1996	72.1	48	138.1	258.2
1981	80.3	59.2	70.2	209.7	1997	83.7	57	136	276.7
1982	71.5	51.6	64.3	187.4	1998	77.3	52.2	150.3	279.8
1983	67.7	48.4	62.9	179	1999	81.4	53.5	148.8	283.7
1984	79.3	54.6	74.1	208	2000	83.4	56.1	166.2	305.7
1985	78.9	55	80.1	214	2001	74.9	53.8	166.2	294.9

Source: Compiled by the Author from 'Statistical Bulletin', Sri Lanka Tea Board, 2001.
Notes: T.P: Total Production, H.G.: High Grown, M.G.: Medium Grown, L.G.: Low Grown.

Annual tea production has steadily increased after 1992, in all the tea growing areas, but increasing trend is much stronger in the low tea grown areas as compared to other tea growing areas, like high and medium grown areas (Figure 6.2a).

Figure 6.2a: Annual tea production by tea grown areas



(b) Analyses of Tea Extent Areas

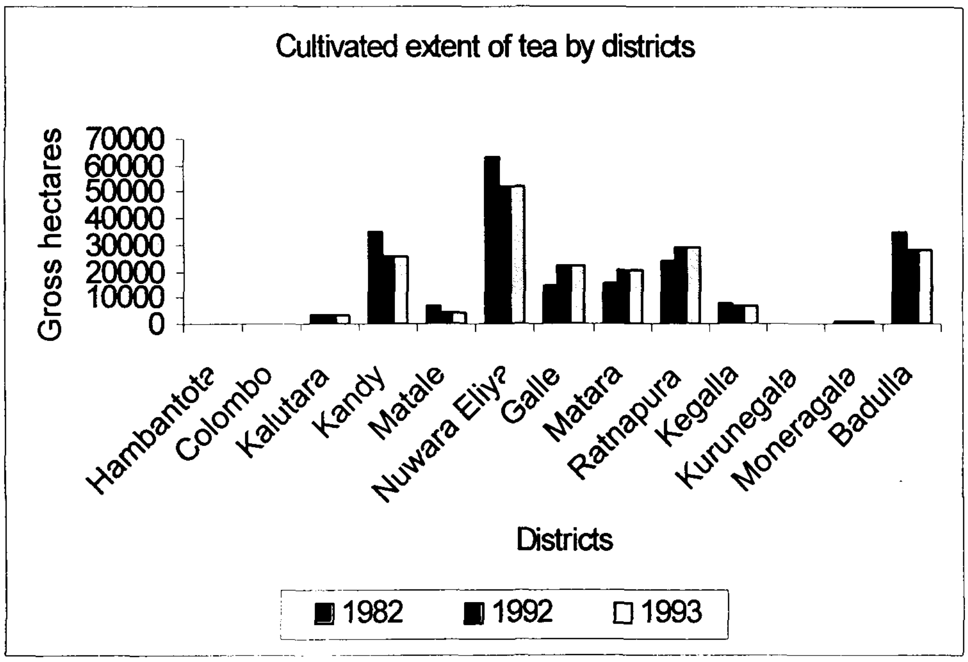
Table 6.2b: Cultivated area of tea by districts (Gross Hectares)

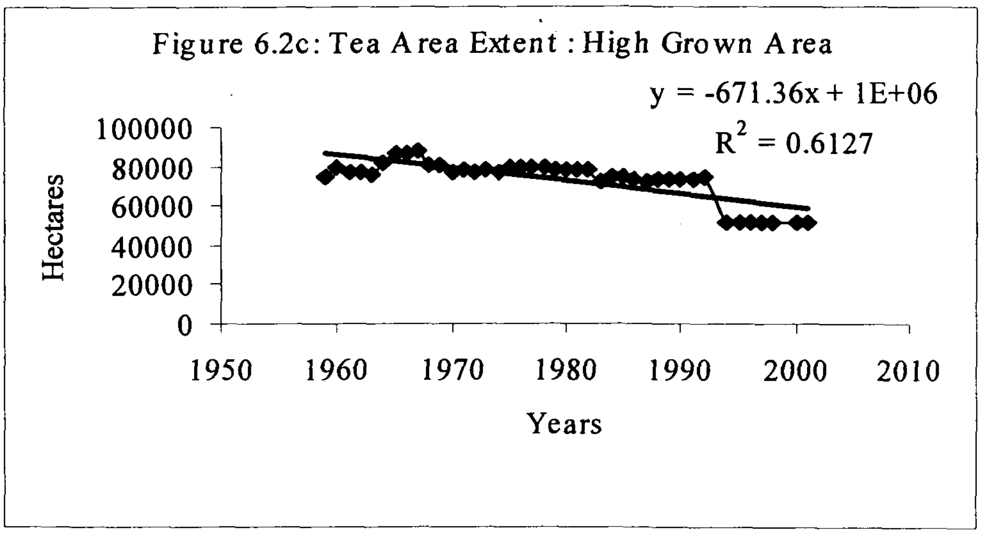
Districts	1982	1992	1993
Hambantota	142	273	273
Colombo	251	72	72
Kalutara	3586	3658	3658
Kandy	35062	25488	25438
Matale	7105	4098	4098
Nuwara Eliya	62822	51817	51817
Galle	14609	22084	22084
Matara	15540	20295	20817
Ratnapura	24064	28819	28819
Kegalla	7987	6867	6857
Kurunegala	420	350	94
Moneragala	797	543	543
Badulla	34741	28160	28160
Total	207126	192524	192730

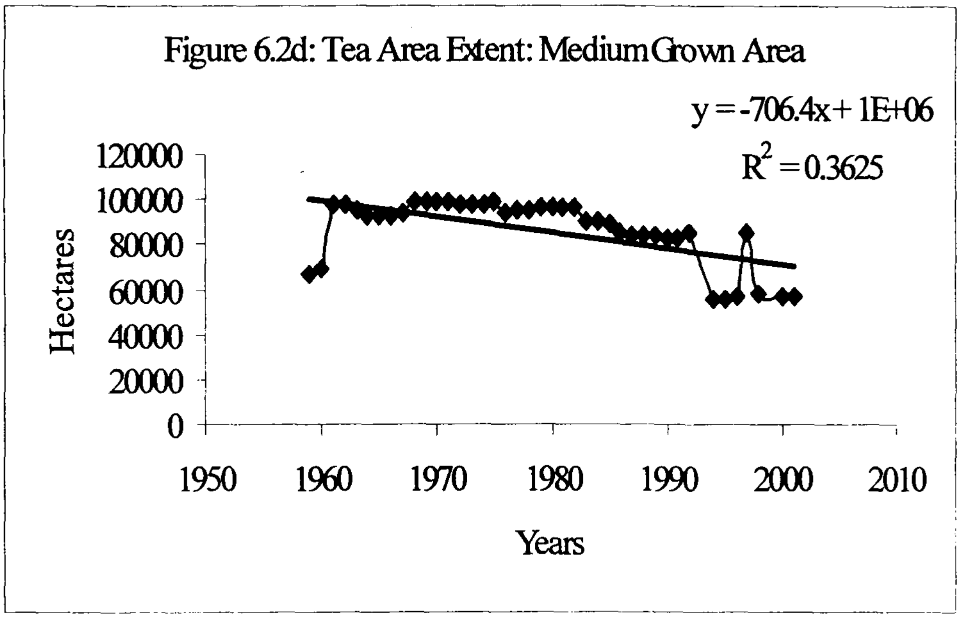
Source: Department of Census and Statistics, Census of Agriculture, 1982, 1992 and 1993.

Tea area coverage by tea grown areas is provided in Appendix 1. Table 6.2b provides information on tea cultivated area by districts between 1982 and 1993. Out of the thirteen districts, eight of the districts show that the tea cultivation area has been decreasing. According to cultivated tea coverage by districts, Nuwaraeliys was the highest tea cultivation district. But cultivation area has been decreasing since 1982 (Figure 6.2b). Kandy and Badulla districts are next in important for tea cultivation. But cultivated area has been decreasing these two districts too, since 1982. According to classification of tea grown areas in Sri Lanka, these three district belongs to Low, Medium and High grown tea areas. Colombo and Kurunegala recorded the lowest tea cultivation districts. Tea cultivated area has been increasing in the districts of Galle, Matara and Ratnapura, which are situated in the Wet zone in Sri Lanka.

Figure 6.2b: Tea Cultivated Area by Districts



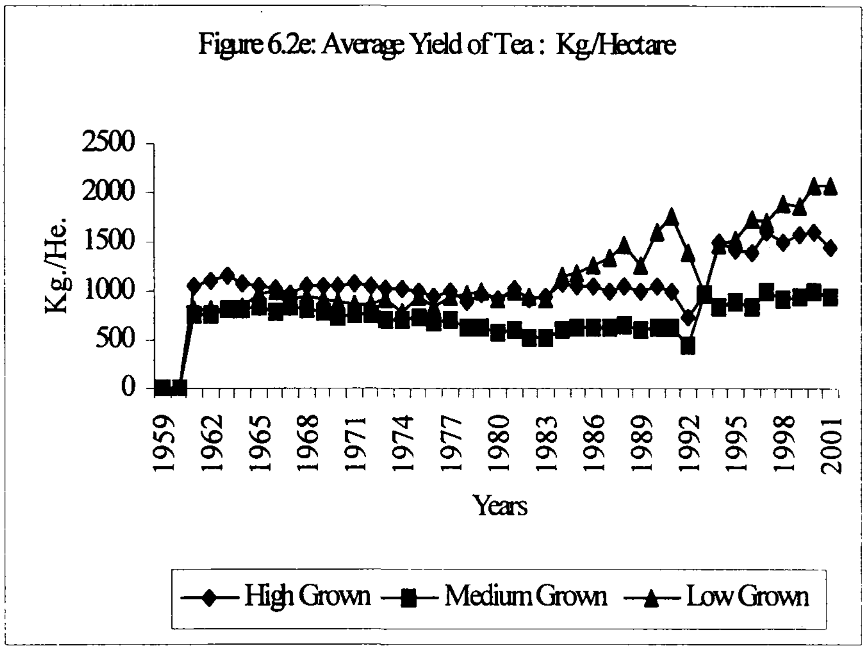




The coverage of tea crop according to tea growing areas are given in the Appendix 1. Area coverage of the crop has been decreasing at the high (Figures 6.2c) and medium grown areas (Figures 6.2d), whereas, in low grown areas the trend is that of increasing one.

(c) Average Yield of Tea

Average yield of tea between 1970 and 2001 are given in the table 6.2c, separately according to the tea grown areas. It is noted, that the high grown and low grown areas where yield of tea have been increasing, while medium grown yield of tea has been decreasing (Figure 6.2e).



The small-holding tea sector (less than 4 hectares) is the mainstay in national tea production of Sri Lanka. The small-holder tea sector, which controls 48 per cent of the area under tea and contributes to 62 per cent of the national output, indicates that the productivity of the small-holdings is higher than those of the corporate (larger gardens) sector. The average yield in the small-holding sector amount to 2212 Kg. /ha., whereas, in the corporate sector, it was only 1441 Kg /ha during 2001. The small holdings are mainly concentrated in the lower elevations and have high yielding propagated (VP) tea bushes compared to the corporate sector, which still has a substantial area with low yielding old tea plants.

Table 6.2c: Average yield of tea (Kg. /hectares)

Years	H.G	M.G	L.G	T.A.	Years	H.G	M.G	L.G	T.A.
1970	1046	732	898	892	1986	1053	626	1255	978
1971	1085	770	872	909	1987	1009	634	1344	996
1972	1048	763	866	892	1988	1054	645	1484	1061
1973	1036	717	909	887	1989	1013	595	1276	961
1974	1033	720	799	851	1990	1041	624	1607	1091
1975	1010	742	943	898	1991	999	622	1764	1128
1976	950	683	847	827	1992	725	443	1404	857
1977	988	703	937	876	1993	979	979	979	979
1978	902	640	971	838	1994	1491	845	1481	1272
1979	974	643	986	868	1995	1428	902	1529	1286
1980	921	573	917	804	1996	1382	845	1730	1319
1981	1024	613	1012	883	1997	1603	1004	1704	1437
1982	922	534	952	803	1998	1504	932	1886	1441
1983	942	537	930	803	1999	1580	953	1868	1467
1984	1070	606	1166	947	2000	1597	988	2081	1555
1985	1054	619	1183	952	2001	1437	946	2082	1488
1986	1053	626	1255	978	-	-	-	-	-

Source: Compiled by the author from 'Statistical Bulletin', Sri Lanka Tea Board, 2001.
Notes: T.A: Total Average, H.G.: High Grown, M.G.: Medium Grown, L.G.: Low Grown.

6.3 Analyses of Rubber Production, coverage and Yield

(a) Analyses of Rubber Production

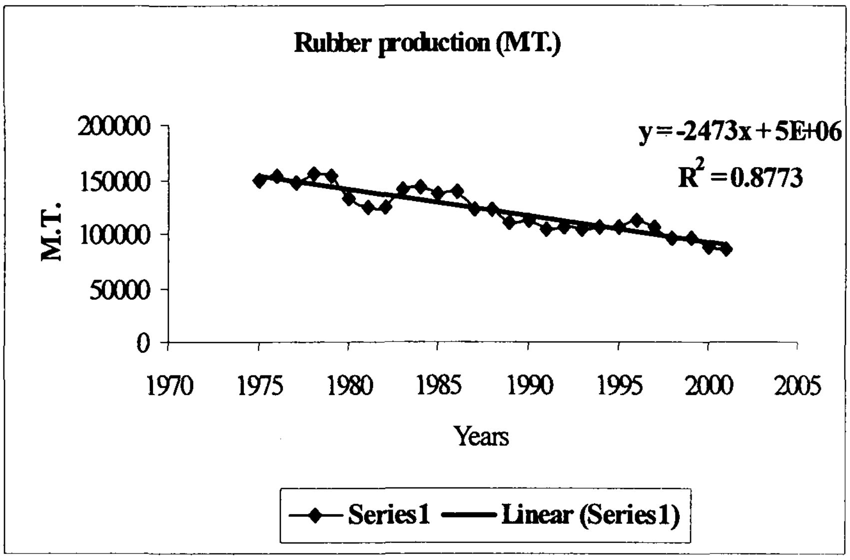
Rubber is mainly a Wet zone mid-country crop, with over 60 per cent of the total area covered concentrated in the Kegalle, Kalutara and Ratnapura districts. Colombo and Galle account for another 20 per cent and the balance are dispersed over other areas in the Wet zone or in the Intermediate zone with at least 1500mm annual and 400mm Southwest Monsoon rainfall. Due to other agro-ecological requirements, rubber occupies the undulating terrains, generally sandwiched between upper tier of tea and a lower tier of coconut/rice areas. The spatial distribution of tea and rubber are thus more or less controlled by rainfall conditions and also, the plantation crops generally are cultivated under rain-fed conditions.

Table 6.3a: Rubber production of Sri Lanka (M.T)

Years	Production	Years	Production	Years	Production
1970	156644	1981	123944	1992	106150
1971	139174	1982	125230	1993	104200
1972	138153	1983	139997	1994	105301
1973	152232	1984	141924	1995	105717
1974	129923	1985	137493	1996	112490
1975	148753	1986	137810	1997	105782
1976	152134	1987	121806	1998	95710
1977	146243	1988	122393	1999	96585
1978	155662	1989	110743	2000	87636
1979	152703	1990	113096	2001	86232
1980	133150	1991	103854	-	-

Source: Compiled by Author from 'Rubber Statistics' 1970-2001, Rubber Development Department.

Figure 6.3a: Rubber production in Sri Lanka



The rubber sector shows variations in production during the past years. The total rubber production of 156644 metric tons in 1970 declined to 86232 metric tons in 2001 and has further declined to 86,232 metric tons in 2001 (Table 6.3a). Even though, the over all trend of rubber production in Sri Lanka shows an increasing trend, but the trend was not significant for the production. The rubber production trends are negative and decreasing, particularly after the year 1975 (Figure 6.3a).

(b) Analysis of Rubber Area Coverage

The total land area under rubber presently covers only 157,000 hectares, as a result of the continuous shrinkage of coverage, i.e., by 19 per cent during past ten years.

Out of this coverage, 101,175 hectares are under the small-holding sector, and it contributes to around 60 per cent of the rubber production.

Table 6.3b: Rubber average area extent hectares

Districts	1971-80	1981-1990	1991-2000
Colombo	25547	22888	16377
Kalutara	51119	46202	42446
Galle	30800	19832	12669
Matara	12059	8070	5793
Hambantota	93	84	38
Ratnapura	40697	36723	30771
Kegalle	58015	49794	47415
Kurunegala	9079	4688	3343
Kandy	17499	4908	2442
Matale	12361	5772	2788
Badulla	8093	3768	2158
Nuwara Eliya	202	n.a	n.a

Source: Calculated by the author from 'Rubber Statistics' from 1971-2000, Rubber Development Department.

Notes: Since 1981 Gampaha joined to Colombo, and Moneragala Joined to Badulla
n.a = not available.

Coverage of rubber area are shown in the table 6.3b. Kegalle, Kalutara and Ratnapura are the most cultivated districts, and these three districts belong to the Wet zone. A linear trend analysis for rubber coverage clearly shows that the coverage of rubber has been decreasing in most of the rubber districts (Table 6.3c), except Hambantota and Kurunegala districts.

Table 6.3c: Linear Trends (equation) for Rubber Coverage: 1961-2001

Districts	Equation	R values
Colombo	Y= -343.06x+70234	*R^2=0.673
Kalutara	Y= -335.39x+71227	*R^2=0.774
Galle	Y= -610.66x+1E+06	*R^2=0.797
Matara	Y= -206.24x+41789	*R^2=0.695
Hambantota	Y= -2.0887x+4305	R^2=0.002
Ratnapura	Y= -398.87+827701	*R^2=0.799
Kegalle	Y= -457.88x+96079	*R^2=0.799
Kurunegala	Y= -150.64x+30452	R^2=0.2408
Kandy	Y= -580.11x+1E+06	*R^2=0.849
Matale	Y= -369.39x+74014	*R^2=0.904
Badulla	Y= -208.81x+41903	*R^2=0.842

Source: Calculated by the author from 'Rubber Statistics' Rubber Development Department, 1961-2001.
Note: *=Significant.

(c) Yield of Rubber

Average yield of rubber from 1982 to 1997 has been given in the table 6.3d. Average yield of rubber is fluctuating, and the yield is less than the potential yield of 2000 Kg per hectare.

Table 6.3d: Average yield of rubber

Years	Average yield per Ha./kg	Years	Average yield per Ha./kg
1982	733	1990	773
1983	821	1991	706
1984	841	1992	725
1985	890	1993	873
1986	919	1994	870
1987	826	1995	872
1988	841	1996	920
1989	752	1997	857

Source: Rubber Development Department, 'Rubber Statistics', 1998.

6.4 Analysis of Trend of Coconut Production, Coverage and Yield

Coconut due to its greater tolerance of a wide range of rainfall and other environmental conditions is more widespread in its spatial distribution (Map 6.2) in Sri Lanka. Ideal conditions are found, under well distributed rainfall of over 2000 mm with no prolonged drought periods. Hence, the importance of the coastal areas of the Wet zone and the Intermediate zone are the major habitat of the coconut palm, particularly in the districts of Kurunegala, Colombo and Puttalam that account for more than 65 per cent of the total acreage. The rest of the Wet zone and areas in the Intermediate zone have around 20 per cent. The balance is scattered over the Dry zones in places where ground water availability partly makes up for lower or uneven rainfall. The optimal area of coconut cultivation in terms of extent and yields is the "coconut triangle" formed by Colombo, Chilaw and Kurunegala (Abeywardene, 1972).

(a) Analysis of coconut production

Coconut production (million nuts) between 1970 and 2001 is indicted in the table 6.4a. Coconut production has been fluctuating over the whole period, and in some years, the production is below the average of 2435, viz. 1973-81, 1983-84, 1987-88 and 1991-93. The highest production was recorded (3096 million nuts) in the year 2000, but in the next year (2001) production plumetted to 2769 million nuts (Table 6.4a).

Table 6.4a: Coconut production in Sri Lanka: Million nuts*

Years	Production	Years	Production	Years	Production	Years	Production
1970	2510	1978	2207	1986	3039	1994	2622
1971	2610	1979	2393	1987	2292	1995	2755
1972	2963	1980	2026	1988	1937	1996	2546
1973	1935	1981	2258	1989	2484	1997	2631
1974	2031	1982	2521	1990	2532	1998	2504
1975	2398	1983	2312	1991	2184	1999	2828
1976	2330	1984	1942	1992	2296	2000	3096
1977	1821	1985	2958	1993	2164	2001	2769

Source: Sri Lanka Coconut Statistics, Coconut Development Authority, From 1970- 2001 and Sri Lanka Census of Agriculture, Department of Census & Statistics.

* No district-wise statistics for coco-nut production is available for Sri Lanka.

It is noticed that coconut production in Sri Lanka increased between 1950 to 1970, and hereafter, during the decade of 1970-1980 it decreased steadily. After 1986, the production went up and started to increase continuously. It may be noted that coconut production susceptible to the drought years in Sri Lanka.

(b) Analyses of Area Extent of Coconut

The coverage of coco-nut crop is shown in the table 6.4b. Districts-wise coverage of coconut have been reported only by decades. Between 1960s and 1993s, the coconut cultivation area has been decreasing significantly in some districts. Colombo, Kalutara, Ratmalana, Puttalama and Kegalla are the excellent examples (Figure 6.4a). Coconut area has increased in the districts of Moneragala, Rathnapura and Mathale. It is noticed that the districts of Intermediate zone, the coverage of coconut cultivation has been increasing in the recent past.

Table 6.4b: Area Coverage of Coconut: 1962-1993

Districts	1962	1973	1982	1993
Colombo+Gampaha	89029	77838	66271	65824
Kalutara	15238	11838	12358	12716
Kandy	8471	9062	8306	8363
Matale	8703	12836	9296	11880
Nuwara Eliya	583	444	834	1037
Galle	15010	18189	13244	12879
Matara	15086	16346	14370	16179
Kurunegala	156630	161285	149106	159829
Anuradhapura	5371	6040	5727	5728
Badulla	513	2298	885	1212
Rathnapura	11404	12529	12429	16777
Puttalam	58916	57788	51784	51781
Kegalla	28301	20836	20420	21458
Moneragala	2882	2327	4172	6401
Polonnaruwa	2882	1274	3002	3003
Hambantota	20910	24329	20430	23173

Source: Sri Lanka Coconut Statistics, Coconut Development Authority, From 1962-1993 and Sri Lanka Census of Agriculture, Department of Census & Statistics, From 1962-1993

Figure 6.4a: Coverage of Coconut in Puttalama District

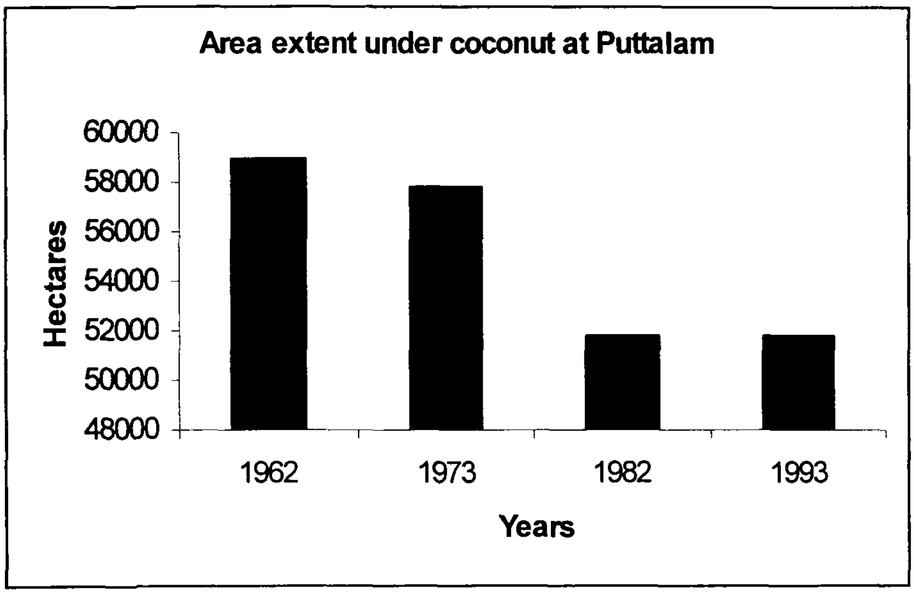


Table 6.4c: Linear Trend of Coconut Coverage: 1963-1993

Districts	Equation	R values
Colombo+Gampaha	Y = -8118.2x+95036	*R=0.903
Kalutara	Y = -70.539x+15253	*R=0.379
Kandy	Y = -9.7428x+27817	R=0.136
Matale	Y = 63.941x-11577	R=0.179
Nuwara Eliya	Y = 16.875x-32646	*R=0.712
Galle	Y = -106.11x+22466	R=0.333
Matara	Y = 15.45x-15057	R=0.047
Kurunegala	Y = -10.021x+17653	R=0.001
Anuradhapura	Y = 7.9175x-9940.3	R=0.146
Badulla	Y = 8.5912x-15762	R=0.022
Rathnapura	Y = 158.99x-30111	*R=0.773
Puttalam	Y = -264.13x+57738	*R=0.830
Kegalla	Y = -207.19x+43244	*R=0.538
Moneragala	Y = 120.63x-23460	*R=0.771
Polonnaruwa	Y =18.525x-34093	R=0.083
Hambantota	Y = 33.649x-44330	R=0.057

Source: Calculated by author from' Sri Lanka Coconut Statistics', Coconut Development Authority, from 1963-1993 and 'Sri Lanka Census of Agriculture', Department of Census & Statistics, from 1963-1993.
Notes: *=Significant.

A linear trend analysis has been carried-out that indicate the coverage of the crop has been decreasing in the districts of Colombo (and Gampaha), Kalutara, Kandy, Galle, Kurunegala, Puttalama and Kegalle. The negative trends are significant at Colombo (and Gampaha), Kalutara, Puttalama and Kegalle. Positive trends are noticed in the districts of Nuwaraeliya, Rathnapura and Moneragala (Table 6.4c).

(c) Yield of Coconut

Present annual average yield is around 6300 nuts per hectares. Generally, the average estimated optimum yield is around 10,000 nuts per hectare per annum. The low yield in coconut is mainly the results of poor cultivation practices adopted by the small-holders, neglecting field maintenance, insufficient usage of scientific and modern cultivation practices, apart from the unfavourable weather conditions that prevail year to year.

6.5 Summary of Findings

(a) Paddy

(1) Trend of rice production was positive for Anuradhapura, Kurunegala, Kalutara, Badulla, Galle, Matale, Ratnapura and Matara during 'Maha' season from 1969 to 2001. Linear trend is significant in the districts of Kalutara, Badulla, Galle, Matale, Ratnapura and Matara. The rice production declined in the districts of Colombo Kandy, Nuwaraeliya, Gampaha and Kegalle during the 'Maha' season. The negative trend is stronger at Colombo, Kandy, Nuwaraeliya and Gampaha.

(2) The trend of rice production was positive in the districts of Anuradhapura, Kurunegala, Kalutara, Badulla, Matale and Matara during 'Yala' cultivation season from 1969 to 2001. Trends indicate that the production has been increasing in the districts of Kalutara, Badulla, Mathale and Matara. However, during 'Yala' season during the reference period, in the districts of Colombo, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle rice production were negative. The negative trends are particularly stronger in Colombo, Kandy and Nuwaraeliya

(3) The trend of rice coverage was positive in the districts of Badulla, Galle Matale and Matara during 'Maha' cultivation between 1969 and 2001. The positive trend is significant only in the districts of Badulla and Matale. The trends of rice coverage were negative in the districts of Anuradhapura, Kurunegala, Kalutara, Colombo, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle during 'Maha' season. The negative trends are particularly significant in the districts of Colombo, Kandy, Gampaha and Kegalle during the same season.

(4) The trend of rice coverage was positive only at Badulla and Matale during 'Yala' cultivation season between 1969 and 2001. The positive trend is significant only at Badulla. The trends of rice coverage suffered in the districts of Anuradhapura, Kurunegala, Kalutara, Colombo, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha, Kegalla and Matara during the 'Yala' season. The trends are particularly significant in the districts of Kalutara, Colombo, Galle, Kandy and Nuwaraeliya and Gampaha.

(5) Average yield of paddy has been increasing continuously, almost in all the districts in the 'Maha' and 'Yala' seasons, since 1971. The average yield of rice in 'Yala' season is similar to average yield of 'Maha' season, in some of the districts. Anuradhapura, Badulla and Mathale have recorded the highest yields in the 'Maha' season (more than 80 bushels per net acres) in the 2000-0. The lowest yield was recorded in the districts of Galle and Kalutara. The districts of Anuradhapura and Badulla recorded the highest yield in the 'Yala' season (more

than 80 bushels per net acres) in the 2001. The lowest yields were recorded in Colombo, Gampaha, Galle and Kalutara.

(6) Growth rate of rice coverage is negative in the districts of Anuradhapura, Colombo, and Nuwaraeliya between 1970 and 1981 for the 'Maha' season. Negative growth rate of coverage of the crop have been recorded in the districts of Anuradhapura, Kurunegala, Colombo, Gampaha, Galle, Kalutara, Kandy, Kegalla, Matale, Ratnapura and Matara during 1980 to 2001'(Maha' season). During 1970-2001 period, negative growth rate can be noticed above districts, except the districts of Matale and Matara. Growth rate of rice yield is negative in the districts of Badulla, and Nuwaraeliya during 1970-81. Growth rate of rice production is negative at Colombo and Nuwaraeliya during the decade of 1970-81. During 1980-2001 period, the Maha season production observed a negative growth rates in districts of Kurunegala, Colombo, Kandy and Kegalle. Negative growth rates of rice coverage were observed in the districts of Anuradhapura, Kurunegala, Colombo, Gampaha, Kandy and Kegalle from 1980-81 to 2000-2001 (less than -1.5%/per year), during Maha season. Rice production also recorded negative growth rate (less than -1.5%/per year) in the districts of Kurunegala, Gampaha and Kegalle from 1980-81 to 2000-2001, during Maha season.

(7) During the 'Yala' season, negative growth rates of rice coverage is observed in the districts of Anuradhapura, Badulla, Colombo, Kandy, Matale, Nuwaraeliya, through out the decade of 1970-1981. During the same season for the decades of

1980-2001, negative growth rates of rice coverage could be observed in the districts of Kurunegala, Colombo, Gampaha, Galle, Kalutara, Kandy, Kegalle, Nuwaraeliya, Ratnapura, and Matara. Anuradhapura, Kurunegala, Colombo, Galle, Kalutara, Kandy, Kegalle, Nuwaraeliya, Ratnapura and Matara districts, all show negative growth rates of rice coverage for the entire period of 1970-2001.

(b) Tea

(1) High and medium grown tea production have been decreasing, whereas low grown tea production has been increasing. Overall, annual tea production has steadily increased after 1992, in all the tea grown areas. Districts-wise high grown areas are located in the districts of Kandy, Nuwaraeliya and Badulla. According to tea cultivation districts, Nuwaraeliys was the highest tea cultivation district. But cultivation area has been decreasing from 1982 to 1993. Kandy and Badulla are the next important tea cultivation districts. But cultivation area has been decreasing in these two districts too, after 1982. According to classification of tea grown areas in Sri Lanka, these three districts belong to Low, Medium and High grown tea areas.

(2) The high grown and low grown yield of tea has been increasing, while medium grown yield of tea has been decreasing. The average yield in the small-holder sector amounted to 2212 Kg. per hectare, which is higher than the corporate

sector. The small holders, mainly concentrated in the low elevations, have high yielding propagated (VP) tea, as compared to the corporate sector.

(c) Rubber

(1) Rubber is mainly wet zone mid-country plantation crop, with over 60 per cent of the total area concentrated in the districts of Kegalle, Kalutara and Ratnapura. Colombo and Galle account for another 20 per cent. The trends of rubber area cultivated has been decreasing, drastically in most of the districts. All the districts reported negative trend of area coverage, except, Hambantota and Kurunegala.

(2) The rubber sector has shown variations in its production, during the past few years. The total rubber production of 156644 metric tons in 1970 declined to 86232 metric tons in 2001 and has further declined to 86,232 metric tons in 2001. Even though, the over all trend of rubber production in Sri Lanka, shows increasing trends but the trend was not significant for the production.

(d) Coconut

(1) Coconut production has been fluctuating over the years, particularly during 1973-81, 1983-84, 1987-88 and 1991-93. Highest production was recorded (3096 million nuts) in the year 2000, but year 2001, the production decreased to 2769 million nuts. The coconut production is severely affected during the drought years in Sri Lanka.

(2) Districts wise coconut cultivation coverage are measured by only at intervals of decades in Sri Lanka. Between 1960s and 1993s, the coconut cultivation area has decreased significantly, e.g., at Colombo, Kalutara, Ratmalana, Puttalama, and Kegalla districts. Coconut area has increased in the districts of Moneragala, Rathnapura and Mathale.

(3) The coverage of coconut cultivation has been decreasing in the districts of Colombo (and Gampaha), Kalutara, Kandy, Galle, Kurunegala, Puttalama and Kegalle. The negative trends are significant in the districts of Colombo (and Gampaha), Kalutara, Puttalama and Kegalle. Positive trends are noticed in Nuwaraeliya, Rathnapura and Moneragala districts.

Appendix 1: Tea area extent hectares by elevation

Hectares	1959	1960	1961	1962	1963	1964	1965	1966
High G.	74581	79586	76557	76707	76157	81538	87345	87214
Medium G.	66711	69482	97521	97857	95691	92281	92896	93305
Low G.	46101	48113	63644	64661	65862	65759	60365	60563
Total	187393	197181	237722	239225	237710	239578	240606	241082

1967	1968	1969	1970	1971	1972	1973	1974	1975
87529	81144	81092	77549	77936	77639	77793	77693	79337
93872	99359	98675	98624	98624	98252	98165	97875	98446
60945	61292	61616	65625	65625	65968	66343	66622	64099
242346	241795	241383	241798	242185	241859	242301	242190	241882

1976	1977	1978	1979	1980	1981	1982	1983	1984
79877	79653	79628	78614	78786	78621	77769	71959	74157
94338	94835	95591	97084	96950	96853	96644	90272	90203
66363	67523	68023	68401	68969	69444	67728	67834	63514
240578	242011	243242	244099	244705	244918	242141	230065	227874

1985	1986	1987	1988	1989	1990	1991	1992	1993
74706	73206	72773	72901	73110	73138	73331	74141	n.a
89175	85216	84445	84227	84062	83223	82467	85510	n.a
67769	64483	64280	64555	64938	65397	65893	62185	n.a
231650	222905	221498	221683	222110	221758	221691	221836	n.a

1994	1995	1996	1997	1998	1999	2000	2001
51433	51443	52272	51444	51444	n.a	52272	52272
56155	56155	56863	85155	58155	n.a	56863	56863
79711	79711	79836	79711	79711	n.a	79836	79836
187299	187309	188971	216310	189310	n.a	188971	188971

Source: Statistical Bulletin, Sri Lanka Tea Board, 2002.

Notes: High Grown Tea Areas: Tea lands average elevation of which is 4000ft=1220m. and above: Districts: Kandy,Nuwaraeliya, Badulla.

Medium Grown Tea Areas: Tea lands average elevation of which is above 2000ft.=610m but below 4000ft.=1220m Districts: Kandy, Nuwaraeliya, Badulla, Matale, Matara, Ratnapura, Kegalle, Kurunegala.

Low Grown Tea Areas: Tea lands average elevation of which is below 2000ft.=610m Districts: Kandy, Nuwaraeliya, Badulla, Matale, Matara, Ratnapura, Kegalle, Kurunegala, Colombo, Kalutara, Galle, Hambantota.

n.a.= not available.

Chapter – VII

Impacts of Climate Change on Agriculture in Sri Lanka

Agriculture is a complex process that involves natural, economic, social and cultural factors. The influence of climatic conditions or changes thereof can, at best, partly explain the successes or failures of crop husbandry in a region or a country like Sri Lanka, where agriculture plays a crucial role in the economic and social life of the people of the Island Nation.

This chapter examines the relationship between climate change and major agricultural crops in Sri Lanka. Major crops studied are: principal cereal crop rice and major plantation crops like, tea, rubber and coconut. The main climatic parameters are: rainfall and temperature. This chapter is divided into four parts: Part I concentrate on paddy and climate relationship; Part II analyses tea and climate relationship; Part III examines relationship of coconut and climate and part IV examines rubber plantation economy and climate relationship.

Part I: Relationship between Paddy and Climate

7.1 Paddy and Climate

7.1.1 (i) Paddy Production and Rainfall (Maha and Yala) 1969-70 to 2000-01

Positive correlation between paddy production and rainfall were found for 'Maha' season in districts of Anuradhapura, Kalutara, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle during the 'Yala' season, in districts of Anuradhapura, Colombo, Galle, Kandy, Nuwaraeliya, Matara, Gampaha and Kegalla. Significant positive correlations were found during 'Maha' season in districts of Galle, Nuwaraeliya, Ratnapura and Kegalle during 'Yala' season in districts of Anuradhapura and Kandy.

During 'Maha' negative correlation between paddy production and rainfall were found in districts of Kurunegala, Badulla, Mathale, Colombo and Matara during 'Yala' in the districts of Kurunegala, Badulla, Mathale, Kalutara and Ratnapura. Out of these negative cases, significant negative correlations were found for Kurunegala and during 'Yala' (Table 7.1 & Map 7.1).

(ii) Paddy Production and Temperature (Maha and Yala): 1969-70 to 2000-2001

During the 'Maha' season, positive correlations between paddy production and temperature were found in all the districts, except in districts of Colombo, Gampaha and Kegalla, and during 'Yala' season, in districts of Kurunegala, Badulla, Matara, Kalutara, Galle and Kegalle. Out of these positive cases, significant positive correlations were found in during 'Maha' at Anuradhapura, Kalutara, Badulla, Galle, Ratnapura and Matara during 'Yala' at Badulla, Mathale and Kalutara (Table 7.1 and Map 7.2).

During the 'Maha' season, negative correlation between paddy production and temperature were found in the districts of Colombo, Gampaha and Kegalle, and during 'Yala' season, in districts of Anuradhapura, Colombo, Kandy, Nuwaraeliya, Gampaha, Matara and Ratnapura. Out of these negative cases, significant negative correlation were found during 'Maha' at Colombo and Gampaha during 'Yala' at Anuradhapura, Colombo, Kandy, Ratnapura and Gampaha.

Table 7.1: Correlation coefficient between paddy production (000'bushels) of Maha and Yala and corresponding Maha and Yala seasons rainfall (mm) and temperature(°C) : 1969-70 to 2000-2001

Districts Maha Production	Maha Rainfall	Maha Temp.	Districts Yala Production	Yala Rainfall	Yala Temp.
Anuradhapura	0.32	*0.50	Anuradhapura	*0.45	*-0.35
Kurunegala	-0.08	0.27	Kurunegala	*-0.63	0.28
Badulla	-0.08	*0.82	Badulla	-0.26	*0.61
Mathale	-0.21	*0.37	Mathale	-0.18	*0.60
Kalutara	0.16	*0.92	Kalutara	-0.25	*0.81
Colombo	-0.28	*-0.69	Colombo	0.10	-0.44
Galle	*0.41	*0.74	Galle	0.10	0.16
Kandy	0.02	0.08	Kandy	*0.87	*-0.82
Nuwaraeliya	*0.65	0.32	Nuwaraeliya	0.19	-0.02
Ratnapura	*0.48	*0.71	Ratnapura	-0.05	*-0.69
Matara	-0.06	*0.70	Matara	0.04	-0.27
Gampaha	0.24	*-0.55	Gampaha	*-0.70	*-0.59
Kegalla	*0.49	-0.09	Kegalla	0.08	0.15

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on paddy records from Department of Census and Statistics, 1969-2001.

Notes: * = Significant.

7.1.2 Linear Regression Analyses: 1969-70 to 2000

(i) 'Maha' Rainfall on Paddy Production:

Linear Regression analysis of rainfall on paddy production shows positive slopes in the districts of Anuradhapura, Kalutara, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle, during the 'Maha' season. Negative slopes can be seen in the districts of Kurunegala, Badulla, Colombo, Mathale and Matara.

(ii) 'Maha' Temperature on Paddy Production:

Linear Regression analyses of temperature on paddy production shows positive slope at all the districts except Colombo, Gampaha and Kegalle during 'Maha' (Table 7.2).

Table 7.2: Linear regression equations for 'Maha' rainfall and temperature on paddy production: 1969 to 2001

Districts/Paddy Production of Maha	'Maha' : Rainfall	'Maha' : Temperature
Anuradhapura	Y= 43.343x-1249.9 R^2= 0.1036	Y= 1344x-29113 R^2= 0.2461
Kurunegala	Y= -4.4118x+9835 R^2= 0.0062	Y= 2047.9x-45190 R^2= 0.0735
Kalutara	Y= 1.9224x+1242 R^2= 0264	Y=624.36x-15155 R^2=0.8377
Badulla	Y= -2.6495x+3170.9 R^2= 0.0061	Y= 655.61x-11352 R^2= 0.6749
Colombo	Y= -0.0111x+196.81 R^2= 0.0776	Y= -1493.5x+41138 R^2= 0.4749
Galle	Y= 3.4144x+859.44 R^2= 0.1642	Y= 1258.7x-31969 R^2= 0.5526
Kandy	Y= 0.2086x+2457.1 R^2= 0.0006	Y= 76.721x+655.27 R^2= 0.0057
Mathale	Y= -2.1664x+2643.8 R^2=0.0441	Y=587.95x+12056 R^2=0.1368
Nuwaraeliya	Y= 3.5125x-53.936 R^2= 0.4279	Y= 212.64x-2645.2 R^2= 0.1014
Ratnapura	Y= 4.0578x+692.68 R^2= 0.2324	Y= 926.9x-23621 R^2= 0.4981
Matara	Y=-0.8918x+1884.6 R^2=0.0037	Y=173512x-44430 R^2=0.4943
Gampaha	Y=4.1169x+806.8 R^2=0.0575	Y=-1138.2x+32283 R^2=0.2999
Kegalle	Y=8E-05x+25.57 R^2=0.0002	Y=-85.333x+3718.5 R^2=0.009

Source: Calculate by author, based on temperature and rainfall records of Department of Meteorology and based on paddy records of Department of Census and Statistics, 1969-2001.

Note: Y is production of rice and X, rainfall/ temperature.

Table 7.3: Linear regression equations for 'Yala' rainfall and temperature on paddy production: 1969-70 to 2000-2001

Districts/ Paddy Production of Yala	'Yala' Rainfall	'Yala' Temperature
Anuradhapura	Y= 42.203x-2654.3 R^2= 0.1989	Y= -1220.9x+36037 R^2= 0.1248
Kurunegala	Y= -15.221x+7145.1 R^2= 0.4028	Y= 904.16x-21107 R^2= 0.0763
Kalutara	Y= -2.0593x+1936.3 R^2= 0.0629	Y=380.38x+9331.7 R^2=0.6508
Badulla	Y= -9.1962x+2442.1 R^2= 0.0653	Y= 1644.6x+35497 R^2= 0.3713
Colombo	Y= 1.1075x+259.56 R^2= 0.0104	Y= -950.81x+27175 R^2= 0.194
Galle	Y= -0.0038x+28.422 R^2= 0.0211	Y= 51.708x-280.26 R^2= 0.0247
Kandy	Y= 7.0773x+529.91 R^2= 0.7558	Y= -157.47x+5671.6 R^2= 0.6657
Mathale	Y= -1.367x+940.59 R^2= 0.0333	Y=82.131x-1407.5 R^2=0.366
Nuwaraeliya	Y= 0.7252x+151.39 R^2= 0.038	Y= -10.649x+474.47 R^2= 0.0006
Ratnapura	Y= -4.1435x+3268.1 R^2= 0.0022	Y= -3863.8x+109698 R^2= 0.4803
Matara	Y=0.4382x+1563.1 R^2=0.0015	Y=-113.13x+4801 R^2=0.0738
Gampaha	Y=-12.506x+3351.1 R^2=0.4968	Y=-1980.8x+56435 R^2=0.3483
Kegalle	Y=0.5847x+912.63 R^2=0.0071	Y=169.83x+3433.1 R^2=0.024

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on paddy records of Department of Census and Statistics, 1969-2001.

Note: Y is production of rice and X, rainfall/ temperature.

(iii) 'Yala' Rainfall on Paddy Production:

Linear Regression analyses of rainfall on paddy production shows positive slope in districts of Anuradhapura, Colombo, Kandy, Nuwaraeliya, Matara and Kegalle during

'Yala'. Negative slope can be seen in districts of Kurunegala, Kalutara, Badulla, Galle, Matale, Ratnapura and Gampaha (Table 7.3).

(iv) 'Yala' Temperature on Paddy Production

Linear Regression analyses of temperature on paddy production shows positive slope in districts of Kurunegala, Kalutara, Badulla, Galle, Mathale and Kegalle during 'Maha'. Negative slope can be seen in districts of Anuradhapura, Colombo, Kandy, Nuwaraeliya, Ratnapura, Matara and Gampaha (Table 7.3).

7.1.3 Correlation Analyses: 1969 to 2001

(i) Paddy Area Coverage and Rainfall

Positive correlation between paddy coverage and rainfall were found during the 'Maha' season in the districts of Anuradhapura, Kurunegala, Kalutara, Galle, Nuwaraeliya, Gampaha and Kegalle during the 'Maha' season. Positive correlation between coverage of paddy and rainfall were found during 'Yala' in districts of Anuradhapura, Colombo, Galle, Kandy, Nuwaraeliya and Kegalla. Out of these, significant positive correlations were found during 'Maha' season in the districts of Kalutara, Nuwaraeliya, Gampaha and Kegalle and during the 'Yala' season, in the districts of Anuradhapura, Colombo and Kandy (Table 7.4 & Map 7.3):

Negative correlation between paddy coverage and rainfall were found during 'Maha'season in districts of Badulla, Matale, Colombo, Kandy, Matara and Ratnapura. Negative correlation between paddy coverage and rainfall were found during 'Yala' in districts of Kurunegala, Badulla, Matale, Kalutara, Ratnapura, Gampaha and Matara. Out of these negative cases significant negative correlation were found during 'Maha' at Kandy and Ratnapura and during 'Yala' at Gampaha .

(ii) Paddy Area Coverage and Temperature

Positive correlation between paddy coverage and temperature were found during 'Maha' at Badulla, Mathale, Nuwaraeliya, Ratnapura and Matara. Positive correlation between coverage of paddy and temperature were found during 'Yala' at Badulla Mathale and Galle. Out of these positive cases, significant positive correlations were found during the 'Maha' at Badulla and Nuwaraeliya and during the 'Yala' at Badulla.

Table 7.4: Correlation coefficient between paddy coverage (Acres) of Maha and Yala and corresponding Maha and Yala seasons Rainfall (mm) and Temperature (°C) : 1969-2001

Districts and Seasons	Maha Rainfall	Maha Temp.	Districts and Seasons	Yala Rainfall	Yala Temp.
Anuradhapura	0.22	-0.01	Anuradapura	*0.79	*-0.59
Kurunegala	0.20	-0.25	Kurunegala	-0.07	-0.26
Badulla	-0.17	*0.76	Badulla	-0.32	*0.59
Mathale	-0.21	0.26	Mathale	-0.22	0.03
Kalutara	*0.63	-0.18	Kalutara	-0.28	-0.26
Colombo	-0.32	*-0.70	Colombo	*0.76	*-0.42
Galle	0.27	-0.03	Galle	0.33	0.06
Kandy	*-0.43	*-0.43	Kandy	*0.86	*-0.78
Nuwaraeliya	*0.55	*0.56	Nuwaraeliya	0.32	-0.08
Ratnapura	*-0.40	0.12	Ratnapura	-0.29	*-0.62
Matara	-0.07	0.31	Matara	*-0.39	*-0.56
Gampaha	*0.44	-0.14	Gampaha	*-0.74	*-0.53
Kegalla	*0.55	*-0.64	Kegalla	0.24	-0.08

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on paddy records of Department of Census and Statistics, 1969-2001.
Notes: * = Significant.

Negative correlation between paddy coverage and temperature were found during 'Maha' at Anuradhapura, Kurunegala, Kalutara, Colombo, Galle, Kandy, Gampaha and Kegalle. Negative correlation between paddy coverage and temperature were found during 'Yala' in districts of Anuradhapura, Kurunegala, Kalutara, Colombo, Kandy, Nuwaraelya, Ratnapura, Matara, Gampaha, and Kegalle. Out of these negative cases, significant negative correlations were found during the 'Maha' at Colombo, Kandy and Kegalle and during the 'Yala', in districts of Anuradhapura, Colombo, Kandy, Ratnapura, Matara and Gampaha (Table 7.4 and Map 7.4).

(iii) Regression of 'Maha' Rainfall and Temperature on Paddy Area Coverage

Linear Regression analyses of 'Maha' rainfall on paddy coverage shows positive slope in districts of Anuradhapura, Kurunegala, Kalutara, Galle, Nuwaraeliya, Gampaha and Kegalle. During the same season, negative slopes are observed in districts of Badulla, Colombo, Kandy, Mathale, Ratnapura and Matarta (Table 7.5).

Linear Regression analyses of 'Maha' season temperature on paddy coverage shows positive slopes in districts of Badulla, Matale, Nuwaraeliya, Ratnapura and Matara. During the same season, the negative slopes are observed in districts of Anuradhapura, Kurunegala, Kalutara, Colombo, Galle, Kandy, Gampaha and Kegalle (Table 7.5).

(iv) 'Yala' Rainfall and Temperature on Paddy Area Coverage

Linear regression analyses of 'Yala' rainfall on paddy coverage shows positive slope in districts of Anuradhapura, Colombo, Galle, Kandy, Nuwaraeliya and Kegalle. During the same season, the negative slopes are observed in districts of Kurunegala, Kalutara, Badulla, Matale, Ratnapura, Gampaha and Matara (Table 7.6).

Table 7.5: Linear regression equations for Maha rainfall and temperature on paddy area coverage: 1969-70 to 2000-2001

Districts/Maha: Paddy area coverage	'Maha' Rainfall	'Maha' Temperature
Anuradhapura	Y= 484.85x+31826 R^2= 0.499	Y=-538.06x+133002 R^2= 0.0002
Kurunegala	Y=89.592x+137466 R^2= 0.0384	Y= -15571x+565102 R^2= 0.0643
Kalutara	Y= 72.176x+24118 R^2= 0.3948	Y=-1188x+74117 R^2=0.0322
Badulla	Y= -60.213x+53291 R^2= 0.0278	Y= 6413.4x-95450 R^2= 0.5733
Colombo	Y= -302.27x+81.70 R^2= 0.1006	Y=-57505x+2E+06 R^2= 0.4878
Galle	Y=21.393x+39481 R^2= 0.0713	Y= -405.18x+54251 R^2= 0.0006
Kandy	Y= -67.563x+60361 R^2= 0.1854	Y= -7642.9x+230562 R^2= 0.1819
Mathale	Y= -18.149x+35999 R^2= 0.0444	Y=3389.2x-50240 R^2=0.0652
Nuwaraeliya	Y= 43.082x+6354.4 R^2= 0.307	Y= 5377.8x-68288 R^2= 0.3093
Ratnapura	Y= -8.8441x+39477 R^2= 0.1597	Y=426.61x+25519 R^2=0.0153
Gampaha	Y=192.35x+3333.8 R^2=0.1905	Y=-7400.6x+232782 R^2=0.0193
Kegalle	Y=44.873x+15397 R^2=0.3033	-10262x+288035 R^2=0.4092
Matara	Y=-13.418x+44504 R^2=0.0049	Y=10109x-227158 R^2=0.0988

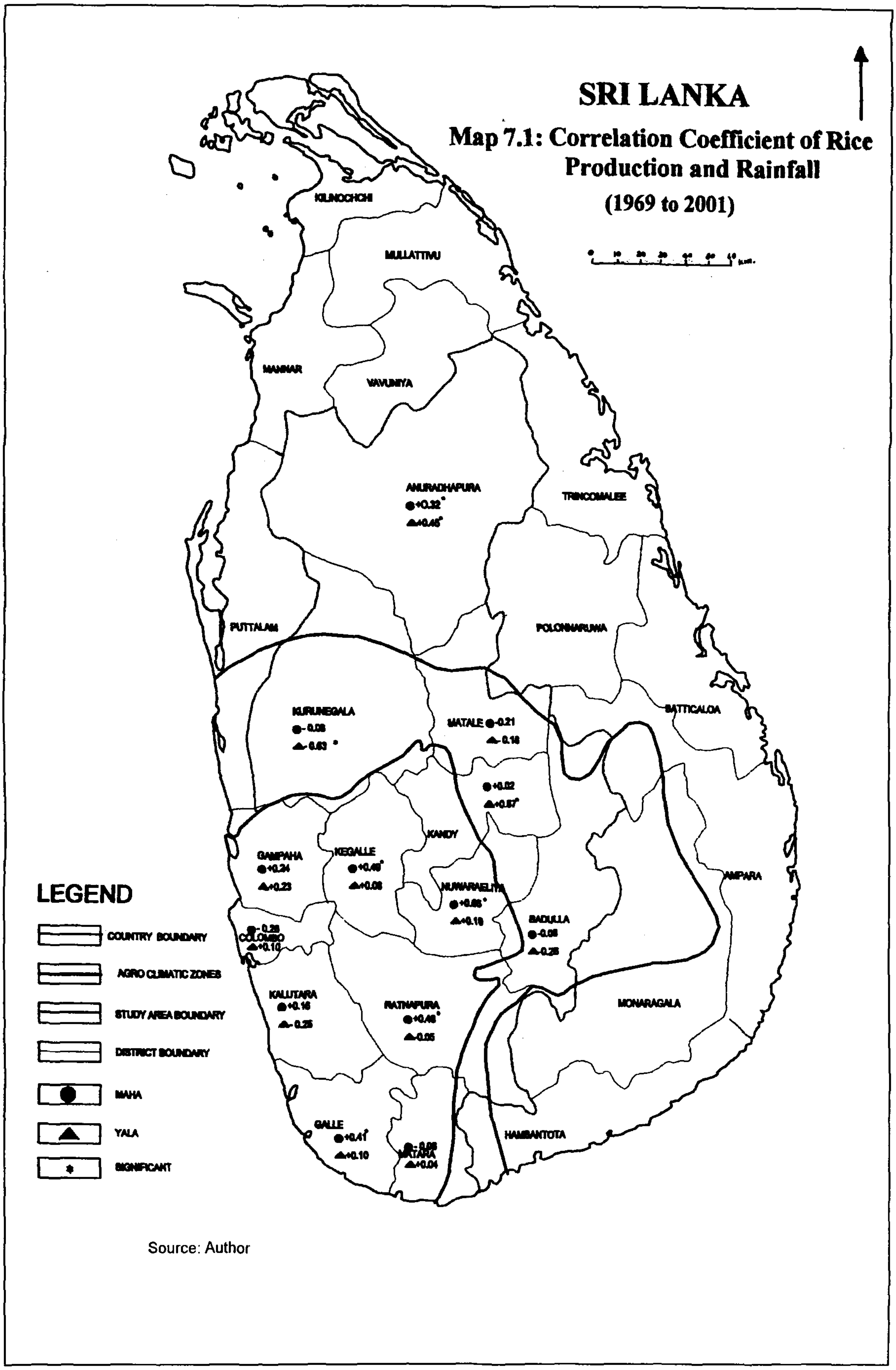
Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on paddy records of Department of Census and Statistics, 1969-2001.
Note: Y is coverage of rice and X, rainfall/ temperature.

Linear Regression analyses of 'Yala' temperature on paddy coverage shows positive slopes at Badulla, Colombo, Galle and Matale. During the same season, the negative slope can be seen in districts of Anuradhapura, Kurunegala, Kalutara, Kandy, Nuwaraeliya, Ratnapura, Gampaha, Kegalle, and Matara.

Table 7.6: Linear regression equations for Yala rainfall and temperature on paddy area coverage: 1969-70 to 2000-2001

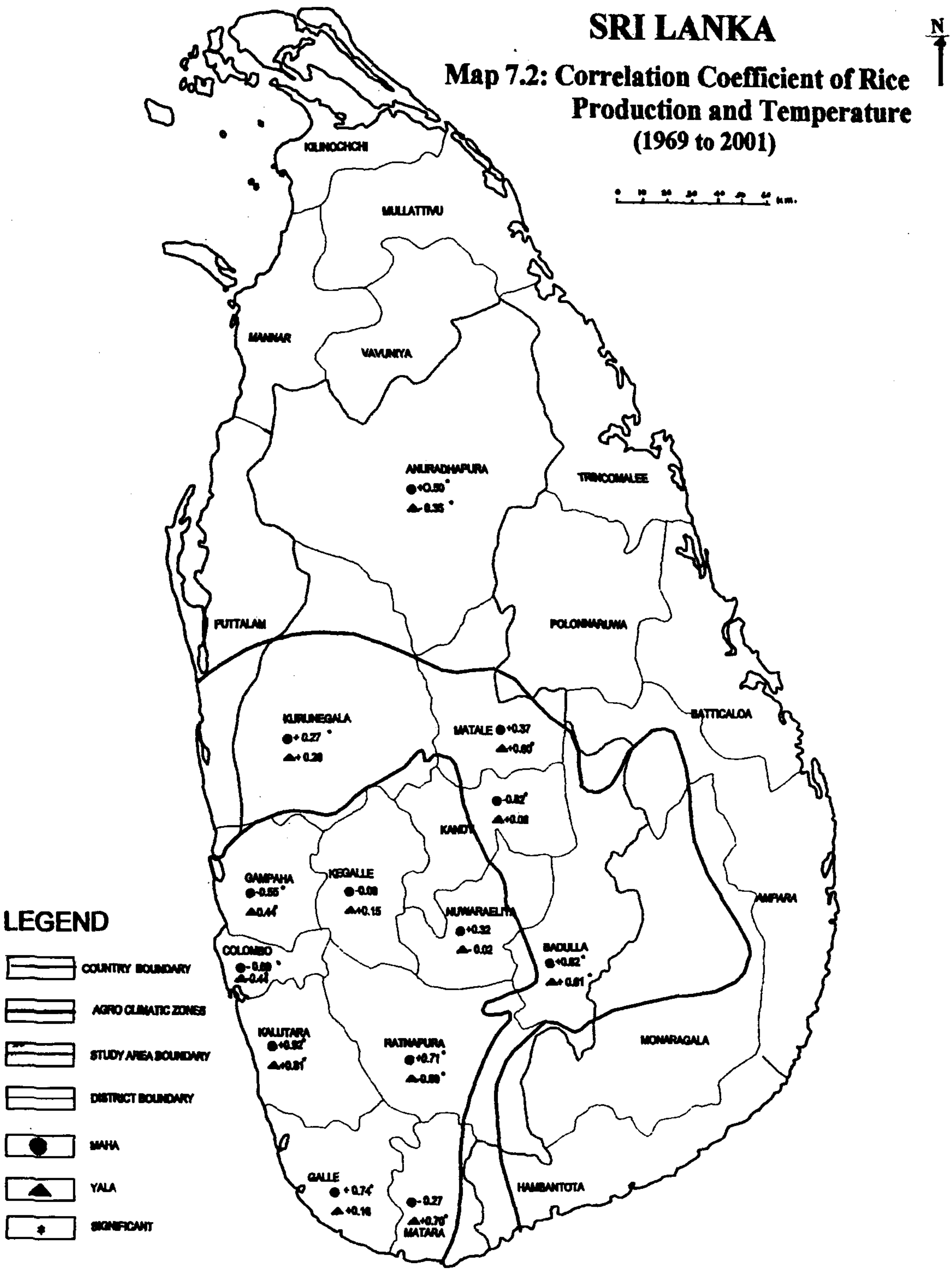
Districts/ Yala: Paddy Area coverage	'Yala' Rainfall	'Yala' Temperature
Anuradhapura	Y=1258.9x-101937 R^2= 0.6307	Y= -34104x+987791 R^2= 0.3469
Kurunegala	Y= -26.854x+86407 R^2= 0.0047	Y= -13958x+473201 R^2= 0.0681
Kalutara	Y= -42.35x+49370 R^2= 0.0789	Y=-2243.4x+101500 R^2=0.0672
Badulla	Y= -113.48x+35265 R^2= 0.0994	Y=15909x-335268 R^2= 0.3473
Colombo	Y= 65.664x+915.27 R^2= 0.0239	Y= 2330.7x-2302.4 R^2= 1
Galle	Y= 103.7x+20872 R^2= 0.1094	Y= 719.06x+19144 R^2= 0.0036
Kandy	Y= 189.99x+4354.5 R^2= 0.731	Y= -4123.1x+139714 R^2= 0.6126
Mathale	Y= -72.571x+28944 R^2= 0.0473	Y=184.72x+11336 R^2=0.0009
Nuwaraeliya	Y= 23.567x+3049.1 R^2= 0.1023	Y= -709.62x+19488 R^2= 0.0063
Ratnapura	Y= -34.528x+41750 R^2= 0.0849	Y= -4606.5x+160917 R^2= 0.3879
Gampaha	Y=-299.16x+79157 R^2=0.5483	Y=-40189x+1E+06 R^2=0.2766
Kegalle	Y=32.163x+10954 R^2=0.0576	Y=-177.1x+69751 R^2=0.0071
Matara	Y=-41.496x+50391 R^2=0.1501	Y=-21850.4x+101705 R^2=0.3139

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on paddy records of Department of Census and Statistics, 1969-2001. Note: Y is coverage of rice and X, rainfall/ temperature.

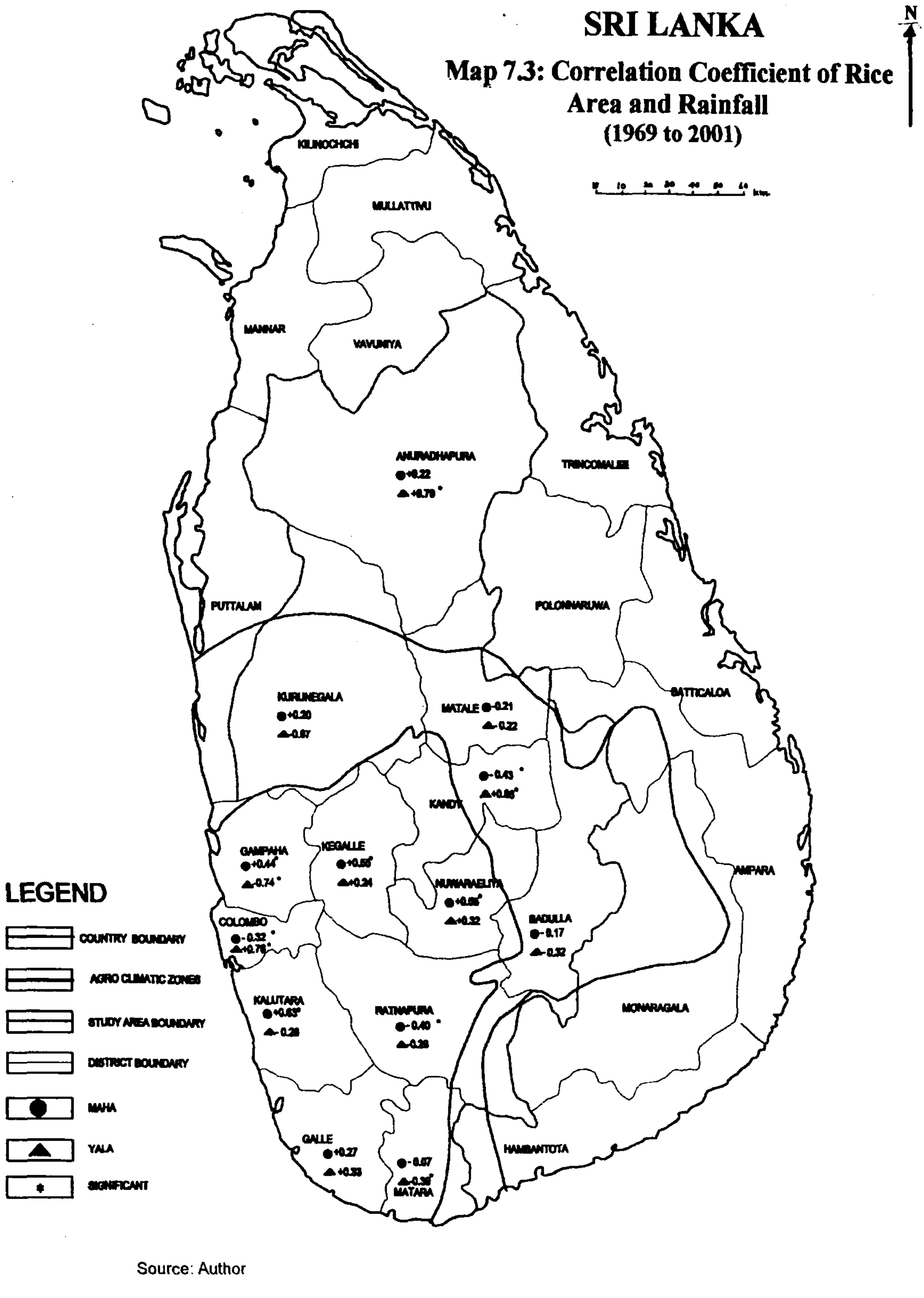

SRI LANKA
Map 7.1: Correlation Coefficient of Rice Production and Rainfall
(1969 to 2001)
KILINOCHCHI
MULLATTIVU
MANNAR
VAVUNIYA
ANURADHAPURA
+0.32*
+0.45*
TRINCOMALEE
PUTTALAM
POLONNARUWA
KURUNEGALA
MATALE -0.21
-0.18
BATTICALOA
+0.02
+0.57*
KANDY
GAMPAHA
+0.24
+0.23
KEGALLE
NUWARAELIYA
AMPARA
BADULLA
COLOMBO
+0.10
KALUTARA
+0.16
-0.25
RATNAPURA
-0.05
MONARAGALA
GALLE
+0.41*
+0.10
MATARA
+0.04
HAMBANTOTA
LEGEND
COUNTRY BOUNDARY
AGRO CLIMATIC ZONES
STUDY AREA BOUNDARY
DISTRICT BOUNDARY
MAHA
YALA
SIGNIFICANT
Source: Author

SRI LANKA

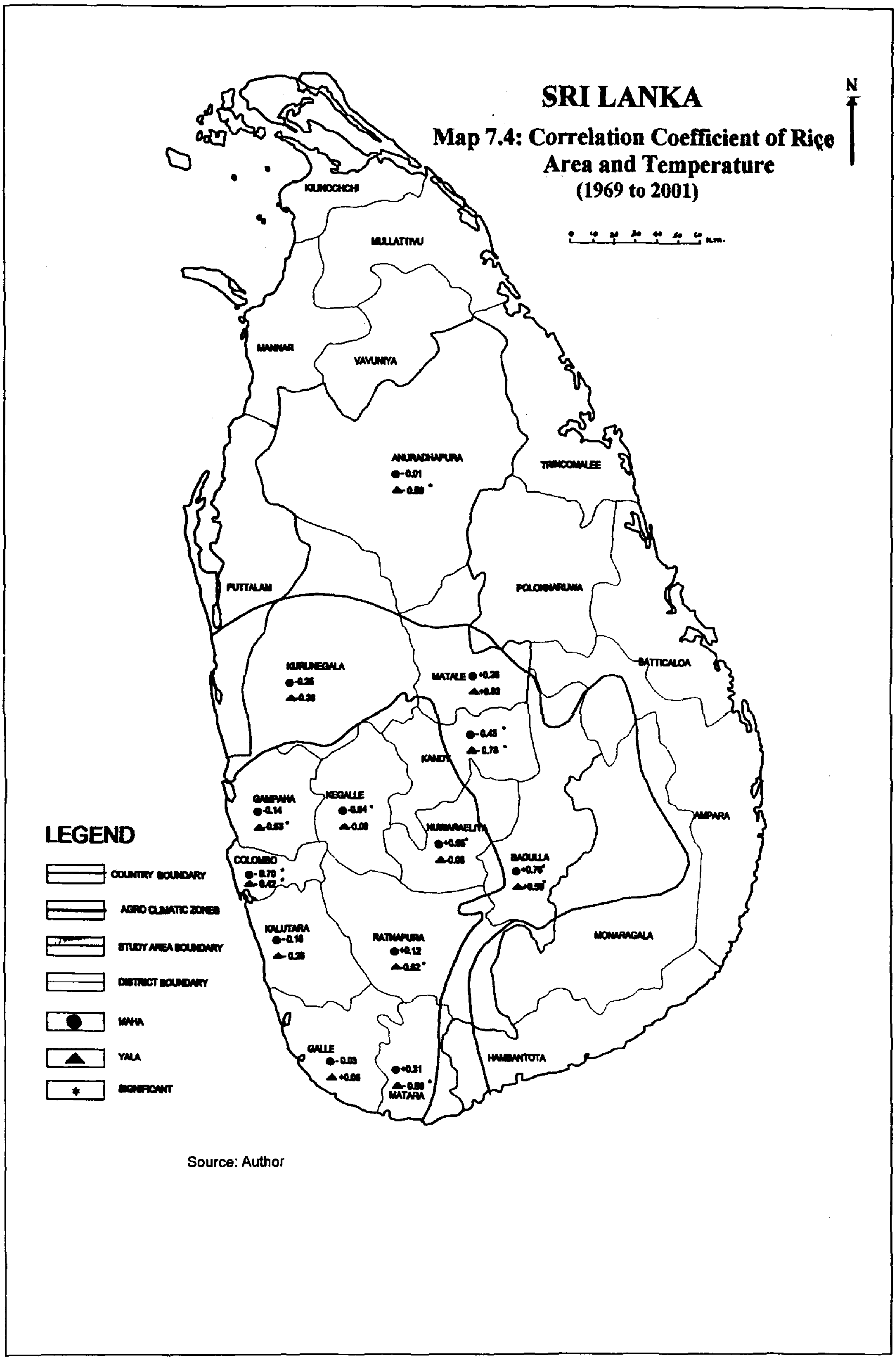
Map 7.2: Correlation Coefficient of Rice Production and Temperature (1969 to 2001)



Source: Author



Source: Author



SRI LANKA
Map 7.4: Correlation Coefficient of Rice Area and Temperature
(1969 to 2001)

Part II: Tea and Climate Relationship

This part concentrates tea and climate relationship. Basically, the statistical relationship tea production, area coverage and yield with climate (rainfall and temperature). Correlation and regression analyses have been carried-out for each case.

7.2 Tea and Climate

7.2.1 (i) Tea Production and Rainfall

Significant positive correlation between annual average tea production and annual average rainfall were found in the High grown and Medium grown areas. Significant negative correlation was found in low grown areas (Table 7.7).

(ii) Tea Production and Temperature

Significant negative correlation between annual average tea production and annual average temperature were found in the high grown and medium grown areas. Significant positive correlation was found in Low grown areas (Table 7.7).

Table 7.7: Correlation coefficient between tea production and corresponding annual average rainfall and temperature: 1970 to 2001

****Tea Grown Areas/ Annual average tea production**	**Annual Average Rainfall**	**Annual Average Temperature**
Higher elevations	*0.558	*-0.378
Medium elevations	*0.599	*-0.790
Low elevations	*-0.688	*0.788

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on Tea Records from Sri Lanka Tea Board, 1970-2001.
Notes: * = Significant. ** = the general reference to tea production in Sri Lanka is classified by elevations as "high grown", "medium grown" and "low grown".

7.2.2 Regression Analyses

(i) Rainfall on Tea Production

Linear Regression analyses of rainfall on tea production shows positive slopes at High grown and Medium grown areas. On the other hand, rainfall on tea production shows negative slopes in the low grown areas (Table 7.8).

(ii) Temperature on Tea Production

Linear Regression analyses of temperature on tea production shows positive slopes at Low grown areas and negative slopes at high and medium grown areas (Table 7.8).

Table 7.8: Regression analyses of annual average rainfall and temperature on tea production: 1970 to 2001

Tea Grown Areas	Annual Average Rainfall	Annual Average Temperature
High grown: Annual average tea production	Y= 0.0147x+4.2784 R^2=0.3119	Y= -1.2857x+35.571 R^2=0.2967
Medium grown: Annual average tea production	Y= 0.0175x+1.8058 R^2=0.3583	Y= -2.1071x+55.27 R^2=0.6249
Low grown: Annual average tea production	Y= -0.0942x+24.16 R^2=0.4461	Y= 6.1838x-146.37 R^2=0.605

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based Tea Records from Sri Lanka Tea Board, 1970-2001.

Note: Y is production of tea and X, rainfall/ temperature.

7.2.3 Correlation Analyses

(i) Tea Area Coverage and Rainfall:

Significant positive correlation between tea area coverage and annual average rainfall were found in the medium grown area. Significant negative correlation was found in high and low grown areas (Table 7.9).

(ii) Tea Area Coverage and Temperature

Negative correlation between tea area coverage and annual average temperature were found in the high grown areas and it was not much significant. Positive correlations were found in medium (significant) and low grown areas (Table 7.9).

Table 7.9: Correlation coefficient between tea area coverage and corresponding annual average rainfall and temperature: 1970 to 2001

Tea Grown Areas Extent	Annual Average Rainfall	Annual Average Temperature
High grown: Tea extent area	-0.005	-0.263
Medium grown: Tea extent area	*0.401	*0.637
Low grown: Tea extent area	*-0.752	0.184

Source: Calculate by author, based on temperature and rainfall records of Department of Meteorology and based on Tea Records from Sri Lanka Tea Board, 1970-2001.
Notes: * = Significant.

7.2.4 Regression Analyses

(i) Rainfall on Tea Area Coverage

Linear Regression analyses of rainfall on tea area coverage shows positive slopes at medium grown areas. On the other hand, rainfall on tea area coverage shows negative slopes in the high and low grown areas (Table 7.10).

(ii) Temperature on Tea Area Coverage

Linear Regression analyses of temperature on tea area coverage shows positive slopes in the low grown areas. On the other hand, temperature on tea area coverage shows negative slopes in the high and medium grown (Table 7.10).

Table 7.10: Regression analyses of tea area coverage on annual average rainfall and temperature: 1970 to 2001

Tea Grown Areas	Annual Average Rainfall	Annual Average Temperature
High grown: Tea area extent	$Y= -2.7855x+70910$ $R^2=2E-05$	$Y= -8511.9x+273709$ $R^2=0.069$
Medium grown: Tea area extent	$Y= 276.93x+3320$ $R^2=0.161$	$Y= -50965x+1E+06$ $R^2=0.6374$
Low grown: Tea area extent	$Y= -169.5x+98258$ $R^2=0.5647$	$Y= 5857.5x-76800$ $R^2=0.1841$

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based Tea Records from Sri Lanka Tea Board, 1970-2001.

7.2.5 Correlation Analysis

(i)Tea Yield and Rainfall

Positive correlation between tea yield and annual average rainfall were found in the high and medium grown area but not significant. Significant negative correlation was found in low grown areas (Table 7.11).

(ii) Tea Yield and Temperature

Correlation was positive in all the three grown areas, in between tea yield and annual average temperature. Significant positive correlations were observed in the medium and low grown areas (Table 7.11).

Table 7.11: Correlation coefficient between annual average tea yield and corresponding annual average rainfall and temperature: (1970-2001)

Annual Average Tea Yield	Annual Average Rainfall	Annual Average Temperature
High grown: Annual average tea yield	0.196	0.099
Medium grown: Annual average tea yield	0.102	*0.37
Low grown: Annual average tea yield	*-0.64	*0.791

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on Tea Records from Sri Lanka Tea Board, 1970-2001.
Notes: * = Significant.

7.2.6 Linear Regression Analyses

(i) Rainfall on Tea Area Coverage

Linear Regression analyses of rainfall on tea yield shows positive slopes at high and medium grown areas. On the other hand rainfall and tea yield shows significant negative slopes in the low grown areas (Table 7.12).

Table 7.12: Regression analyses of annual average rainfall and temperature on tea yield: 1970 to 2001

Tea Grown Areas	Annual Average Rainfall	Annual Average Temperature
High grown: Annual average tea yield	Y=2.3056x+794.74 R^2=0.0099	Y=67.143x-459.29 R^2=0.069
Medium grown: Annual average tea yield	Y=0.6235x+619.56 R^2=0.0104	Y=209.29x-4266 R^2=0.1366
Low grown: Annual average tea yield	Y=-12.451x+3474.1 R^2=0.4093	Y=931.7x-21958 R^2=0.6257

Source: Calculated by author, based on temperature and rainfall records of Department of Meteorology and based on Tea Records from Sri Lanka Tea Board, 1970-2001. Note: Y is yield of tea and X, rainfall/ temperature.

(ii) Temperature on Tea Area coverage

Linear Regression analyses of temperature on tea yield shows positive slopes of all the tea grown areas (Table 7.12).

Part III: Coconut and Climate Relationship

This part concentrates on coconut and climate relationship. Coconut production with climate has been examined in respect of coconut area coverage with climate.

7.3 Coconut and Climate

(i) Coconut Area Coverage and Rainfall

Positive correlation between coconut area coverage and annual average rainfall were found in the districts of Colombo, Kalutara, Nuwaraeliya, Badulla, Ratnapura, Puttalama and Kegalle.

Out of these districts, the correlations are significant at Nuwaraeliya and Puttalama. Significant negative correlations are in the districts of Kandy, Mathale, Galle Matara, Kurunegala, and Anuradhapura (Table 7.13).

Table 7.13: Coconut area coverage and rainfall relationship: 1962 to 1993

Districts	Correlation Coefficient
Colombo	0.322
Kalutara	0.141
Kandy	*-0.918
Matale	*-0.627
Nuwaraeliya	*0.888
Galle	*-0.752
Matara	*-0.597
Kurunegala	*-0.924
Anuradhapura	*-0.519
Badulla	0.18
Ratnapura	0.294
Puttalam	*0.982
Kegalla	0.198

Source: Calculated by author, based on rainfall records of Department of Meteorology and based on coconut records of Coconut Development Authority, and Census of Agriculture, 1962-1993.
Notes: * = Significant.

(ii) Coconut Area Coverage and Temperature

Table 7.14: Coconut area coverage and temperature relationship: 1962 to 1993

Districts	Correlation Coefficient
Colombo	*-0.587
Kandy	0.289
Nuwaraeliya	*-0.349
Galle	*-0.609
Kurunegala	*0.428
Anuradhapura	*0.715
Badulla	*0.589
Ratnapura	*-0.371
Puttalama	*-0.499
Hambantota	*0.936

Source: Calculated by author, based on temperature records of Department of Meteorology and based on coconut records of Coconut Development Authority, and Census of Agriculture, 1962-1993.
Notes: * = Significant.

Positive correlation between coconut area coverage and annual average temperature were found in the districts of Kandy, Kurunegala, Anuradhapura, Badulla and Hambantota. Out of these districts, the correlation are significant in the districts of Anuradhapura, Kurunegala, Badulla and Hambantota. Significant negative correlations are found in the districts of Colombo, Nuwaraelya, Galle, Ratnapura and Puttalama (Table 7.14).

7.3.1 Linear Regression Analyses

(i) Temperature on Coconut Area Coverage

Linear Regression analyses of temperature on coconut area coverage shows positive slopes in the districts of Kandy, Kurunegala, Anuradhapura, Badulla and Hambantota during period 1962 to 1993. Negative slopes are estimated for the districts of Colombo, Nuwaraeliya, Galle, Ratnapura and Puttalama.

Table 7.15: Linear regression equation of temperature on coconut area coverage: 1962 to1993

Districts	Equation	R^2 value
Colombo	Y= -19034x+59674	R^2=0.345
Kandy	Y= 355x-218	R^2=0.083
Nuwaraeliya	Y= -262.45x+4917	R^2=0.122
Galle	Y= -6837.1x+19825	R^2=0.371
Kurunegala	Y= 7003x-34820	R^2=0.183
Anuradhapura	Y= 543.61x-9409.5	R^2=0.511
Badulla	y= 1755x-40191	R^2=0.347
Ratnapura	Y= -5890.4x+17553	R^2=0.138
Puttalama	Y= -8592.7x+29416	R^2=0.249
Hambantota	Y= 6932x-166860	R^2=0.877

Source: Calculated by author, based on temperature records of Department of Meteorology and based on coconut records of Coconut Development Authority, and Census of Agriculture, 1962-1993.

Note: Y is coverage of coconut crop and X, temperature.

(ii) Rainfall on Coconut Area Coverage

Linear Regression analyses of rainfall on coconut area coverage shows positive slopes in the districts of Colombo, Kalutara, Nuwaraeliya, Badulla, Ratnapura, Puttalama and Kegalle from 1962 to 1993. Significant negative slopes can be seen in the districts of Kandy, Matale, Galle, Matara, Kurunegala and Anuradhapura.

Table 7.16: Linear regression equation for rainfall on coconut area coverage: 1962 to 1993

Districts	Equation	R^2 value
Colombo	Y= 11.882x+46586	R^2=0.104
Kalutara	Y= 0.8219x+10336	R^2=0.0199
Kandy	Y= -1.0096x+10426	R^2=0.8422
Matale	Y= -2.4113x+15123	R^2=0.393
Nuwaraeliya	Y= 0.6838x-503.06	R^2=0.7893
Galle	Y= -13.82x+48095	R^2=0.566
Matara	Y= -1.2089x+17485	R^2=0.356
Kurunegala	Y= -11.093x+179343	R^2=0.8538
Anuradhapura	Y= -5.5178x+6363.8	R^2=0.2693
Badulla	Y= 1.3296x-981.78	R^2=0.0323
Ratnapura	Y= 1.0858x+9191.2	R^2=0.0862
Puttalam	Y= 14.582x+38400	R^2=0.964
Kegalla	Y= 0.4118x+21654	R^2=0.039

Source: Calculated by author, based on rainfall records of Department of Meteorology and based on coconut records of Coconut Development Authority, and Census of Agriculture, 1962-1993.

Note: Y is coverage of coconut crop and X, temperature.

Part IV: Rubber and Climate Relationship

This part concentrates rubber and climate relationship. Basically, the statistical relationships between rubber area coverage and rainfall and temperature have been examined.

7.4 Rubber and Climate

(i) Rubber Area Coverage and Rainfall

Positive correlation between rubber area coverage and annual average rainfall were found in the districts of Ratnapura, Kandy, Hambantota, Kalutara, and Kegalle. Out of these districts, the correlations are significant at Kegalla and Hambantota. Negative correlations are found in the districts of Colombo, Galle, Kurunegala (significant) Matara, Matale and Badulla (Table7.17).

Table 7.17: Rubber area coverage and rainfall relationship: 1965 to 2000

Districts	Correlation Coefficient
Colombo	-1.000
Galle	-0.204
Ratnapura	0.276
Kandy	0.189
Nuwara Eliya	n.a
Kurunegala	*-0.479
Badulla	-0.01
Hambantota	*0.457
Kalutara	0.035
Matara	-0.091
Kegalle	*0.441
Matale	-0.236

Source: Calculated by author, based on rainfall records of Department of Meteorology and based on Rubber Development Department, 1965-2000.
Notes: * = Significant. n.a. = not available.

Table 7.18: Rubber area coverage and temperature relationship: 1965 to 2000

Districts	Correlation Coefficient
Colombo	*-0.859
Galle	*-0.62
Ratnapura	*-0.563
Kandy	*-0.597
Nuwara Eliya	0.29
Kurunegala	0.265
Badulla	*-0.76
Hambantota	*-0.581

Source: Calculated by author, based on temperature records of Department of Meteorology and records based on Rubber Development Department, 1965-2000.
Notes: * = Significant.

(ii) Rubber Area Coverage and Temperature

Positive correlation in between rubber coverage and annual average temperature are found in the districts of Nuwaraeliya and Kurunegala, but, not significant. Significant negative correlations are found in the districts of Colombo, Galle, Ratnapura, Kandy, Badulla and Hambantota (Table 7.18).

7.4.1 Linear Regression Analyses

(i) Rainfall on Rubber Area Coverage

Linear Regression analyses of rainfall on rubber area coverage shows positive slopes at Colombo, Ratnapura, Kandy, Hambantota, Kalutara, and Kegalla from 1965 to 2000. Negative slopes are observed in the districts of Galle, Kurunegala, Badulla, Matara and Matale (Table 7.19).

Table 7.19: Linear regression equation for rainfall on rubber area coverage: 1965 to 2000

Districts	Equation	R^2 value
Colombo	Y= 18.889x-24346	R^2=0.636
Galle	Y= -7.914x+41662	R^2=0.0416
Ratnapura	Y= 3.3393x+23634	R^2=0.0761
Kandy	Y=6.5262x-1788	R^2=0.0359
Nuwara Eliya (up-to 1975)	Y=2.7985x-5547.7	R=0.8999
Kurunegala	Y= -12.777x+32984	R^2=0.2297
Badulla	Y= -0.1014x+5640.4	R^2=0.0002
Hambantota	Y= 0.098x-39.161	R^2=0.2087
Kalutara	Y= 0.3888x+46505	R^2=0.0012
Matara	Y= -0.8843x+11703	R^2=0.0083
Kegalle	Y= 3.888x+39604	R^2=0.1944
Matale	Y= -2.3587x+12413	R^2=0.0558

Source: Calculated by author, based on rainfall records of Department of Meteorology and based on Rubber records from Rubber Development Department, 1965-2000.
Note: Y is coverage of rubber crop and X, rainfall.

(ii) Temperature on Rubber Area Coverage

Linear Regression analyses of temperature on rubber area coverage shows positive slopes in the districts of Nuwaraeliya and Kurunegala from 1965 to 2000.

Table 7.20: Linear regression equation for temperature on rubber area coverage: 1965 to 2000

Districts	**Equation**	**R^2 value**
Colombo	Y= -16684x+480213	R^2=0.7387
Galle	Y= -21922x+615003	R^2=0.3842
Ratnapura	Y= -12303x+373736	R^2=0.3166
Kandy	Y= -14781x+374447	R^2=0.3563
Nuwara Eliya	Y= 1822.4x-27358	R^2=0.0841
Kurunegala	Y= 5637.3x+145666	R^2=0.0704
Badulla	Y= -5462.5x+135386	R^2=0.5769
Hambantota	Y= -65x+1853	R^2=0.337

Source: Calculated by author, based on temperature and records of Department of Meteorology and based on rubber records of Rubber Development Department, 1965-2000.
Note: Y is coverage of rubber crop and X, temperature.

Negative slopes can be seen in the districts of Colombo, Galle, Ratnapura, Kandy Badulla and Hambantota except Nuwaraeliya and Kurunegala.

7.5 Findings

As outlined earlier, the current chapter attempted to analyse the influence of climatic factors like rainfall and temperature changes over the past 30 years[1]. Chapter V quite successfully put forth the process of climate change in Sri Lanka, particularly the

[1] Whereas, climatic data was available for 40 years, the crop data was available from only 1968-69.

consistent increases in average and seasonal temperature and decline in average monthly incidence of rainfall. Chapter VI clearly indicates general stagnation in rice output of Sri Lanka, at least for the past two decades, despite increases in rice yield over the period! There is, undoubtedly decline in areal coverage of the crop, which especially is susceptible to erratic rainfall in the rain-fed dry regions of Sri Lanka, like the district of Anuradhapura. On the other hand, the output of tea has either declined or stagnated. Output of rubber and coconut crops, undoubtedly has been declining over the past couple of decades.

The purpose of this chapter is to explore the possible (statistical) relationships between rainfall and temperature changes with changes in the principal four crops, in terms of changes in output (total production), coverage of the crop and yields. This analysis uses the respective data sets at the district level (13) within the reference study area, between 1970s and 2000. The climatic data, which is station (point) based has been averaged for the respective districts. Simple correlation coefficients and bi-variate regressions were carried out for generalisation purposes. The seasonal analysis has also been carried out for Maha (NE Monsoon) and Yala (SW Monsoon) seasons, wherein the reference segregated production, coverage and yield data and segregated seasonal average rainfall and temperature data has been used.

It would be foolhardy to say, agriculture is entirely explained by climatic factors. A variety of socio-economic as well as technological factors are important considerations, along with the role played by bio-physical and climatic elements. The study area (of Sri Lanka) that has been under investigation samples all the three major agro-climatic areas of the country. But, most farming practices are under rain-fed conditions (particularly the plantation crops). Therefore, the influence of climate change, especially increasing temperature as well as falling precipitation conditions are likely to have much more pronounced influence on the areal coverage of (rain-fed) crops, whether rice or other plantation crops, which in turn will impact the total out-put of each of the crops. The yield is governed by several socio-economic, technological and farm management practices and is relatively less governed by climatic factors, though by no means immune to climatic influences.

(a) Climate change and rice: (* = significant)

(1) Positive correlation between paddy production and rainfall were found for 'Maha' season in districts of Anuradhapura, Kalutara, *Galle, Kandy, *Nuwaraeliya, *Ratnapura, Gampaha and *Kegalle and during the 'Yala', in districts of *Anuradhapura, Colombo, Galle, *Kandy, Nuwaraeliya, Matara, Gampaha and Kegalla. During 'Maha' negative correlation between paddy production and rainfall were found in districts of Kurunegala, Badulla, Mathale, Colombo and Matara and during the 'Yala', in the districts of *Kurunegala, Badulla, Mathale, Kalutara and Ratnapura. Except Anuradhapura (dry zone), most of the districts are in the Wet zone and expectedly, in a number of districts, increased rainfall has a positive contribution to rice output. Therefore, the long-term trends in decline in monthly average rainfall will undoubtedly result in decline in output. This happens for both the principal seasons.

(2) Similarly, during the 'Maha' season, positive correlations between paddy production and temperature were found in all the districts, except in districts of Colombo, Gampaha and Kegalla, and during 'Yala' season, in districts of Kurunegala, Badulla, Matara, Kalutara, Galle and Kegalle. Out of these positive cases, significant positive correlation were found in during 'Maha' at Anuradhapura, Kalutara, Badulla, Galle, Ratnapura and Matara during 'Yala' at Badulla, Mathale and Kalutara. During the 'Maha' season, negative correlation between paddy production and temperature were found in the districts of *Colombo, *Gampaha and Kegalle, and during 'Yala' season, in districts of *Anuradhapura, *Colombo, *Kandy, Nuwaraeliya, *Gampaha, Matara and *Ratnapura.

(3) Linear regression analysis of rainfall on paddy production shows positive slopes in the districts of Anuradhapura, Kalutara, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle, during 'Maha'. Negative slopes can be seen in districts of Kurunegala, Badulla, Colombo, Mathale and Matara. Linear regression analyses of temperature on paddy production shows positive slopes in all the districts, except Colombo, Gampaha and Kegalle during 'Maha'.

(4) Linear regression analyses of rainfall on paddy production shows positive slopes in districts of Anuradhapura, Colombo, Kandy, Nuwaraeliya, Matara and Kegalle during 'Yala'. Negative slope can be seen in districts of Kurunegala, Kalutara, Badulla, Galle, Matale, Ratnapura and Gampaha. Linear Regression analyses of temperature on paddy production shows positive slopes in districts of

Kurunegala, Kalutara, Badulla, Galle, Mathale and Kegalle during 'Maha'and negative slopes, in districts of Anuradhapura, Colombo, Kandy, Nuwaraeliya, Ratnapura, Matara and Gampaha.

(5) Positive correlation in between paddy coverage and rainfall were found during 'Maha' in districts of Anuradhapura, Kurunegala, *Kalutara, Galle, *Nuwaraeliya, *Gampaha and *Kegalle during 'Maha'. Positive correlation in between coverage of paddy and rainfall were found during 'Yala' in districts of *Anuradhapura, *Colombo, Galle, *Kandy, Nuwaraeliya and Kegalla during 'Yala'. Negative correlation between paddy coverage and rainfall were found during 'Maha' in districts of Badulla, Matale, Colombo, *Kandy, Matara and *Ratnapura and negative correlations, during 'Yala' in districts of Kurunegala, Badulla, Matale, Kalutara, Ratnapura, *Gampaha and Matara.

(6) Positive correlations between paddy coverage and temperature were found during 'Maha' at *Badulla, Mathale, *Nuwaraeliya, Ratnapura and Matara and during 'Yala', at *Badulla Mathale and Galle. Negative correlations between paddy coverage and temperature were found during 'Maha' at Anuradhapura, Kurunegala, Kalutara, *Colombo, Galle, *Kandy, Gampaha and *Kegalle and negative correlations, during 'Yala' in districts of *Anuradhapura, Kurunegala, Kalutara, *Colombo, *Kandy, Nuwaraelya, *Ratnapura, *Matara, *Gampaha, and Kegalle.

(7) Linear regression analyses of 'Maha' rainfall on paddy coverage shows positive slopes at Anuradhapura, Kurunegala, Kalutara, Galle, Nuwaraeliya, Gampaha

and Kegalle during 'Maha' and negative slopes, in districts of Badulla, Colombo, Kandy, Mathale, Ratnapura and Matarta. Linear regression analyses of 'Maha' season temperature on paddy coverage shows positive slopes in districts of Badulla, Matale, Nuwaraeliya, Ratnapura and Matara and negative slopes, in districts of Anuradhapura, Kurunegala, Kalutara, Colombo, Galle, Kandy, Gampaha and Kegalle .

(8) Linear regression analyses of 'Yala' rainfall on paddy coverage shows positive slopes in districts of Anuradhapura, Colombo, Galle, Kandy, Nuwaraeliya and Kegalle and negative slopes in districts of Kurunegala, Kalutara, Badulla, Matale, Ratnapura, Gampaha and Matara. Linear regression analyses of 'Yala' temperature on paddy coverage shows positive slopes at Badulla, Colombo, Galle and Matale and negative slopes in districts of Anuradhapura, Kurunegala, Kalutara, Kandy, Nuwaraeliya, Ratnapura, Gampaha, Kegalle, and Matara.

(b) Climate Change and Tea:

(1) Significant positive correlation between annual average tea production and annual average rainfall were found in the High grown and Medium grown areas. Significant negative correlation was found in Low grown areas. Significant negative correlation between annual average tea production and annual average temperature were found in the high grown and medium grown areas. Significant positive correlation was found in Low grown areas. This clearly indicates that whereas, increased rainfall has salubrious influence on tea output, temperature

increases have negative impact. Given the long-term trend of decreasing rainfall and increasing average temperature condition, the impact on tea output could be debilitating.

(2) Linear regression analyses of rainfall on tea area coverage shows positive slopes at medium grown areas. On the other hand, rainfall on tea area coverage shows negative slopes in the high and low grown areas. Linear regression analyses of temperature on tea area coverage shows positive slopes in the low grown areas. On the other hand, temperature on tea area coverage shows negative slopes in the high and medium grown.

(c) Climate Change and Coconut Crop: (1962 to 1993): (* = significant)

(1) Positive correlation between coconut area coverage and annual average rainfall were found in the districts of Colombo, Kalutara, *Nuwaraeliya, Badulla, Ratnapura, *Puttalama and Kegalle and significant negative correlation were found in the districts of Kandy, Mathale, Galle Matara, Kurunegala, and Anuradhapura. Positive correlation between coconut area coverage and annual average (daily) temperature were found in the districts of Kandy, *Kurunegala, *Anuradhapura, *Badulla and *Hambantota and significant negative correlations, in the districts of Colombo, Nuwaraelya, Galle, Ratnapura and Puttalama.

(2) Linear regression analyses of temperature on coconut area coverage show positive slopes in the districts of Kandy, Kurunegala, Anuradhapura, Badulla and

Hambantota and negative slopes, in the districts of Colombo, Nuwaraeliya, Galle, Ratnapura and Puttalama.

(3) Linear regression analyses of rainfall on coconut area coverage shows positive slopes in the districts of Colombo, Kalutara, Nuwaraeliya, Badulla, Ratnapura, Puttalama and Kegalle and significant negative slopes, in the districts of Kandy, Matale, Galle, Matara, Kurunegala and Anuradhapura.

(d) Climate Change and Rubber: (1965 to 2000): (* = significant)

(1) Positive correlation between rubber area coverage and annual average rainfall were found in the districts of Ratnapura, Kandy, *Hambantota, Kalutara, and *Kegalle and negative correlations, in the districts of Colombo, Galle, *Kurunegala Matara, Matale and Badulla. Positive correlation between rubber area coverage and annual average temperature were found in the districts of Nuwaraeliya and Kurunegala and significant negative correlations, in the districts of Colombo, Galle, Ratnapura, Kandy, Badulla and Hambantota .

(2) Linear regression analyses of rainfall on rubber area coverage shows positive slope at Colombo, Ratnapura, Kandy, Hambantota, Kalutara, and Kegalle and negative slopes at Galle, Kurunegala, Badulla, Matara and Matale. Linear Regression analyses of temperature on rubber area coverage shows positive slopes in the districts of Nuwaraeliya and Kurunegala and negative slopes in the districts of Colombo, Galle, Ratnapura, Kandy Badulla and Hambantota except Nuwaraeliya and Kurunegala.

Chapter – VIII

Farmers' Attitudes and Perceptions towards Climate Change

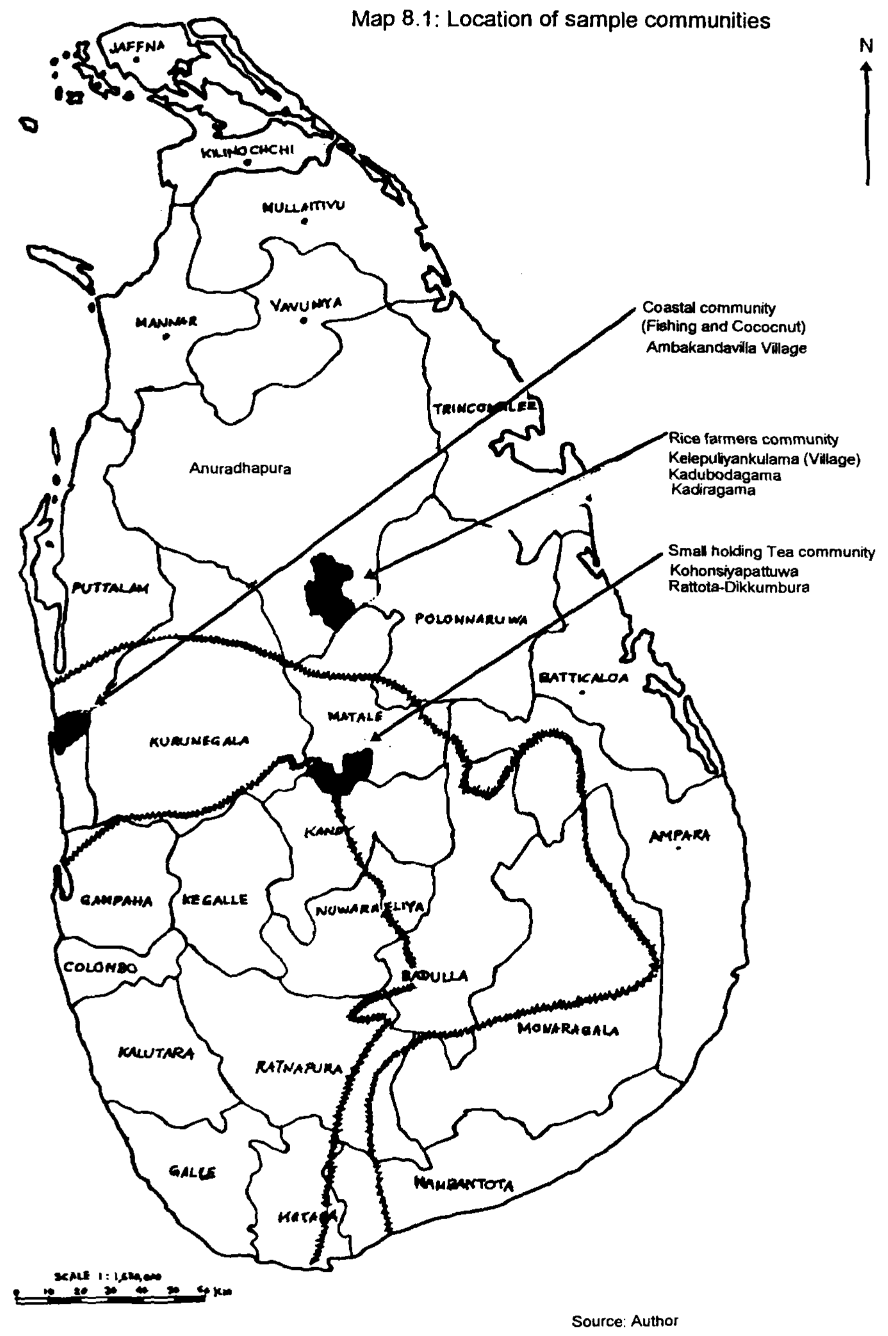
Farmers' attitudes and perceptions towards climate change and adjustment of farm management practices were examined in this chapter. Three communities were selected for the primary level study. These are: the rice-farming community, plantation community (tea small-holders) and coastal community (coconut-farmers and fishermen). This chapter is divided into three main parts. Part I contains, paddy farmers' problems, attitudes and perception towards climate change. Part II contains small-holdings tea cultivators' problems and perceptions regarding climate change. Part III contains, coconut cultivators and fishermen's problems and perceptions and their views. Three separate questionnaires (Appendix II) were canvassed to elicit information from each of the communities.

Part I: Rice-farmers Community

8.1 Introduction

As the Dry Zone is a water deficit area, its agriculture is highly vulnerable to climate change. Rainfall fluctuations are however, not a recent phenomena in Sri Lanka. There have been many severe and widespread droughts in the past, in this region. The economic disruption, social dislocation and human suffering caused by drought, among

Map 8.1: Location of sample communities



Source: Author

Dry zone peasant communities have often been described in historical chronicles such as the Mahavansa and the Chulavansa[1]. In modern time too, almost every year, the media reports on the effects of drought on human life in many parts of the country, especially in the Dry zone.

Study area is heavily dependent on the availability of water and timely rainfall. Drought and dry spells are, often caused by the failure of expected Monsoon rains in the Dry zone of Sri Lanka. Such failure may lead to continuous decline in water sources, resulting in shortage of water for agriculture. The effect of the drought on communities depending on rainfall in any part of the Dry zone was particularly severe.

The Dry zone accounts for a major share of the country's output of rice, approximately 75 per cent. Paddy is the main cultivation crop in the area. In the study area, seasonal crops are predominant, generally within the Northeast and Southwest Monsoonal seasons. The crops include rice and several subsidiary food crops such as chillies, onions, a variety of lentils and pulses and vegetables. Given the importance of agriculture in the economy, the impact of climate variation on agricultural output can have far reaching consequences both for the population dependent on agriculture and the economy of the country as a whole. The area too, has been vulnerable to droughts from prehistoric times. Its irrigation system consisted of seven (07) rain-fed tanks in the present study area. But these small tank systems do not protect the farmers of the study area from severe droughts. Droughts, either results in a complete loss of production or a

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[1] The Mahavansa and the Chulavansa: Which appear to date from at least the 5th century AD and were compiled over a period of some centuries before that, trace the course of events over 2500 years

reduction of yields depending on the severity. Climatic factors seem to significantly affect production, extent and yield, particularly under rain-fed conditions in the study area.

8.1.1 Study Area and Survey Methodology

In consideration climate change and its vulnerability to the paddy cultivation and to understand reality of the problems in the Dry zone farmers, a questionnaire-based survey was carried out to collect primary level information. Three (03) villages were selected from Kekirawa AGA division from the district of Anuradhapura, which belongs to the North Central Province (Dry zone) in Sri Lanka. The villages are: 1: Kelepuliyankulama, 2: Kadubodagama, and 3: Kadiragama (Map 8.1). The three villages are nearby, small in size with no remarkable differences between them and therefore, were analysed together, with 99 households were surveyed for the purpose.

The history of human settlements in this area as revealed by ancient ruins and archaeological evidences go back to the very beginning of the written history of Sri Lanka. Since ancient times, people in this area and in most other parts of the Dry zone depend for their livelihood on agriculture, especially on the paddy cultivation.

The Field survey for the paddy farmers was carried out during the months of October to March of 2003-2004. These months represent the season of 'Maha' cultivation in the Dry zone. However, in the study area, this year the 'Maha' cultivation was not possible due to inadequate rainfall from Northeast Monsoon (the main rainy season in Sri Lanka). The preceding 'Yala' cultivation had also failed in majority of areas due to inadequate rainfall, also. The farmers were able to cultivate only a few crops on their paddies, and 'Chena' lands (Shifting cultivation land) on 'Yala' season during the 2003-2004 was also severely affected by the drought.

Detailed discussion on the methodology has been mentioned in the chapter four. Initially, in these villages, household list ('Gramasevaka Households List') was prepared from the records maintained by the Gramaseva Niladhari. The selected families were interviewed by using standard questionnaire which contained a series of questioned and data schedules related to the weather affects and its socio economic consequences. Once the list was finalised, the households were selected for the interviews. The present survey was based on a 'Simple Random Sampling Method' from the 'table of statistical random numbers' (Abdul, 1996). Population and the selected sample frames were given in the table 8.1a.

Table 8.1a: Selected villages and percentage of the sample

Villages	Number of households	Sample %	Selected households
Kelepuliyankulama	63	50%	32
Kadubodagama	46	50%	23
Kadiragama	44	100%	44
Total number	153	-	99

Source: Field Survey done by the Author, 2003/2004.

8.1.2 Demographic, Economic and Social Aspects of the Study Area

(a) Marital Status, Age, Religion and Sex

According to the field survey, 92.9 per cent of the respondents are married and 6 per cent, unmarried. According to the sex, the male household respondents (heads) are 80.8 per cent and female were 19.2 per cent. A large majority of the households in the three villages are Sinhalese, and are also Buddhists by religion. According to the age of respondents, 20.2 per cent of the respondents are in between 31-40 age groups; 39.4 per cent of the respondents are in between 41-50 age groups; 27.3 per cent respondents in between 51-60 and 11.11 per cent are in between 61-70 age groups. According to the survey, the paddy cultivators are comparatively young, i.e., 60 per cent respondents are below 50 years.

(b) Education

The educational level in the study area is quite high; 82.8 per cent of the farmers are literate (having passed 6th grade). This is not surprising, since the literacy rate of Sri Lanka is 92.3 per cent (The World Fact-Book, 2004), is among the highest in Asia. Younger people generally had a better education than the older ones. None of the farmers older than 70 years had a higher education. According to the educational level of respondents, most of the heads of the households are able to pass grade one or above level of schooling. Table 8.1b shows the educational level of the farm respondents.

Table 8.1b: Educational level

Educational level	Percentage
Illiterate	1.01
Up to grade five	16.16
Grade five passed	38.38
Up to grade ten	29.29
Ordinary Level (O/L)	11.11
Advanced Level (A/L)	4.04
Total	100.00

Source: Field Survey by the Author, 2003/2004.

(c) Employment

Of the households surveyed, 25.5 per cent were employed in different services., i.e., only 10 per cent are engaged on Government services, 3 per cent are in the private sector and 12 per cent are in the self employment and small businesses. The remaining 74.8 per cent were engaged in farming activities in the study area.

(d) Monthly Income

The monthly households' incomes per month for the majority of the households are below 2000 rupees for more than 59 per cent families (Table 8.1c). Therefore, the economic status and living conditions of the great majority of the people in the study area could be considered as 'poor'. Therefore, most families are eligible to receive food stamps from the Government.

Table 8.1c: Monthly households income

Monthly households income (Rupees)	Percentage
500-2000	59
2001-5000	30
5001-10000	07
10001+	03
Total	100

Source: Field Survey by the Author, 2003/2004.

8.1.3 Water Availability in the Study Area

Currently, seven rain-fed small tanks are functioning in the study area but there is invariably no water in the 'Yala' season in these all tanks (Photo 8.1). Therefore, none of the farmers has not been able to cultivate paddy due to shortage of water. Even in the 'Maha' season, during the field survey (October to February of 2003-2004) water had dried up in all the tanks in the study area, due to insufficient rainfall from Northeast Monsoon.

Next to paddy cultivation, *shifting cultivation*[2] has been the main source of livelihood for paddy farmers in this area. Especially, when water is not enough for the paddy cultivation, substantial portion of the paddy farm population depends on it for survival. According to farmers views, due to uncertainty of timely rainfall, it has been noticed that there is an increasing trend of engaged in *'Chena cultivation'* than paddy cultivation especially in the 'Yala' season.

[2] *Shifting cultivation* or slash and burn agriculture is known as 'Chena cultivation' in Sri Lanka

All the tanks depend on local rainfall and therefore, subject to recurrent of droughts; and most of the years, especially in the 'Yala' season tanks have totally dried up (Photo 8.2).

Table 8.1d: Rain-fed tanks in the study area

Village no:1 **Kelepuliyan kulama**	**Area acres**	**Village no:2** **Kadiragama**	**Area acres**	**Village no:3** **Kaduboda gama**	**Area acres**
Kuratiyawa Tank	36	Pajjothi Tank	100	Kadiragama Ihalawewa Tank	40
Kelepuliyan Kulam-Tank	68			Panikillagama Tank	38
Pahala Halmillewa Tank	35			Nawakkulama Tank	30

Source: Field Survey by the Author, 2003/2004.

None of the tanks are linked to any major irrigation schemes in the study area and therefore, are vulnerable to local rainfall failure. Even today, this area remains one of the few areas of the Dry zone, which is one of the least benefited regions by any major irrigation project. The livelihood of peasant communities in this area is largely dependent on paddy cultivation, based on a highly variable rainfall system. Although, 100 per cent of farmers had cultivated paddy during the 'Maha' season, the crop was completely damaged by the prevailing drought due to inadequate rainfall during the Northeast Monsoon.

8.1.4 Fluctuation of Rainfall

The rainfall regime in the Dry Zone area is characterised by marked seasonality. This brings into focus an important fact of the Dry zone climate, which does not seem to have received adequate attention of agricultural planners and policy makers in Sri Lanka. The farmers` perception of the condition of 'climate change' is reported to be influenced by a number of factors. It is mainly influenced by the impact of water shortages on one's vital interest, past experiences of working and living in abundant or low rainfall areas, the perceived advantage of one's place of living, varying aridity in given geographical areas, the frequency of drought occurrence and the magnitude of the drought.

8.1.5 Operational Holdings and Ownership of the Paddy Land

Of the sample households, 84 per cent of the total operational holdings of the paddy lands are less than two acres (Table 8.1e). According to Table 8.1e, 4 per cent of the households did not have paddy fields. The majority (89%) of the households, the self-owned paddy farming acreage were less than two acres.

Table 8.1e: Total operational holdings and self -owned: Acres

Total Operational holdings	Percentage	Self -Owned	Percentage
0.00-1.00	46	0.00-1.00	55
1.01-2.00	38	1.01-2.00	34
2.01-3.00	09	2.01-3.00	10
3.01-4.00	02	3.01-4.00	01
Total	96	Total	100

Source: Field Survey by the Author, 2003/2004.

Most of the farmers with monthly income less than SRs.2000 are having total operational holdings only less than 1.00 acre (Table 8.1f).

Table 8.1f: Monthly household income and total operational holdings

Monthly household income (Rupees)	Total operational holdings: Acre			
	0.00-1.00	**1.01-2.00**	**2.01-3.00**	**3.01+**
500-2000	32	19	05	00
2001-5000	11	15	03	00
5001-10000	03	04	00	00
10001+	00	00	01	02
Total	46	38	09	02

Source: Field Survey by the Author, 2003/2004.

8.1.6 Weather and Climate Change

The rainfall fluctuations have also affected average yields and consequent adoption by paddy farmers of poor management practices, such as dry sowing, poor weeding, low levels of fertiliser application and inadequate disease and pest control. The weather failures had discouraged them from using costly inputs or adopting expensive management practices, due to high investment risks.

The poor economic status of the farming families, at the time of the survey was, obviously caused by the failure of crops due to weather changes or disturbances. The value of the weather effects on rice is 96 per cent for all the households. Reasons for weather effect on rice and respondents' replies are given in the table 8.1g. Table 8.1g shows the effects of rainfall and other weather conditions on the paddy cultivation in the study area in 2003-2004.

Table 8.1g: Weather effect on rice

	Drying crops	Flooding the field and damage to field	Storm damage of harvesting	Lost harvests	Decrease income
No paddy cultivation	04	04	04	04	04
Not agreed	02	24	02	32	84
Agreed	93	72	94	64	12
Total	100	100	100	100	100

Source: Field Survey by the Author, 2003/2004.

According to farmers, during the last two decades, rainfall has decreased drastically. Majority of (96 per cent) farmers reported that the rainfall has decreased in the study area. Farmers have noted a variety of changes in climate that affected their paddy farms, including increasingly erratic weather patterns, general warming of the climate with reduced rainfall and a shift in the seasonal pattern of rainfall. In the study villages, 96 per cent farmers answered that the 'heat in summer' has been increasing. Weather disturbances such as cyclones, storms, un-seasonal rains are also increasing.

Table 8.1h: Effect of rainfall, high temperature and other weather conditions on paddy cultivation in study area:2003/2004

Rainfall in last 1-2 decades	Percent	Heat in summer	Percent	Cyclones, storms, un-seasonal rains, droughts	Percent
No paddy field	04	No paddy	04	No paddy field	04
Declined	96	Heat in summer : Increased	96	Increased	96
Total	100	Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

The respondents' perception of the frequency of drought on the basis of their past experiences, also indicate remarkable similarities. The majority of the farmers indicated, that drought occurred in a 3 to 7 year cycle. Other indicated, drought as a more frequent phenomenon in the study area. Overall, 100 per cent of the households indicated that they were very vulnerable to the droughts and the recent droughts had been particularly severe on their agricultural activities.

The perception of the climate change among selected paddy farmers appears to be remarkably similar. The majority of the respondents (96%) mentioned that they are not getting timely rainfall to undertake paddy cultivation during the 'Maha' season. Therefore, it affected cultivation of paddy or other seasonal crops during the 'Yala' season too. The responses for reasons are given in Table 8.1i. There are thus a few key issues, especially climate change, which is dominant in farmers' minds. Farmers had multiple answers regarding the perception of climate change; 83 per cent of them agreed that the climate is changing in the study area; 53 per cent respondents mentioned that the reasons for not timely getting rainfall were cutting down of local forests; 33 per cent farmers reported that it is due to un-reliability of monsoon onset (timing).

Table 8.1i: Reasons for, timely not getting rainfall

	Due to forest clearing	**Climate is changing**	**Un-reliability of monsoon onset**
No paddy land	04	04	04
Agreed	53	83	33
Not agreed	43	13	63
Total	100	100	100

Source: Field Survey by the Author, 2003/2004.

However, discussions with farmers, in the study area indicated that the reasons for non-cultivation of large tracts of paddy land during the last 'Maha' and 'Yala' season, were mainly due to the uncertainty of rainfall, both Northeast and Southwest monsoons. In the study villages, 80 per cent of the paddy farmers were not able to harvest more than 150 bushels of paddy from their paddy lands during the 'Maha' season. The effects were much higher in the following 'Yala' season too (Table 8.1j).

Table 8.1j: Total Rice Out-put: 'Maha' and 'Yala' seasons (Bushels)

Total rice out put 'Maha'	Percentage	Total rice out put 'Yala'	Percentage
0.00-50.00	22	0.00-50.00	25
51.00-100	29	51.00-100	46
101-150	29	101-150	21
151-200	13	151-200	05
201-250	04	201-250	01
251-300	02	251-300	01

Source: Field Survey by the Author, 2003/2004.

Thus, the economic status of a farmer can become extremely weak making him unable to start the 'Yala' cultivation. In the current year, of course, the April 'Yala' rain was too inadequate to start any cultivation. The farmers affected by the droughts needed drought relief.

All the farmers are willing to cultivate paddy in the 'Maha' season, since the major cultivation season is 'Maha'. Due to uncertainty of the rainfall, cultivating double/triple crops are observed in paddy land in the 'Yala' season. Table 8.1k shows the proportion of farmers who are growing paddy in the 'Maha' season. Table 8.1l shows how the farmers cope with the adverse effects of climate change. The issues are simplification of the more varied and separate answers given by farmers.

Table 8.1k: Cultivating double/triple crops: 'Maha' and 'Yala'

Area, % : Maha Season	Percentage	Area, %: Yala Season	Percentage
Not cultivated double triple crops	100	0.00-25	12
		26-50	82
		51-75	06
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

With greater water use, land development cost during flooding, higher use of fertiliser and high use of pesticides, the farmers were not able to cope with (table 8.1l). Majority (58 per cent) of the farmers are willing to cultivate different crops in their paddy fields, especially when they do not have enough water for paddy cultivation; 85 per cent farmers agreed that their paddy yields have been decreasing

Table 8.1l: Coping with difficulties

Ability of coping	More water use	Land development cost during the flooding	Higher use of fertilisers	High use of pesticides
No paddy field	04	04	04	04
Able to cope	-	03	-	-
Unable to cope	96	93	96	96
Total	100	100	100	100

Table 8.11 continued..

Ability of coping	Cultivating different crops	Increasing labour cost	Increasing losses or yield decreases	Planting some varieties which is resistance to drought
No paddy field	04	04	04	04
Able to cope	58	01	85	03
Unable to cope	38	95	11	93
Total	100	100	100	100

Source: Field Survey by the Author, 2003/2004.

Part II: Small Holding Tea Community

8.2 Introduction

The Sri Lankan tea industry is the country's highest net foreign exchange earner. Tea is the most labour intensive plantation crop in Sri Lanka. The last completed tea land survey in 1994-1995 recorded that the total tea area in the country 189,000 hectares, and its altitudinal distribution is, 42 per cent in Low country, 30 per cent in Mid-country and 28 percent in Up-country. Wijeratne (1996) examined the vulnerability of Sri Lanka tea production to global climate change. Tea yield is highly influenced by droughts, which cause irreversible losses, because irrigation is less available on tea plantations in Sri Lanka. On the other hand, heavy rains also affect the tea plants by eroding fertile topsoils, fertilisers and other chemicals.

8.2.1 Study Area and Survey Methodology

Two small-holders tea committees were selected from two AGA divisions one from Ukuwela and one from Rattota, which belong to district of Matale, in the Central

Province in Sri Lanka (Map 8.1). Tea small-holders committee no: 1 is 'Kohonsiya-pattuwa- tea small holders committee', and no: 2 is 'Rattota Dikkumbura tea small-holders committee'.

The Field survey for tea was carried out during the months on December 2003 to February of 2004. The present survey was based on a 'Random Sampling Method'. The interviews were conducted with the aid of pre-designed questionnaires, which contained a series of questions and data schedules related to the changing climate and its socio-economic consequences on tea cultivation. Initially, these small holding tea farmers' lists were prepared from the records maintained by the secretary of the tea small holding committee. According to the list given by him, the committee members (householders) were selected for the field interview. 'Kohonsiyapattuwa-tea small holders committee' has 95 committee members, and for this study 50 per cent sample has been taken, i.e., 48 members for the survey. Committee no. 2: Dikkumubura – Rattota-tea small-holder's committee has 105 committee members of which 50 per cent sample was selected, i.e., 53 members. Altogether 101 tea small farmers were selected for this primary survey.

8.2.2 Demographic, Economic and Social Aspects

(a) Education

The educational level of the small tea growers was quite high in the study area, i.e., 99 per cent of the tea farmers are literate (having passed 5^{th} grade). Table 8.2a shows the educational level of the tea small holders.

Table 8.2a: Educational level

Educational level	Percent
Up-to grade five	0.99
Grade five passed	20.79
Up-to grade ten	23.76
O/L passed	32.67
A/L passed	14.85
Graduate	6.93
Total	100

Source: Field Survey by the Author, 2003/ 2004.

(b) Employment

All the committee members are tea small holders. Among them, 52.5 per cent are employed in different services and 47.5 per cent are fully employed in tea cultivation. Only 19 per cent respondents are engaged in Government services; 19 per cent are in the private sector employment, and 15 per cent are in the self-employment ventures, apart from tea growing activities (Table 8.2b).

Table 8.2b: Employment Status and employment type

Employment Status	Percentage	Employment type	Percentage
Employed different Services (including tea cultivation)	52.48	Government	18.82
Only tea cultivation	47.52	Private	18.81
-	-	Self-employed	14.85
-	-	Others (Only Tea)	47.52
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

(c) Monthly Income

The monthly households' incomes of the majority of the tea farmers are better than the rice farmers, i.e., 50.1 per cent small holders are getting between SRs.3500-10000 per month (Table 8.2c). Therefore, the economic status and living conditions of the great majority of the tea farmers in the study area is much better.

Table 8.2c: Monthly households' income

Monthly households income	Percentage
3500-5000	17.82
5001-10000	32.67
10001-15000	27.72
15001-20000	16.83
20001-25000	3.96
25001-30000	0.99
Total	100.00

Source: Field Survey by the Author, 2003/ 2004.

Table 8.2d: Relationship between monthly household incomes and educational level

Monthly household income	Educational level					
	Up-to grade five	Grade five passed	Up-to grade ten	O/L passed	A/L passed	Graduate
3500-5000	0	11	3	2	2	0
5001-10000	0	6	11	14	2	0
10001-15000	0	1	6	10	7	4
15001-20000	1	3	4	6	1	2
20001-25000	0	0	0	1	2	1
25001-30000	0	0	0	0	1	0
	1	21	24	33	15	7

Source: Field Survey by the Author, 2003/2004.

8.2.3 Operational Holdings and Ownership of the Tea Land

Of the tea growers studied, 66 per cent of the total operational holdings of the tea lands are less than two acres (Table 8.2e). The majority (55%) of the tea members self-owned tea allotments is less than two acres; 80 per cent of the tea members were able to harvest tea (leaves) less than 15000 kilograms from their tea lands per year.

Table 8.2e: Total operational holdings and self owned: Acres

Total operational holdings: Acres	Percentage	Self - Owned Acres	Percentage
0.00-1.00	27.72	0.00-1.00	22.77
1.01-2.00	38.61	1.01-2.00	32.67
2.01-3.00	15.84	2.01-3.00	21.78
3.01-4.00	3.96	3.01-4.00	5.94
4.01-5.00	1.98	4.01-5.00	4.95
5.01-10.00	11.88	5.01-10.00	7.92
-	-	10001-25000	3.96
Total	100.00	Total	100.00

Source: Field Survey by the Author, 2003/2004.

Table 8.2f: Total tea out-put

Total tea out-put/ per year	Percentage
120-1000	2.97
1001-15000	82.18
15001-20000	3.96
20001-25000	3.96
25001-30000	2.97
30001+	3.96
Total	100.00

Source: Field Survey by the Author, 2003/ 2004.

All the small tea farmers reported that the rainfall has been decreasing since past two three decades. The effect of rainfall decline on the value of tea is 100 per cent. How has this situation been affecting tea cultivation, are given in the table 8.2g.

8.2.4 Weather effects on tea cultivation

Most of the respondents agree that the rainfall has been declining since last few decades; and it affects the tea cultivation in different ways. Drought is also one of the main problems, which seriously affects the tea cultivation.

Table 8.2g: Rainfall decreases: Affecting tea cultivation

Drying tea leaves	**Percent**	**Decreases out-put**	**Percent**	**Decreasing quality**	**Percent**
Agreed	50.50	Agreed	58.42	Agreed	3.96
Disagreed	49.50	Disagreed	41.58	Disagreed	96.04
Total	100	Total	100	Total	100

Table 8.2g continued

Decreasing income	**Percent**	**Increasing crop diseases**	**Percent**
Agreed	76.24	Agreed	1.98
Disagreed	23.76	Disagreed	98.02
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

All the small tea growers agree that the high temperature conditions during the summer months have been increasing since last two-three decades in the study area. Reasons for this increasing summer heat as per the respondent's views are given in the table 8.2h. Most of the farmers (99%) agreed that the heat in summer has been increasing due to climate change in Sri Lanka; 15.8 per cent attribute this to cutting trees in the study area. Other local activities like stone quarrying are also attributed as one of the reasons for increasing heat in summer in the study area. The respondents` perceptions of the frequent droughts, on the basis of their past experiences, also indicate similarities among the respondents. All of the farmers indicated that their tea plants are vulnerable to droughts, and the recent drought has been particularly severe on the tea productions. For an example, percentage of drought damage in their tea production is 67 per cent (Table 8.2i).

Table 8.2h: Reasons for heat in summer

Due to local deforestation	**Percentage**	**Due to climate change**	**Percentage**	**Breaking Quarry**	**Percentage**
Agreed	15.84	Agreed	99.01	Agreed	15.84
Disagreed	84.16	Dis-agreed	0.99	Dis-agreed	84.16
Total	100	Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

Table 8.2i: Drought damage percentage of tea production and events of weather disturbances

Drought damage % of production	**Percentage**	**More Cyclones, storms and un-seasonal rains are getting**	**Percentage**
20-40	67.33	Agreed	53.47
41-60	30.69	Disagreed	46.53
61-100	1.98		
	100.00	Total	100

Source: Field Survey by the Author, 2003/2004.

According to the survey, the drought damage percentage of the total tea production was quite high. Effects of drought damage on tea cultivation are given in the table 8.2j. Due to the continuous droughts, cultivators' income has been decreasing by as much as 96 per cent, and also the effect on drying of the tea bushes has increased by 72 per cent. Poor yield also is one of the negative results of the drought damage affecting tea cultivation (Photo 8.4).

Table 8.2j: Effect of the drought damage on tea cultivation

Decreased income	Percentage	Increased maintain cost	Percentage	Drying crops	Percentage
Disagreed	3.96	Disagreed	80.20	Disagreed	28.71
Agreed	96.04	Agreed	19.80	Agreed	71.29
Total	100	Total	100	Total	100

Table 8.2j continued

Poor yield	Percentage	Poor quality	Percentage
Not agreed	10.89	Agreed	4.95
Agreed	89.11	Not agreed	95.05
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

8.2.5 Relationship of tea yield with operational holding

Of the sample tea farmers, 83 per cent were able to obtain tea yield between 3001 and 4500 Kg. Per acre/ year. Nearly 7 per cent get yield in between 4501-6000 Kg. per year (Table 8.2k).

Table 8.2k: Tea Yield Kg. / per year

Yield	Percentage
0-1500	2.97
1501-3000	5.94
3001-4500	83.17
4501-6000	6.93
6001+	0.99
	100.00

Source: Field Survey by the Author, 2003/2004.

Relationship in between tea yield and operational holdings are given in the table 8.2l. Yield per year is much higher in tea farms of size between 1.01 and 2.00 acres.

Table 8.2l: Yield and operational holdings

Yield Kgs. per year	Operational holdings acres					
	0.00-1.00	**1.01-2.00**	**2.01-3.00**	**3.01-4.00**	**4.01-5.00**	**5.01-10.00**
0-1500	3	0	0	0	0	0
1501-3000	3	2	1	0	0	0
3001-4500	20	35	14	4	1	10
4501-6000	2	2	0	0	1	2
6001+	0	0	1	0	0	0
Total	28	39	16	4	2	12

Source: Field Survey by the Author, 2003/2004.

The relationship between education and employment types are shown in the table 8.2m. Farmers with educational level of up-to grade ten and above (19%) are engaged Government services; 19 per cent are employed in the private sector employment; 15 per cent were self-employed.

Table 8.2m: Employment type and education level

Employment type	Employment status	Educational level					
		Up-to grade five	**Grade five passed**	**Up-to grade ten**	**O/L passed**	**A/L passed**	**Graduate**
Government	Employed			1	9	6	3
Private	Employed		2	3	7	6	1
Self-employed	Employed	1	1	5	8		
Others	Employed (tea only)		18	15	9	3	3

Source: Field Survey by the Author, 2003/ 2004.

Under the 'Other' category, all the members are carrying out tea cultivation. Even though the members are employed in some other occupations, all the committee members are tea small holders.

Table 8.2n: Monthly household income and operational holdings

	Operational holdings acres					
Monthly household income in SRs.	**0.00-1.00**	**1.01-2.00**	**2.01-3.00**	**3.01-4.00**	**4.01-5.00**	**5.01-10.00**
3500-5000	12	5	1	0	0	0
5001-10000	13	16	4	0	0	0
10001-15000	3	14	10	0	0	1
15001-20000	0	4	1	4	2	6
20001-25000	0	0	0	0	0	4
25001-30000	0	0	0	0	0	1
	28	39	16	4	2	12

Source: Field Survey by the Author, 2003/2004.

Table 8.2n shows monthly household income according to the size of operational holding. Those who are having monthly income in the class of SRs. 5001.00-15000.00, the operational holdings size is less than 3.00 acres.

Weather disturbances such as cyclone, storms and un-seasonal rains are also much noticeable in the study area. These weather disturbances mostly affect operational holdings less than 3 acres, i.e., very small farms, 43 per cent. Larger holdings (in between 4.01-10.00 acres) have fewer chances for getting damage from weather disturbances (Table 8.2o).

Table 8.2o: Operational holdings and more cyclones, Storms, un-seasonal rains

	More cyclone, storms, un-seasonal rains	
Operational holdings: acres	Agreed	Not Agreed
0.00-1.00	17	11
1.01-2.00	18	21
2.01-3.00	8	8
3.01-4.00	2	2
4.01-5.00	1	1
5.01-10.00	8	4
	54	47

Source: Field Survey by the Author, 2003/2004.

The relationship between operational holdings and high summer temperature conditions are given in the table 8.2p. Heat in summer is affecting tea operational holding, particularly the size of less than 3 acres; 83 respondents agree that the heat in summer is affecting to the tea cultivation. Table 8.2p also shows how the decline in rainfall affects tea cultivation too. It is interesting to observe, that the effects of rainfall decline in tea cultivation was also similar to the effects heat in summer.

Table 8.2p: Relationship with operational holdings and heat in summer and rainfall decline affecting tea cultivation

Operational holdings: Acres	Heat in summer (response)	Operational holdings: Acres	Rainfall decline affecting tea cultivation (response)
0.00-1.00	28	0.00-1.00	28
1.01-2.00	39	1.01-2.00	39
2.01-3.00	16	2.01-3.00	16
3.01-4.00	4	3.01-4.00	4
4.01-5.00	2	4.01-5.00	2
5.01-10.00	12	5.01-10.00	12
	101		101

Source: Field Survey by the Author, 2003/2004.

Part III: Coastal Community: Fishing and Coconut

8.3 Introduction

The total annual value of coconut production in the country in 1990 was SRs. 4852 million. The total cultivated land area was 0.25 million hectares. Impacts of climate change are serious threats for the coconut production in Sri Lanka. The coconut sector exhibited continuing adverse effects of the drought years. The main reasons for the shortfall in the crop production are the cumulative effects of adverse weather conditions as well as poor cultivation practices.

Coastal and marine fisheries contribute 85 per cent of all fish production in the Island, and provide about 65 per cent of animal protein and 13 per cent of the total protein consumed in Sri Lanka. It also provides full or part time employment for about 100,000 persons. The fishery industry is affected in many ways due weather disturbances and it impedes fishing activities of coastal communities. Further, a temperature rise of about 2 ^{0}C can have substantial impacts on the distribution, growth and reproduction of fish stocks, due to the resulting changes in productive areas.

8.3.1 Study Area and Survey Methodology

The village of Ambakandavila was selected from Ambakandavila GN division of Chillaw AGA division of the district of Puttalam in the Northwestern Province (Map 8.1). The field survey was carried out during the months of December 2003 to February of 2004. The interviews were conducted with the aid of pre-designed questionnaire, which contains a series of questions and data schedules related to the changing climate and its socio economic consequences on coastal community. The field survey began with the compilation of names of head of the households in the village. Initially, the farmers' lists were prepared from the records maintained by the Gramaseva Niladhari. According to the list, the households were selected for the field interview. Ambakandavilla village has 203 household and 50 per cent sample was taken; i.e., 102 households.

8.3.2 Demographic, Economic and Social Aspects

(a) Education

Of the sample households, most of had passed grade one and more. The education level in the study area is quite high, 86 per cent of the farmers are literate (having passed 6^{th} grade). Younger people generally had a better education than the older ones. Table 8.3a shows the educational level of the respondents.

Table 8.3a: Educational level

Educational level	Percentage
Up-to grade five	13.73
Grade five passed	27.45
Up-to grade ten	36.27
O/L passed	10.78
A/L passed	9.80
Graduate	1.96
Total	100

Source: Field Survey by the Author, 2003/2004.

(b) Employment

Of the sample village, 26.5 per cent are employed in different services, i.e., only 12.8 per cent are engaged in Government service, 6.9 per cent in the private sector employment and 6.9 per cent are in self employment and the remaining 73.5 per cent are directly engaged in fishing activities. Out of these respondents, most are in fishing activities or in coconut cultivation.

(c) Monthly Income

The monthly household income per month for the majority of the households are as follows: more than 72 per cent of the families are above 5001 thousands rupees (Table 8.3b), 20.6 per cent families, between 2001-5000 thousands rupees. Therefore, the economic status and living conditions of the great majority of the people in the study area is somewhat better. Only 6.86 per cent families are eligible to receive food stamps from the government.

Table 8.3b: Monthly household income

Household income	Percentage
1000-2000	6.86
2001-5000	20.59
5001-10000	27.45
10001-15000	19.61
15001-20000	19.61
20001-25000	2.94
25001+	2.94
Total	100

Source: Field Survey by the Author, 2003/2004.

Table 8.3c: Monthly household income and educational level

Monthly household income	Educational level					
	Up-to Grade five	Grade five passed	Up-to Grade ten	O/L passed	A/L passed	Graduates
0.00-2000	2	3	2	0	0	0
2001-5000	4	8	7	2	0	0
5001-10000	6	7	9	1	5	0
10001-15000	1	2	7	6	3	1
15001-20000	1	6	8	2	2	1
20001-25000	0	1	2	0	0	0
25001-30000	0	1	2	0	0	0
Total	14	28	37	11	10	2

Source: Field Survey by the Author, 2003/2004.

Six percent of the farmers who have passed the Ordinary Level (O/L) the income level, have incomes between SRs. 10001 and 15000 per month, 15 per cent having passed up-to grade ten, the income level was SRs. 15001-20000 per month; and 03 per cent farmers having passed up-to grade ten, the income level was between SRs. 25001-30000 per month.

Table 8.3d: Educational level and employment status

Educational level	Employment status	
	Employed	Un-employed
Up-to grade five	2	12
Grade five passed	5	23
Up-to grade ten	6	31
O/L passed	4	7
A/L passed	8	2
Graduate	2	-

Source: Field Survey by the Author, 2003/2004.

Table 8.3e: Monthly household income and employment type

Monthly household income	Employment type			
	Government	**Private**	**Self-employment**	**Others (fishing activities)**
1000-5000	0	1	3	24
5001-10000	4	4	2	18
10001-15000	6	2	0	12
15001-20000	3	0	1	16
20001-25000	0	0	1	2
25001-30000	0	0	0	3
Total	13	7	7	75

Source: Field Survey by the Author, 2003/2004.

The nature of the fishing activities are of three types in the study area. These are: Catching fish, drying fish and selling fish (Table 8.3f). Some families are engaged in all the activities, while some are engaged in one or two of the activities. Of the sample households, 29.4 per cent are not involved in any kind of fishing activities, whereas 62.8 per cent are engaged in catching fish only and 30 per cent are in dry fish related activities and 67.6 per cent are engaged in selling and marketing of fish products.

Table 8.3f: Nature of the fishing activities

Catching fish	Percentage	Drying fish	Percentage	Selling fish	Percentage
Not doing fishing activities	29.41	Not doing fishing activities	29.41	Not doing fishing activities	29.41
Catching	62.79	Drying	30.33	Selling	67.57
Not catching	7.80	Not drying	40.26	Not selling	3.02
Total	100	Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

Of the total fish production, 13.7 per cent households belong to below SRs 50,000 income class. Farmers with income between SRs. 50001 and 15000 are higher, i.e., percentage was 28.4. Farmers with fish production of more than SRs. 200001 per year constitute only 12.7 per cent (Table 8.3g).

Table 8.3g: Total fish production by money/year

Fish production by money	Percentage
Not doing fishing activities	29.41
0.00-50000	13.73
50001-100000	17.65
100001-150000	10.78
150001-200000	15.69
200001-250000	6.86
250001-300000	2.94
300001-350000	1.96
350001-400000	0.98
Total	100

Source: Field Survey by the Author, 2003/2004.

Nearly 70 per cent respondents agreed that the total fish production has been decreasing, since past two to three decades, 4 per cent received financial supports for the fish activities from the banks.

Table 8.3h: Total fish production

Total fish production	Percentage
Not doing fishing activities	29.41
Decreasing	69.61
Not agreed	0.98
Total	100

Source: Field Survey by the Author, 2003/2004.

Rainfall has also been decreasing in the study area since few decades, but un-seasonal rainfall has been on the increase that affects fishing activities. Weather disturbances like cyclones, storms are increasing in the surrounding sea area. Of the surveyed households, 71.6 per cent respondents agreed that. Frequent storms can damage fish harvesting.

Table 8.3i: Rainfall and other weather disturbances

Rain decrease	Percentage	More cyclone, storms, un-seasonal rains	Percentage
Rainfall not decreased	28.43	No disturbances	28.43
Rainfall decreased	71.57	More disturbances	71.57
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

Table 8.3j: Coping with difficulties

Storage	Percentage	Increasing labour cost	Percentage
Not doing fishing activities	29.41	Not doing fishing activities	29.41
Problem of storage	70.59	Not agreed	10.79
		Agreed	59.80
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

Coping with all the difficulties, the respondents are have problems of storage facilities for their fish production; i.e., 70.6 per cent. Nearly 60 per cent respondents reported that the labour cost has been increasing for fishing activities.

Table 8.3k: Government supports for fishing activities

Government supports	Percentage	Relief or monetary	Percentage
Not agreed	76.43	No supports	76.43
Agreed	23.57	Relief supports	16.77
		Monetary supports	6.80
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

8.3.3 Coconut Cultivation

While engaged in fishing activities, most of the families are having coconut lands too, i.e. 89 per cent of the respondents; whereas 10.78 per cent are not having coconut land. Of the households, 88 per cent respondents have total operational holdings less than one acre. Only 11.76 per cent have more than 1.01 acres. Out of 89 per cent of the coconut land, 74.5 per cent are less than one acre and also, self-owned. Only 25.49 per cent of the households have land between 0.01 and 4.00 acres (of self owned).

Table 8.3l: Total coconut nuts/ per year

Total coconut nuts	Percent
0	13.73
0.01-1000	16.67
1001-5000	57.84
5001-10000	9.80
10000+	1.96
	100

Source: Field Survey by the Author, 2003/2004.

Of the surveyed households, 55.88 per cent of the cultivators sell their coconut by SRs. 800.00 /100 nuts, 29.41 per cent at SRs 750 /100 nuts. Cost of production for 44.12

per cent cultivators is less than SRs. 0.00-2000 per acre of coconut land. That having a large area of coconut land, the total cost of production is also high. More than 15 per cent of the cultivators spend more than SRs. 8001 for their coconut cultivation as the cost of production (Table 8.3m).

Table 8.3m: Total cost of production for coconut

Total cost of production	Percent
0	11.76
0.00-2000	44.12
2001-4000	15.69
4001-6000	6.86
6001-8000	5.88
8001-10000	13.73
10001+	1.96
	100

Source: Field Survey by the Author, 2003/2004.

Most of the coconut cultivators reported that their production has been decreasing, since the past two to three decades due to bad weather conditions. Drought is one of the most telling weather events on coconut farming, which affects coconut cultivation in different stages of growth of the plant. Some farmers say that un-seasonal rains and unpredictable weather conditions also affect coconut production.

When drought occurs, the coconut crops dry (Photo 8.5) and the production gets affected; 89 per cent cultivators agree that the coconut plants are dieing due to drought. Un-seasonal rains also make crop failure, especially in the first planting stage of coconut plants. Weather affects coconut in several ways in the study area is given in table 8.3n.

Table 8.3n: Weather Effects on Coconut

Storm or wind damage of harvesting time	Percentage	Drying plants	Percentage	Excessive rain coconut	Percentage
No coconut land	10.78	No coconut land	10.78	No coconut land	10.78
Agreed	11.76	Agreed	89.22	Agreed	58.83
Not agreed	77.46			Not agreed	30.39
Total	100	Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

To cope with all the difficulties, coconut farmers seek some alternative avenues of better income; 66.67 per cent are willing to plants different crops in their coconut lands; 66.67 per cent agree that they are loosing their income due to bad weather conditions (Table 8.3n and 8.3o).

Table 8.3o: Cope with difficulties

Higher use of fertiliser	Percent	Cultivating different crops	Percent	Increasing losses-coconut	Percent
No coconut	10.78	No coconut	10.78	No coconut	10.78
Agreed	1.96	Agreed	66.67	Agreed	66.67
Not agreed	87.26	Not agreed	22.55	Not agreed	22.55
Total	100	Total	100	Total	100

Table 8.3o continued

More water use	Percentage	More labour cost	Percentage
No coconut land	10.78	No coconut land	10.78
Agreed	2.94	Not agreed	89.22
Not agreed	86.28	-	-
Total	100	Total	100

Source: Field Survey by the Author, 2003/2004.

According to the survey, 30.4 per cent families are receiving relief support from the Government for their crop damage; 22 per cent received monitory supports. Out of this 22 per cent, 11.8 per cent received SRs. 1000 for crop damages, according to their income levels; 10.78 per cent cultivators received relief of SRs. 1500 and 3000.

8.4 Findings

(a) Rice-farming Community

(1) Of the households surveyed, 25.5 per cent were employed in different services and other 74.8 per cent were employed paddy farm activities in the study area. The monthly households' incomes per month for the majority of the households are below 2000 rupees for more than 59 per cent families. Therefore, the economic status and living conditions of the great majority of the people in the study area are 'poor'. Therefore, most families are eligible to receive food stamps from the Government.

(2) Currently seven rain-fed small tanks are functioning in the study area but there is invariably no water in the 'Yala' season in these all tanks. Therefore, none of the farmers has not been able to cultivate paddy in their paddy land due to shortage of water. Even 'Maha' season, during the field survey (October to April of 2003/2004) water had dried up in all the tanks in the study area, due to less rainfall from Northeast Monsoon.

(3) Next to paddy cultivation, *Shifting cultivation* (slash and burn agriculture is known as 'Chena cultivation' in Sri Lanka) has been the main source of

livelihood for paddy farmers in this area. Especially, when water is not enough for the paddy cultivation, substantial portion of the paddy farm population depends on it for survival. According to farmers views, due to uncertainty of timely rainfall, it has been noticed that there is an increasing trend of engaged in *'Chena cultivation'* than paddy cultivation especially in the 'Yala' season.

(4) All the tanks depend on local rainfall and therefore, subject to recurrent of droughts; and most of the years, especially in the 'Yala' season tanks are totally, dry. None of the tanks, are linked to any major irrigation schemes in the study area and therefore, vulnerability to local rainfall failure. Even today, this area remains one of the few areas of the Dry zone, which is one of the least benefited regions by any major irrigation project. The livelihood of peasant communities in this area is largely dependent on paddy cultivation, based on a highly variable rainfall system. Although, 100 per cent of farmers had cultivated paddy during the 'Maha' season, the crop was completely damaged by the prevailing drought due to inadequate rainfall during the Northeast Monsoon.

(5) Of the sample households, 84 per cent of the total operational holdings of the paddy lands are less than two acres. 4 per cent of the households did not have paddy fields. The majority (89%) of the households, the self-owned paddy farming acreage were less than two acres. Most of the farmers with monthly income less than SRs.2000 are having total operational holdings only less than 1.00 acre.

(6) The rainfall fluctuations have also affected average yields and consequent adoption by paddy farmers of poor management practices, such as dry sowing, poor weeding, low levels of fertiliser application and inadequate disease and pest control. The weather failures had discouraged them from using costly inputs or adopting expensive management practices, due to high investment risks.

(7) According to farmers, during the last two decades, rainfall has decreased drastically; 96 per cent farmers reporting that the rainfall has decreased in the study area. The poor economic status of the farming families, at the time of the survey was obviously caused by the failure of crops due to weather changes or disturbances. The value of the weather effects on rice is 96 per cent for all the households. Farmers who have noted a variety of changes in climate affecting their paddy farms: including increasingly erratic weather patterns, general warming of the climate with reduced rainfall and a shift in the seasonal pattern of rainfall. In the study villages, 96 per cent farmers answered that the 'heat in summer' has been increasing. Weather disturbances such as cyclones, storms, un-seasonal rains are also increasing. The respondents` perceptions of the frequency of drought, on the basis of their past experiences, also indicate remarkable similarities. The majority of the farmers indicated, that drought occurred in a 3 to 7 year cycle. Other indicated, drought as a more frequent phenomenon in the study area. Overall, 100 per cent of the households indicated that they were very vulnerable to the droughts and the recent droughts had been particularly severe on their agricultural activities. The perception of the climate change among

selected paddy farmers appears to be remarkably similar. The rainfall regime in the Dry Zone area is characterised by marked seasonality. This brings into focus an important fact of the Dry zone climatology, which does not seem to have received adequate attention of agricultural planners and policy makers in Sri Lanka. The farmers` perception of the condition of 'climate change' is reported to be influenced by a number of factors. It is mainly influenced by the impact of water shortages on one's vital interest, past experiences of working and living in abundant or low rainfall areas, the perceived advantage of one's place of living, varying aridity in given geographical areas, the frequency of drought occurrence and the magnitude of the drought.

(8) The majority of the respondents (96%) mentioned that they are not getting timely rainfall to undertake paddy cultivation during the 'Maha' season. Therefore, it affected cultivation of paddy or other seasonal crops during the 'Yala' season too. Three major reasons are identified, for erratic rainfall. There are thus a few key issues, especially climate change which is dominant in farmers' minds. Farmers had multiple answers regarding the perception of climate change; 83 per cent of them agreed that the climate is changing in the study area; 53 per cent respondents mentioned that the reasons for not timely getting rainfall were cutting down of local forests; 33 per cent farmers reported that it is due to un-reliability of monsoon onset (timing).However, discussions with farmers, in the study area indicated that the reasons for non-cultivation of large tracts of paddy land during the last 'Maha' and 'Yala' season, were mainly due to the uncertainty

of rainfall, both Northeast and Southwest monsoons. In the study villages, 80 per cent of the paddy farmers were not able to harvest more than 150 bushels of paddy from their paddy lands during the 'Maha' season.

(9) All the farmers are willing to cultivate paddy in the 'Maha' season, since the major cultivation season is 'Maha'. Due to uncertainty of the rainfall, cultivating double/triple crops are observed in paddy land in the 'Yala' season.

(b) Plantation Community (tea small-holdings):

(1) Even though the members are employed in some other occupations, all the committee members are tea small holders. The educational level of the small tea growers was quite high in the study area, i.e., 99 per cent of the tea farmers are literate. All the committee members are tea small holders. The monthly households' incomes of the majority of the tea farmers are better than the rice farmers, i.e., 50.1 per cent small holders are getting between SRs.3500-10000 per month.

(2) Of the tea growers studied, 66 per cent of the total operational holdings of the tea lands are less than two acres. The majority (55%) of the tea members self-owned tea allotments is less than two acres; 80 per cent of the tea members were able to harvest tea leaves less than 15000 kilograms from their tea lands per year.

(3) All the small tea farmers reported that the rainfall has been decreasing since past two three decades. The effect of rainfall decline on the value of tea is 100 per cent. Most of the respondents agree that the rainfall has been declining since last

few decades; and it affects the tea cultivation in different ways. Drought is also one of the main problems, which seriously affects the tea cultivation. All the small tea growers agree that the high temperature conditions during the summer months have been increasing since last two-three decades in the study area. Reasons for this increasing summer heat as per the respondent's views are given in the table 8.2h. Most of the farmers (99%) agreed that the heat in summer has been increasing due to climate change in Sri Lanka; 15.8 per cent attribute this to cutting trees in the study area. Other local activities like stone quarrying are also attributed as one of the reasons for increasing heat in summer in the study area. The respondents\` perceptions of the frequent droughts, on the basis of their past experiences, also indicate similarities among the respondents. Due to the continuous droughts, cultivators\` income has been decreasing by as much as 96 per cent, and also the effect on drying of the tea bushes has increased by 72 per cent. Poor yield also is one of the negative results of the drought damage affecting tea cultivation. Weather disturbances such as cyclone, storms and un-seasonal rains are also much noticeable in the study area. These weather disturbances mostly affect operational holdings less than 3 acres, i.e., very small farms, 43 per cent. Larger holdings (in between 4.01-10.00 acres) have fewer chances for getting damage from weather disturbances.

(4) Of the sample tea farmers, 83 per cent were able to obtain tea yield between 3001 and 4500 Kg. per year. Nearly 7 per cent get yield in between 4501-6000 Kg. per year. Yield per year is much higher in tea farms of size between 1.01 and 2.00

acres. The relationship between education and employment types are shown in the table 8.2m. Farmers with educational level of up-to grade ten and above (19%) are engaged Government services; 19 per cent are employed in the private sector employment; 15 per cent were self-employed.

(c) Coastal community (coconut-farmers and fishermen):

(1) Of the sample village, 26.5 per cent are employed in services and 73.5 per cent are in other occupations including fishing. Out of these respondents, most of them are engaged in fishing activities or in coconut cultivation. The monthly households' income per month for the majority of the households: more than 72 per cent of the families are above 5001 thousands.

(2) Six percent of the farmers who have passed the Ordinary Level (O/L) the income level, have incomes between SRs. 10001 and 15000 per month, 15 per cent having passed up-to grade ten, the income level was SRs. 15001-20000 per month; and 03 per cent farmers having passed up-to grade ten, the income level was between SRs. 25001-30000 per month.

(3) The nature of the fishing activities are three types in the study area. These are: Catching fish, drying fish and selling fish. Some families are engaged in all these activities, while some are engaged in one or two of the activities. Of the sample households, 29.4 per cent are not involved in any kind of fishing activities, whereas 62.8 per cent are engaged in catching fish only and 30 per cent are in

dry fish related activities and 67.6 per cent are engaged in selling and marketing of fish products.

(4) Of total fish production, 13.7 per cent households belong to below SRs 50,000 income class. Farmers with income between SRs. 50001 and 15000 are higher, i.e., percentage was 28.4. Farmers with fish production of more than SRs. 200001 per year constitute only 12.7 per cent. Nearly 70 per cent respondents agreed that the total fish production has been decreasing, since past two to three decades and 4 per cent received financial supports for the fish activities from the banks.

(5) Rainfall has also been decreasing in the study area since few decades, but un-seasonal rainfall has been on the increase that affects fishing activities. Weather disturbances like cyclones, storms are increasing in the surrounding sea area. Of the surveyed households, 71.6 per cent respondents agreed that. Frequent storms can damage fish harvesting.

(6) Coping with all the difficulties, the respondents are have problems of storage facilities for their fish production; i.e., 70.6 per cent. Nearly 60 per cent respondents reported that the labour cost has been increasing for fishing activities.

(d) Coconut Cultivation

(1) While engaged in fishing activities, most of the families are having coconut lands too, i.e. 89 per cent of the respondents are having coconut land. Of the

households, 88 per cent respondents have total operational holdings less than one acre. Only 11.76 per cent have more than 1.01 acres.

(2) Of the surveyed households, 55.88 per cent of the cultivators sell their coconut by SRs. 800.00 /100 nuts, 29.41 per cent at SRs 750 /100 nuts. Cost of production for 44.12 per cent cultivators is less than SRs. 0.00-2000 per acre of coconut land. That having a large area of coconut land, the total cost of production is also high. More than 15 per cent of the cultivators spend more than SRs. 8001 for their coconut cultivation as the cost of production.

(3) Most of the coconut cultivators reported that their production has been decreasing, since the past two to three decades due to bad weather conditions. Drought is one of the most telling weather events on coconut farming, which affects coconut cultivation in different stages of growth of the plant. Some farmers say that un-seasonal rains and unpredictable weather conditions also affect coconut production. When drought occurs, the coconut crops dry and the production gets affected; 89 per cent cultivators agree that the coconut plants are dieing due to drought.

(4) According to the survey, 30.4 per cent families are receiving relief support from the Government for their crop damage; 22 per cent received monitory supports. Out of this 22 per cent, 11.8 per cent received SRs. 1000 for crop damages, according to their income levels; 10.78 per cent cultivators received relief of SRs. 1500 and 3000.

Photo 8.1: Dry bed of an irrigation tank at Kelepuliyankulama

Photo 8.2: Extensive dried up an irrigation tank at Kelepuliyankulama

Photo 8.3 Drought and effect on dried up rice crop at Kandubodagama

Photo 8.4: Wilting tea crop at Ovilkanda

Photo 8.5: Drought and drying of coconut plantations at Ambakandavilla

Appendix – II

Questionnaire On

Farmers` attitudes & Perception towards Climate change and Adjustment of Farm Management

Identification Schedule:

1. Name of the respondent: (1.Male, 2.Female):
2. Age:
3. District: Division: G.N. Division and Village: ---------
4. Marital Status: (1.Unmarried, 2.Married, 3. Separated/divorced, 4.Widow/Widower):
5. Address:--

Socio-economic Background:

1. Religion: (1. Buddhist, 2. Hindu, 3. Muslim, 4. Christian)
2. Language: (1. Sinhalese, 2. Tamils)
3. Educational level: (1. Illiterate, 2. Grade five passed, 3. Up to grade ten, 4. O/L passed, 5. A/L passed, 6. Graduate, 7. Post Graduate, 8. Professional, 9. Up to grade five, 10. Schooling)
4. Employment Status: (1. Employed, 2. Unemployed)
5. If employed: Employment type: (1. Govt., 2. Private, 3. Self- employed, 5. Others)
6. Type of occupation: (1.Farmer, 2. Wage-earner, 3.Small business, 4. Teacher, 5. Other professions, 6. Abroad)
7. Monthly income of the respondent (S/L Rupees): ……….
8. House ownership status: (1. Own-house, 2. Rented house, 3. Others)
9. Durable goods in the house:
   (1. T.V, 2. Fridge, 3. Radio, 4. VCD/DVD, 5. Sound system, 6. Washing Mech.
   7. Computer, 8. Telephone, 9. Cooking gas, 10. Cycle, 11. Scooter, 12. .M/Cycle,
   13. Tractors, 14. Three wheelers, 15. Land master, 16. Fishing boats or nets,
   17. Motor car or van)

Family profile:

1. Family demography:

Members	Sex 1.Male 2.Female	Age (Years)	*Edu. level	**Employ. status	***If, employed, Employment. type	****Occupation
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

*Education level for an each members: (1. Illiterate, 2. Grade five passed, 3. Up to grade ten, 4. O/L passed, 5. A/L passed, 6. Graduate, 7. Post Graduate, 8. Professional, 9. Up to five, 10. Schooling)
** Employment status: (1. Employed, 2. Un-employed, 3. Self-employed)
*** If employed, Employment type: Nature of the employment: (1. Govt., 2. Private, 3. Self-employed, 5. others)
**** Type of Occupation: (1.Farmer, 2. Wage-earner, 3.Small business, 4.Teacher 5. Other profession, 6. Abroad)

D1. Economic situation (Paddy Farmers):

1. Total operational holdings:
2. How much self-owned:
3. What percentage (%) area is irrigated:
4. What percentage (%) is double/triple cropped:
   (i) Maha (%):
   (ii) Yala (%):
5. What is the type of irrigation: (1. Canals, 2. Tube wells, 3. Lift from rivers, 4. Tanks)
6. Do you think that you have enough irrigation facilities: 1.Yes 2.No:
7. What are the problems you have in related to irrigation water distribution: (1. Not proper canal system, 2. Timely not getting, 3. Scarcity of water, 4. Unequal distribution)
8. Do you get timely rainfall in the main rainy seasons: 1.Yes, 2.No
9. If not, why: (1. Due to forest clearing, 2. Climate is changing, 3.Unrelaibilty of monsoon onset)
10. What other inputs you use: (1. Mechanical, 2. Fertilisers, 3.Pesticides, 4. HYS)
11. What is your total rice out put: (Bushales):

    (i) Maha:
    (ii) Yala:

12. How many days of labour you use including your self :
    (i) Maha:
    (ii) Yala:
13. Do you receive crop finance from bank: (1.Yes, 2. No)
14. If yes, how much per season or year:
15. If no, if from other sources: 1.Family members, 2. Relatives, 3.Friends, 4. Seettu 5. Gold pawn, 6.Businessman)
16. how much:
17. What type of institutional supports you get? (1.Extension services, 2. Irrigation, 3. Flood control, 4.Pest Control, 5.Organic fertilisers)
18. Do you find the rainfall in the last 1-2 decades has: 1. Declined, 2. Increased?
19. What about the heat in summer? 1. Increased, 2. Decreased:
20. Are there more cyclones/storms/un-seasonal rains/droughts: 1.Yes, 2.No)
21. Do you think these changes in weather affect rice crop: (1.Yes, 2.No)
22. If yes, in what way: (1. Drying crops, 2. Increase pest problem, 3. Flooding the fields and damage to crop, 4. Storm damage of harvesting, 5. Poor seed quality, 6. Lost harvest, 7. Decrease income)
23. How do you cope with these difficulties: (1. More irrigation/water use, 2. Land development cost during the flooding, 3. Higher use of fertilisers, 4. High use of pesticides, 5. Cultivating different crops, 6. Increasing labour cost, 7. Increasing losses or yield decrease , 8. Planting some varieties which is resistance to drought)
24. Are there government supports for crop damages: 1. Yes, 2.No:
25. Whether by relief or monetary assistance? 1. Relief, 2. Monetary
26. Do you have enough storage facilities for grains: 1.Yes, 2. No:

D2. Economic situation (Small Tea Planters):

1. Total operational holdings (Ac.):
2. How much self-owned (Ac.) :
3. Water use system: (1.Sprinkler systems, 2.Powered tube wells, 3. Traditional methods, 4. Rain dependant)
4. What other inputs you use: (1. Mechanical, 2. Fertilisers, 3.Pesticides, 4. HYS)
5. What is your total tea out put per year (raw leaf) kg.:
6. How many days of labour you use (per year) :
    (a) Regular labour (No.)
7. Do you receive finance from bank: 1.Yes, 2. No
8. If yes, (a) how much working capital per year?
    (b) Fixed capital (per year):
    (c) Years of amortisation:
9. If no, if from other source: 1. Family, 2.Relatives, 3.Friends, 4. Seettu, 5. Gold pawn, 6.Businessman)
10. Any other institutional supports: (1. Extension services, 2.Drought relief, 3. Tea plants or seeds, 4. Fertiliser)

11. Do you find the rainfall in the last 1-2 decades has: (1. Declined, 2. Increased?)
12. If rainfall is declined, it is affecting your tea cultivation? (1.Yes, 2. No)
13. If Yes, how? (1. Drying tea, 2. Decrease out put, 3. Quality decreasing, 4. Decreasing income, 5. Increasing crop diseases)
14. What stages? (1. First plucking stage, 2.Growth stage, 3.Second plucking stage, 4. Growth stage, 5.Third plucking stage)
15. Which rainfall season is the best and important for your tea plants: (1.FIM, 2.SWM, 3.SIM, 4.NEM)
16. What about the heat in summer? 1. Increased, 2. Decreased:
17. If increases : reasons: (1. Due to local deforestation, 2. Due to climate change, 3.Breaking Quarry)
18. Did you get drought damage in the last 10 years: 1.Yes, 2.No
19. If yes, how did it damage your crop: (1. Decreased income, 2.Increased maintain cost, 3. Drying crops, 4. Poor yield, 5.Poor quality tea, 6.Pest infestation)
20. Percentage of drought damage from your total production /per year:
21. Are there more cyclone/storms/ un-seasonal rains: (1.Yes, 2.No)
22. Do you think these changes in weather affect tea crop: (1.Yes, 2.No)
23. If yes, in what way: (1. Drying crops, 2. Excessive rain with the soil erosion, 3.Storm and wind damage, 4. Poor leaf quality, 5.Pests and diseases)
24. Soil erosion is high in your tea garden: 1.Yes, 2. No
25. If yes, what are the reasons for that: (1. Improper land use, 2.Unsuitable soil structure, 3. Improper planting system, 4. Lack of shade trees, 5. Heavy rainfall)
26. Do you have wind damage in your field: (1.Yes, 2. No)
27. If yes, how it affect to your tea plants: (1. Lack of shelter-belts, 2. Lack of shading trees, 3. Improper pruning style, 4. Improper looping and uprooting of shade tress, 5. Breaking tea young leaves)
28. Do you get frost damage in your field: 1.Yes, 2. No
29. If yes, explain how does it damage your plants and which stage does it most seriously affect the tea plants: (1. Planting stage, 2. Growing stage, 3.Plucking stage)
30. Do you plant any other crops with the tea plants other than shade trees: 1.Yes, 2. No
31. Are there government supports for damages? 1. Yes, 2. No
32. If yes, what type of supports: (1. Relief 2.Monetary assistance, 3. Insurance coverage)
33. Do you have enough storage facilities until send to the market: 1. Yes, 2. No

D3 (a): Economic situation (Coastal community: Fishing and Coconut):

1. Nature of your fishing activities: (1. Catching fish, 2. Selling fish, 3. Drying, 4. others)
2. The types of the fish: (1.Seer, 2.Paraw, 3.Balaya, 4.Kelawalla, 5.Prawns, 6. Small fishes)
3. Total fish production (per year): by weight: kg---------
4. Total fish production: by value/year: Rs:---------

5. How much fresh fish is converted into dry fish from your total fresh fish production: %? ....
6. Do you think your total production is decreasing : (1.Yes, 2. No)
7. If yes, reasons: (1. Due to lack of boats and instruments facilities, 2. Due to weather disturbances, 3. Due to shortage of labour, 4. Due to increasing maintain cost, 5. Due to other source of income, 6. Less breeding of fish)
8. What are the other source of income: (1. Selling eatable things, 2. Selling sea production for tourists, 3. Providing local tourists lodges, 4. Selling coconut, 5. Animal husbandry, 6. Paddy income)
9. What type of fishing boats facilities you have: (1. Traditional non mechanised country boats, 2.Out board mechanised motors with Fibre glass, 3. Trawlers: mechanised, 4. Other mechanised craft (ex: 3 and half ton and above, 5. Fishing nets)
10. How many days of labour you use including your self/ per month:
11. Do you receive finance from bank: (1.Yes, 2. No)
12. If yes, how much per year:
13. If no, if from other sources: : (1. Family, 2.Relatives, 3.Friends, 4. Seettu, 5. Gold pawn, 6.Businessman)
14. How much...
15. What type of institutional supports you get: (1.Supplying boats, 2. Life insurance, 3. Storage facilities, 4. Marketing supports: Buying fish, 5. Transportation, 6. Others)
16. Do you find the rainfall in the last 10 years has: 1. Declined, 2. Increased
17. What about the heat in summer? 1. Increased, 2.Decreased:
18. Are there more cyclone/storms/un-seasonal rains: 1.Yes, 2. No:
19. Do you think these changes in weather affect your fishing activities: 1.Yes, 2.No:
20. If yes, in what way: (1. Decreasing number of fishing days, 2. Lack of boat facilities and lack of improved boats 3. Storm damage of /fishing harvesting, 4. Others)
21. How do you cope with these difficulties: (1. Increasing labour cost, 2. Increasing loan, 3. Problems of storage, 4. Problem of drying fish, 5. Alternative income, 6. Damaging fishing boats, 7. Life insecurity, 8. Others)
22. Are there government supports for damages: 1.Yes, 2.No:
23. Whether : 1. Relief, 2. Monetary help
24. Do you have enough storage facilities for fish production: 1. Yes, 2. No

(b)Coconut cultivation:

1. Do you have coconut land : 1.Yes, 2.No
2. If yes, total operational holdings :
3. How much self-owned :
4. Total number of matured tress:
5. What percentage is inter cropping:
6. If yes, what are the crops: (1. Fruits, 2.vegetables, 3.Leaves, 4. Grass, 5. Others)
7. What other inputs you use: (1. Mechanical, 2. Fertilisers, 3. HYS, 4. Pesticides, 5. Others)
8. What is your total coconut nuts: out put per year/ unit land:

9. At what price do you sell/100:
10. Do you process the coconut: 1. Yes, 2. No , .
    If yes,
    (a) For oil extraction
    (b) Copra
11. How many days of labour you require:
    (a) For land preparation
    (b) For planting
    (c) For harvesting and collecting
    (d) Total days of labour per time or per year:
12. Total cost of production:
13. Do you receive crop finance from bank: (1.Yes, 2. No)
14. If yes, how much per year or time:
15. If no, if from other source: (1. Family, 2.Relatives, 3.Friends, 4. Seettu, 5. Gold pawn, 6.Businessman)
16. How much:
17. Any other supports you receive for coconut plantation: (Yes/No):
18. If yes what type of supports: (1.Seeds, 2. Plants, 3.Fertilisers, 4. Pesticides 5. Guidance for improving production, 6. Buying coconut nuts, 7. Providing selling centres, 8.Others)
19. Do you find the rainfall in the last 10 years has : 1. Declined, 2. Increased:
20. What about the heat in summer? 1. Increased, 2. Decreased:
21. Are there more cyclones/storms/un-seasonal rains/droughts: (1. Yes, 2.No)
22. Do you think these changes in weather affect coconut crop: (1.Yes, 2.No)
23. If yes, in what way: (1. Drying crops, 2.Excessive rain for primary planting stage, 3. Storm or wind damage of harvesting time, 4. Pest/ insect damage 5. Others)
24. Did you get any pest damage in the last 10 years: 1.Yes, 2. No
25. If yes, what are the reasons: (1. Due to drought condition, 2. From other tress species, 3. Due to lack of pesticides, 4. Due to improper maintenance, 5. Others)
26. How do you cope with these difficulties: (1. More water use, 2. Higher use of fertilisers, 3. High use of pesticides, 4. Cultivating different crops, 5. Increasing losses, 6. More labour cost, 7. Engaging other economic activities)
27. Total income from other crops other than coconut: per month:
28. Do you produce by products from your coconut tress: 1.Yes, 2. No
29. What type of products: (1. Fire wood, 2. Ornaments, 3.Cococnut leaves for roof purposes, 4. For timber, 5.Coir, 6. Coir products, 7. Coconut shells)
30. Total income from by products:
31. Are there government supports for damages: 1. Yes, 2. No
32. If yes, Whether: 1. Relief, 2. Monetary help
33. How much?

Chapter – IX

Conclusion

9.0 Summary of Main Findings

Despite varied opinions and prevarications, climate change is a reality to be grasped with and dealt with; after Montreal and Kyoto, the Buenos Aires World Conference in November 2004 is vindication of this realisation. The difficulties arise due to its regionally differentiated impacts as well as the differentiated abilities of different societies to cope-up with its consequences, particularly the abilities of common people in developing societies to deal with the situation. In that context, the present study on climate change in the Island nation of Sri Lanka and its possible impacts on the agricultural economy and the farming communities acquire added importance.

9.1 Climate Change in Sri Lanka

(a) It is estimated that annual average of monthly temperature, mean maximum temperature and mean minimum temperature have been rising in almost all the stations in the study area of Sri Lanka, between 1959 and 2002 and increases are quite pronounced during recent decades. Average annual temperature increased by more than 0.4 ^{0}C at all the stations except, Nuwaraeliya that lies in the Central Highlands at 1895m above mean sea level. When compared across the entire period, it becomes clear that greater increases in temperature (warming) were recorded over more recent periods than over the whole observation period, especially after the 1970s. Almost all the stations show annual average temperature increases, for the entire four decades periods since 1960. Trend computation for mean maximum temperature also shows positive warming trends over the whole period, especially significant after the 1970s. For most of the stations, the month of the May and April are recorded as the warmest months of mean maximum temperature. Mean minimum temperature months are recorded in November, December and January. Mean minimum temperature also has been increasing at all the stations. Decadal temperature changes indicate consistent increase over the entire period, especially after the mid 1970s. Considering overall situation, Sri Lanka had two warmest periods during the last 50 years. The first period was in the 1970s and other period was in the 1990s. Increasing trend of temperature can be noticed for all the seasons and stations during the First Inter Monsoon season, Southwest Monsoon season, Second Inter Monsoon and Northeast Monsoon seasons.

(b) Regional variations in temperature increases indicate that increases are higher in the Dry zone than the other two zones, Intermediate and Wet zone in Sri Lanka. Temperature forecasts indicate that it will increase by more than one degree Celsius in the Dry zone, by 2050. In the year 2000, the monthly average temperature was 27.95 °C in the Dry zone, which will increase to 28.25 ^{0}C in 2010, to 28.44 ^{0}C in 2020, to 28.63 ^{0}C in 2030 and to 29.02 ^{0}C in 2050, respectively. Temperature increases will be higher in the Intermediate zone than Wet zone. Temperature will increase by 1.03 ^{0}C in the Intermediate zone by 2050. Monthly average temperature was 25.84 ^{0}C in the Intermediate zone in the year 2000, which will increase 26.10 in 2010, to 26.29 ^{0}C in 2020, to 26.49 ^{0}C in 2030 and to 26.87 ^{0}C in 2050, respectively. Temperature increases will be lower in the Wet zone than other two zones due to influence of higher precipitation. Temperature will increase by 0.84 0C by 2050 in the Wet zone. Monthly average temperature was 27.18 °C in the Wet zone in the year 2000, which will increase to 27.29 ^{0}C in 2010, 27.47 ^{0}C in 2020, 27.65 ^{0}C in 2030 and 28.02 ^{0}C in 2050, respectively.

9.2 (a) From the foregoing analyses of precipitation conditions in the study area for the past four decades, it is clear that there has been a consistent decline in the quantum of rainfall over the area, especially during the recent decades. Out of 33 stations, 32 stations show, negative trends of annual average rainfall (exception is, positive trend only at Watawala station). Almost all the stations with negative trends show sharp decreases in 1970 and again from 1980 to 1990s. Considering overall situation, the rainfall declines appear to be associated with the warmest periods, i.e., the 1970s and the 1990s in Sri Lanka. This appears somewhat unusual in the sense; warmer periods are associated with increased precipitation. This does not happen in the instant case, for reasons associated with global circulation issues, much beyond the scope of the present study. Slopes of linear trends show, out of 35 stations, 26 stations in First Inter Monsoon season, 30 stations in Southwest Monsoon season, 24 stations in

Second Inter Monsoon season, and 24 stations in Northeast Monsoon seasons have shown decreasing trends in precipitation.

(b) On the basis of the precipitation forecasts, all the three ago-climatic zones indicate consistent decline in average monthly rainfall. The slopes for all the three linear trends are highly significant. The rainfall decline will be somewhat sharper in the Intermediate zone as compared to the other two zones. In the Intermediate zone, the monthly average rainfall will decrease by -58.74 mm in 2050 as compared with 2000 level, i.e., 150.8 mm. The average yearly decline will be 21.40 mm, which is the highest predicted decline among the three zones. The forecasts for average monthly precipitation for the zone, decline by –17.83, -28.06, and -38.28 mm for the years 2010, 2020 and 2030, respectively. In the Wet Zone, the average monthly rainfall will decline by -55.21 mm. by 2050, as compared to the monthly averages for 2000, i.e. 197.73 mm. Rainfall is predicted to decline by –15.68 mm./per year in the Wet zone. The forecasts for other years will be decline by –13.07 mm, -23.6 mm and -34.14 mm for 2010, 2020 and 2030, respectively. The Dry zone appears to be relatively less affected by the predicted decline in average monthly rainfall as compared with the other two zones. The rainfall will decline by –14.69 mm. /per year in the Dry zone, resulting in an average monthly decrease of –38.08 mm. in 2050, as compared with the figures of 2000 (105.2 mm), which could have devastating impact in the largely rain-fed and water deficit area. Monthly average decline in rainfall will be by –12.24 mm, -18.88 mm and -25.52 mm for 2010, 2020 and 2030, respectively.

9.3 Agriculture: Coverage, Production and Yield Changes in Principal Crops:[1] Rice

(a) Trend of rice production was positive for the districts of Anuradhapura, Kurunegala, Kalutara, Badulla, Galle, Matale, Ratnapura and Matara during 'Maha' season from 1969 to 2001. The rice production declined at Colombo Kandy, Nuwaraeliya, Gampaha and Kegalle during the 'Maha' season. The trend of rice production was positive, in the districts of Anuradhapura, Kurunegala, *Kalutara, *Badulla, *Matale and *Matara during 'Yala'. The trends of rice production were negative, at *Colombo, Galle, *Kandy, *Nuwaraeliya, Ratnapura, Gampaha and Kegalle during 'Yala' in concerned period.

(b) The trend of rice coverage was positive at *Badulla, Galle *Matale and Matara during 'Maha' cultivation season since 1969 to 2001. The trends of rice coverage were negative at Anuradhapura, Kurunegala, Kalutara, *Colombo, *Kandy, Nuwaraeliya, Ratnapura, *Gampaha and *Kegalle during 'Maha'. The trend of rice coverage was positive only at *Badulla and Matale during 'Yala'. The trends of Rice coverage were negative at Anuradhapura, Kurunegala, *Kalutara, *Colombo, *Galle, *Kandy, *Nuwaraeliya, Ratnapura, *Gampaha, Kegalla and Matara during 'Yala'.

(c) Average yield of paddy has been increasing continuously, almost all the district in the 'Maha' and 'Yala' seasons, since 1971. Anuradhapura, Badulla and Mathale recorded the highest yields in the 'Maha' season (more than 80 bushels per net acres) in the 2000-01 cultivation period. The lowest rice yields were recorded at Galle and

[1] * indicates statistically significant estimates.

Kalutara. Anuradhapura and Badulla alsorecorded the highest yields in the 'Yala' season.

(d) Growth rates of rice coverage is negative at Anuradhapura, Colombo, and Nuwaraeliya from 1970 to1980 during the 'Maha' season. Negative growth rate of area coverage are observed at Anuradhapura, Kurunegala, Colombo, Gampaha, Galle, Kalutara, Kandy, Kegalla, Matale, Ratnapura and Matara in 1980-2001. Growth rates of rice yield is negative at Badulla, and Nuwaraeliya during 1970-81. The growth rate is negative only at Nuwaraeliya during 1980-2001. Growth rate of rice production is negative at Colombo and Nuwaraeliya since 1970-81. Growth rate was negative at Kurunegala, Colombo, Kandy and Kegalle (1980-2001) in Maha season. Colombo, Kegalle and Nuwaraeliya is negative since 1970-2001 in 'Maha' season. Negative Growth rate of rice gross extent is higher (less than -1.5% per year), during Maha season, in the district of Anuradhapura, Kurunegala, Colombo, Gampaha, Kandy and Kegalle from 1980/81 to 2000/2001. Negative Growth rate of rice production is higher (less than -1.5% per year), during Maha season, in the district of Kurunegala, Gampaha and Kegalle from 1980/81 to 2000/2001. Negative Growth rate of rice gross extent and production is higher (less than -1.0% per year), during Maha season, in the district of Colombo and Kegalle from 1970-71 to 2000-2001.

(e) Growth rates of rice coverage is negative at Anuradhapura, Badulla, Colombo, Kandy, Matale, Nuwaraeliya, between 1970 and 1980 during the 'Yala' season. Negative growth rates are observed in the districts of Kurunegala, Colombo, Gampaha, Galle, Kalutara, Kandy, Kegalle, Nuwaraeliya, Ratnapura, and Matara between 1980 and 2001 during the 'Yala' season. Growth rate of rice yield is negative at Badulla, and Nuwaraeliya during 1970-80.

(f) Growth rates of rice production are negative at Anuradhapura, Badulla, Colombo, Kandy, Matale, Nuwaraeliya and Ratnapura between 1970 and 80 during the 'Yala' season. Negative growth rates can be noticed at Kurunegala, Colombo, Gampaha, Galle, Kandy, Kegalle and Nuwaraeliya between 1980 and 2001 during the 'Yala' season. Negative Growth rate of rice gross extent is higher (less than –2.0% per year), during Yala season, in the district of Colombo, Gampaha, Galle and Kegalle from 1980-81 to 2000-2001. Negative growth rates of rice production is higher (more than –2.0% per year), during the Yala season, in the district of Colombo, Gampaha, Galle and Kegalle from 1980-81 to 2000-2001. Negative growth rate of rice coverage and production is higher (less than –1.5% per year), during Yala season, in the district of Colombo, Galle, Nuwaraeliya and Ratnapura from 1970-71 to 2000-2001.

9.4 Agriculture: Coverage, Production and Yield Changes in Principal Crops: Plantation Crops:

(a) The production of High and Medium grown tea has been decreasing while the Low grown tea production has been increasing. Annual tea production has steadily increased after 1992, in all the tea growing areas, but increasing trend is much higher at high grown areas compared to the medium and the low grown areas. Districts-wise high grown areas include Kandy, Nuwaraeliya and Badulla. Medium and low grown tea production has been decreasing continuously. According to tea cultivation districts, Nuwaraeliys has the highest tea cultivation, but cultivated area has been decreasing since 1982. Next to Nuwaraeliya, Kandy and Badulla are important for tea cultivation. But cultivation area has been decreasing these two districts too, since 1982.

(b) Rubber is mainly a wet zone, mid-country crop, with over 60 per cent of the total extent concentrated in the Kegalle, Kalutara and Ratnapura district. Colombo and Galle account for another 20 per cent and the balance is dispersed over other areas in the Wet zone or in the Intermediate zone with at least 1500mm. The trends of area cultivation of rubber has been decreasing, drastically most of the districts. All the districts are reported significant negative slope of area extent except, Hambantota and Kurunegala. The rubber sector has shown variations in its production, during the past few years. The over all trend of rubber production in Sri Lanka, shows increasing trends but the trend was not significant for the production. Average yield of rubber is fluctuating and still the yield is less than the potential yield of 2000 kg per hectare.

(c) Coconut production have been fluctuating for the entire the period of study and in some years, the production is below the average of 2435 mn nuts (1973-81, 1983-84, 1987-88 and 1991-93). The highest production was recorded (3096 million nuts) in the year 2000, but in year 2001, again the production declined. The districts wise production figures are not available for coconut in Sri Lanka. The coconut production is extremely susceptible during the drought years. The coverage of the crop has been decreasing significantly, e.g., at Colombo, Kalutara, Ratmalana, Puttalama, and Kegalla between 1960s and 1993s; some area increases are noticed in the districts of Moneragala, Rathnapura and Mathale. The negative trends are significant at Colombo/Gampaha, Kalutara, Puttalama and Kegalle. Positive increasing trends also noticed and significant at Nuwaraeliya, Rathnapura and Moneragala.

9.5 Influence of Climate Change on Agriculture:

(a) Climate Change and Rice:

(i) Positive correlation between paddy production and rainfall were found for 'Maha' season in districts of Anuradhapura, Kalutara, *Galle, Kandy, *Nuwaraeliya, *Ratnapura, Gampaha and *Kegalle and during the 'Yala', in districts of *Anuradhapura, Colombo, Galle, *Kandy, Nuwaraeliya, Matara, Gampaha and Kegalla. During 'Maha' negative correlation between paddy production and rainfall were found in districts of Kurunegala, Badulla, Mathale, Colombo and Matara and during the 'Yala', in the districts of *Kurunegala, Badulla, Mathale, Kalutara and Ratnapura. Except Anuradhapura (dry zone), most of the districts are in the Wet zone and expectedly, in a number of districts, increased rainfall has a positive contribution to rice output. Therefore, the long-term trends in decline in monthly average rainfall will undoubtedly result in decline in output. This happens for both the principal seasons.

(ii) Similarly, during the 'Maha' season, positive correlations between paddy production and temperature were found in all the districts, except in districts of Colombo, Gampaha and Kegalla; and during 'Yala' season, in districts of Kurunegala, Badulla, Matara, Kalutara, Galle and Kegalle. Out of these positive cases, significant positive correlations were found in during 'Maha' at Anuradhapura, Kalutara, Badulla, Galle, Ratnapura and Matara during 'Yala' at Badulla, Mathale and Kalutara. During the 'Maha' season, negative correlation between paddy production and temperature were found in the districts of *Colombo, *Gampaha and Kegalle, and during 'Yala' season, in districts of *Anuradhapura, *Colombo, *Kandy, Nuwaraeliya, *Gampaha, Matara and *Ratnapura.

(iii) Linear regression analysis of rainfall (independent) on paddy production (dependent) shows positive slopes in the districts of Anuradhapura, Kalutara, Galle, Kandy, Nuwaraeliya, Ratnapura, Gampaha and Kegalle, during 'Maha'. Negative slopes are estimated for districts of Kurunegala, Badulla, Colombo, Mathale and Matara. Linear regression analyses of temperature on paddy production shows positive slopes in all the districts, except Colombo, Gampaha and Kegalle during the 'Maha' season.

(iv) During the 'Yala' season, linear regression analyses of rainfall on paddy production shows positive slopes in districts of Anuradhapura, Colombo, Kandy, Nuwaraeliya, Matara and Kegalle and negative slopes, in districts of Kurunegala, Kalutara, Badulla, Galle, Matale, Ratnapura and Gampaha.

(v) Linear regression analyses of temperature on paddy production shows positive slopes in districts of Kurunegala, Kalutara, Badulla, Galle, Mathale and Kegalle during 'Maha', and negative slopes, in districts of Anuradhapura, Colombo, Kandy, Nuwaraeliya, Ratnapura, Matara and Gampaha.

(vi) During the 'Maha' season, positive correlations between paddy coverage and rainfall were found in districts of Anuradhapura, Kurunegala, *Kalutara, Galle, *Nuwaraeliya, *Gampaha and *Kegalle during 'Maha'. Positive correlation in between coverage of paddy and rainfall were found during 'Yala' in districts of *Anuradhapura, *Colombo, Galle, *Kandy, Nuwaraeliya and Kegalla and negative correlations, during 'Maha' in districts of Badulla, Matale, Colombo, *Kandy, Matara and *Ratnapura and negative correlations, during 'Yala' in districts of Kurunegala, Badulla, Matale, Kalutara, Ratnapura, *Gampaha and Matara.

(vii) Positive correlations between paddy coverage and temperature were found during 'Maha' at *Badulla, Mathale, *Nuwaraeliya, Ratnapura and Matara and during 'Yala', at *Badulla Mathale and Galle and negative correlations, at Anuradhapura, Kurunegala, Kalutara, *Colombo, Galle, *Kandy, Gampaha and *Kegalle.

(viii) Linear regression analyses of 'Maha' rainfall on paddy coverage shows positive slopes at Anuradhapura, Kurunegala, Kalutara, Galle, Nuwaraeliya, Gampaha and Kegalle during 'Maha' and negative slopes, in districts of Badulla, Colombo, Kandy, Mathale, Ratnapura and Matarta. Linear regression analyses of 'Maha' season temperature on paddy coverage shows positive slopes in districts of Badulla, Matale, Nuwaraeliya, Ratnapura and Matara and negative slopes, in districts of Anuradhapura, Kurunegala, Kalutara, Colombo, Galle, Kandy, Gampaha and Kegalle .

(ix) Linear regression analyses of 'Yala' rainfall on paddy coverage shows positive slopes in districts of Anuradhapura, Colombo, Galle, Kandy, Nuwaraeliya and Kegalle and negative slopes in districts of Kurunegala, Kalutara, Badulla, Matale, Ratnapura, Gampaha and Matara. Linear regression analyses of 'Yala' temperature on paddy coverage shows positive slopes at Badulla, Colombo, Galle and Matale and negative slopes in districts of Anuradhapura, Kurunegala, Kalutara, Kandy, Nuwaraeliya, Ratnapura, Gampaha, Kegalle, and Matara.

(b) Climate Change and Tea:

(i) Significant positive correlations between annual average tea production and annual average rainfall were found in the High grown and Medium grown areas. Significant negative correlation was found in Low grown areas. Significant negative correlation between annual average tea production and annual average temperature were found in the high grown and medium grown areas. Significant positive correlation was found in Low grown areas. This clearly indicates that whereas, increased rainfall has salubrious influence on tea output, temperature increases have negative impact. Given the long-term trend of decreasing rainfall and increasing average temperature condition, the impact on tea output could be debilitating.

(ii) Linear regression analyses of rainfall on tea area coverage show positive slopes at medium grown areas. On the other hand, rainfall on tea area coverage shows negative slopes in the high and low grown areas. Linear regression analyses of temperature on tea area coverage show positive slopes in the low grown areas. On the other hand, temperature on tea area coverage shows negative slopes in the high and medium grown.

(c) Climate Change and Coconut:

(i) Positive correlation between coconut area coverage and annual average rainfall were found in the districts of Colombo, Kalutara, *Nuwaraeliya, Badulla, Ratnapura, *Puttalama and Kegalle and significant negative correlation were found in the districts of Kandy, Mathale, Galle Matara, Kurunegala, and Anuradhapura. Positive correlation between coconut area coverage and annual average (daily) temperature were found in the districts of Kandy, *Kurunegala, *Anuradhapura, *Badulla and *Hambantota and significant negative correlations, in the districts of Colombo, Nuwaraelya, Galle, Ratnapura and Puttalama.

(ii) Linear regression analyses of temperature on coconut area coverage show positive slopes in the districts of Kandy, Kurunegala, Anuradhapura, Badulla and Hambantota and negative slopes, in the districts of Colombo, Nuwaraeliya, Galle, Ratnapura and Puttalama. Linear regression analyses of rainfall on coconut area coverage shows positive slopes in the districts of Colombo, Kalutara, Nuwaraeliya, Badulla, Ratnapura, Puttalama and Kegalle and significant negative slopes, in the districts of Kandy, Matale, Galle, Matara, Kurunegala and Anuradhapura.

(d) Climate Change and Rubber:

(i) Positive correlation between rubber area coverage and annual average rainfall were found in the districts of Ratnapura, Kandy, *Hambantota, Kalutara, and *Kegalle and negative correlations, in the districts of Colombo, Galle, *Kurunegala Matara, Matale and Badulla. Positive correlations between rubber area coverage and annual average temperature were found in the districts of Nuwaraeliya and Kurunegala and significant negative correlations, in the districts of Colombo, Galle, Ratnapura, Kandy, Badulla and Hambantota. Linear regression analyses of rainfall on rubber area coverage show positive slopes at Colombo, Ratnapura, Kandy, Hambantota, Kalutara, and Kegalle and negative slopes at Galle, Kurunegala, Badulla, Matara and Matale. Linear Regression analyses of temperature on rubber area coverage show positive slopes in the districts of Nuwaraeliya and Kurunegala and negative slopes in the districts of Colombo, Galle, Ratnapura, Kandy Badulla and Hambantota except Nuwaraeliya and Kurunegala.

9.6 Climate Change and Community Perception and Adaptation

(a) Rice-farming Community

(i) The study of three villages in the primarily rice cultivating areas of Anuradhapura district indicates that majority of the farmer (around 90%) are conscious of the constantly rising temperatures and declining and increased uncertainty of rainfall during the main monsoons of the Island, on which they depend for their rain-fed crop.

(ii) Currently seven rain-fed small tanks are functioning in the study area but there is invariably no water in the 'Yala' season in these all tanks. Therefore, none of the farmers has not been able to cultivate paddy in their paddy land due to shortage of water. Even 'Maha' season, during the field survey (October to April of 2003-2004) water had dried up in all the tanks in the study area, due to less rainfall from Northeast Monsoon. All the tanks depend on local rainfall and therefore, subject to recurrent of droughts; and most of the years, especially in the 'Yala' season tanks are totally, dry. None of the tanks are linked to any major irrigation schemes in the study area and therefore, vulnerability to local rainfall failure. Even today, this area remains one of the few areas of the Dry zone, which is one of the least benefited regions by any major irrigation project. The livelihood of peasant communities in this area is largely dependent on paddy cultivation, based on a highly variable rainfall system.

(iii) Of the sample households, 84 per cent of the total operational holdings of the paddy lands are less than two acres; they are small and marginal farmers with monthly income less than SRs.2000 are having total operational holdings only less than 1.00 acre.

(iv) The rainfall fluctuations have also affected average yields and consequent adoption by paddy farmers of poor management practices, such as dry sowing, poor weeding, low levels of fertiliser application and inadequate disease and pest control. The weather failures had discouraged them from using costly inputs or adopting expensive management practices, due to high investment risks. According to farmers, during the last two decades, rainfall has decreased drastically; 96 per cent farmers reporting that the rainfall has decreased in the study area.

(v) The majority of the farmers indicated, that drought occurred in a 3 to 7 year cycle. Others indicated, drought as a more frequent phenomenon in the study area. Overall, 100% of the households indicated that they were very vulnerable to the droughts and the recent droughts had been particularly severe on their agricultural activities.

(vi) The perception of the climate change among selected paddy farmers appears to be remarkably similar. The rainfall regime in the Dry Zone area is characterised by marked seasonality. This brings into focus an important fact of the Dry zone climate, which does not seem to have received adequate attention of agricultural planners and policy makers in Sri Lanka. The farmers` perception of the condition of 'climate change' is influenced by a number of factors. It is mainly influenced by the impact of water shortages on one's vital interest, past experiences of working and living in abundant or low rainfall areas, the perceived advantage of one's place of living, varying aridity in given geographical areas, the frequency of drought occurrence and the magnitude of the drought.

(vii) The majority of the respondents (96%) stated that they are not getting timely rainfall to undertake paddy cultivation during the 'Maha' season. Therefore, it affected cultivation of paddy or other seasonal crops during the 'Yala' season too. However, discussions with farmers, in the study area indicated that the reasons for non-cultivation of large tracts of paddy land during the last 'Maha' and 'Yala' season, were mainly due to the uncertainty of rainfall, both Northeast and Southwest monsoons. In the study villages, 80 per cent of the paddy farmers were not able to harvest more than 150 bushels of paddy from their paddy on the average, during the 'Maha' season. There is little multiple cropping in the area due to scarcity of water outside the Maha (North East Monsoon) season.

(b) Plantation Community (tea small-holdings):

(i) The small tea growing community (the two tea growers associations that were studied), appear to be somewhat better off because small tea plantation in many cases, is a subsidiary occupation. The monthly household income of the majority of the tea farmers are (50.1 per cent) between SRs.3500-10000 per month. Of the tea growers studied, 66 per cent of the total operational holdings of the tea lands are less than two acres. The majority (55%) of the tea members self-owned tea allotments is less than two acres; 80 per cent of the tea members were able to harvest tea leaves less than 15000 kilograms from their tea lands per year.

(ii) All the small tea farmers reported that the rainfall has been decreasing since past two three decades. The effect of rainfall decline on the value of tea is substantial, since it is a totally rain-fed crop and very susceptible to high temperature and infrequent rainfall conditions. Periodic drought is one of the main problems, which seriously affects the tea cultivation. Most of the farmers (99%) agreed that the heat in summer has been increasing due to climate change in Sri Lanka; 15.8 per cent attribute this to indiscriminate cutting of trees in the study area.

(iii) Weather disturbances such as cyclone, storms and un-seasonal rains are also much noticeable in the study area. These weather disturbances mostly affect operational holdings less than 3 acres, i.e., very small farms, 43%. Larger holdings (in between 4.01-10.00 acres) have fewer chances for getting damage from weather disturbances.

(c) Coastal community (coconut-farmers and fishermen):

(i) The third sample community study refers to the coastal communities either in fishing or coconut growing or both. Of the sample village, 26.5 per cent are employed in services and 73.5 per cent are in other occupations including fishing. Out of these respondents, most are engaged in fishing activities or in coconut cultivation. The monthly households' income per month for the majority of the households: more than 72 per cent of the families are above SRs. 5001; comparatively they are better off than the rice farmers.

(ii) Nearly 70 per cent respondents agreed that the total fish production has been decreasing, since past two to three decades and 4 per cent received financial supports for the fish activities from the banks.

(iii) Rainfall has also been decreasing in the study area since few decades, but un-seasonal rainfall has been on the increase that affects fishing activities. Weather disturbances like cyclones, storms are increasing in the surrounding sea area. Of the surveyed households, 71.6 per cent respondents agreed that frequent storms can damage fish harvesting. Coping with all the difficulties, the respondents are have problems of storage facilities for their fish production; i.e., 70.6 per cent. Nearly 60 per cent respondents reported that the labour cost has been increasing for fishing activities.

(iv) While engaged in fishing activities, most of the families are having coconut lands too, i.e., (89 per cent). Of the households, 88 per cent respondents have total operational holdings less than one acre. More than 15 per cent of the cultivators spend more than SRs. 8001 for their coconut cultivation as the cost of production.

(v) Most of the coconut cultivators reported that their production has been decreasing, since the past two to three decades due to bad weather conditions. Drought is one of the most telling weather events on coconut farming, which affects coconut cultivation in different stages of growth of the plant. Some farmers say that un-seasonal rains and unpredictable weather conditions also affect coconut production. When drought occurs, the coconut crops dry and the production gets affected; 89 per cent cultivators agree that the coconut plants are drying due to drought.

9.7 General Conclusion:

The broader implications of the study could be summarised as follows:

(i) According to the first objective of the present study, i.e., *to study the present climate changes and the fluctuations, annual and seasonal variability of rainfall and temperature conditions (between 1950 and recent times)*, the major findings are found as follows:

(a) A number of global studies including IPCC do confirm a global level climate change during the last century, but especially after the 1970s. However, region/ country level studies are patchy, but, by and large, agree with the above position. Some recent climatic studies on Sri Lanka (Domores, Chandrapala etc) also confirm a similar process in the Island Nation. The present study that covers nearly half of Sri Lanka (covering all the three major agro climatic zones of the country, 13 out of 25 districts) indicate significant temperature and rainfall (both quantum and seasonal incidence) on the basis of 40 year data for 12 temperature reporting and 33 rainfall reporting stations covering the entire study region. Annual as well as maximum/ minimum temperature conditions are consistently on the rise from 1960s, but are especially pronounced after the 1970s. Both linear trends and growth rates confirm these positions. The position of high altitude area (Nuwaraeliya) is ambiguous due to both being in wet zone as well as the elevations. The same pattern can be seen four main seasons of FIM, SWM, SIM and NEM temperature conditions are consistently on rise from 1970, 1980 and 1990.

(b)There has also a consistent decline in the quantum of annual rainfall over the study area, with exception of a few pockets in the wet and intermediate zones. The slope values (of trend rates) when plotted for seasons, indicate that the decline are more pronounced during the SWM (Yala season) in windward areas, contrary to expectation, and rather has somewhat increased on the leeward areas (of the Central Highlands). On the other hand, during the NEM season, there is a more pronounced decline in areas to the windward side (Dry Zone) as compared to the leeward side (South-western area of the Central Highlands).

(c) Additionally, the overall increase in temperature is associated with a decline in annual average rainfall, especially from mid-1970s, into 1980s and 1990s. This is rather unusual, since a global warming generally could be associated with increased precipitation (suggested by Global Climate Models). The difficulty in this case is, it will be a global trend with disturbed regional as well as seasonal distribution of rainfall. But generally, the rainfall decline is in conformity with global studies that indicate precipitation decline in tropics as against increased rainfall in temperate areas (especially Northern Hemisphere winters). However, since the study is on Sri Lanka, it was not possible to capture the global processes that could be responsible for specific rainfall changes in Sri Lanka.

(ii) The second objective of the present study is *"to study the area coverage, production and yield changes within the study area, in respect of the principal crops like rice, tea, rubber and coconut";* the major findings are as follows:

(a) The above changes in climate have pronounced effects on agriculture in the study region. Rice farming is the principal crop in the dry region (Anuradhapura). An increased in temperature conditions as well as decline in rainfall in the principal growing season (Maha season, NEM season) highly affects the coverage of the crop and consequently the out put. The picture of yield decline is ambiguous, since yield changes respond to number of other factors, technological, farm management practices, prices and so on, well beyond the scope of the present study.

(b) The plantation crops, tea, rubber and coconut are all under rain-fed conditions and are more prone to effects of climate change. These three crops are, however, located more into the either Wet or Intermediate zones. But, never the less, there has been consistent decline in coverage and yield of all the three crops especially into the 1990s, a decade marked by a series of droughts and of high severity. The data for agricultural crops relate to 1970s onward, district-wise. It may be noted that avoid annual fluctuations in crop coverage and yield, the standard method of three-year moving averages were taken. Never the less, the results of trend analysis as well as growth rates confirm consistent declines in plantation crops.

(iii) The third objective of the present study is *"to study the impact of climate changes on the broad Agro-Climatic Zones- the Wet Zone, the Intermediate Zone the Dry Zone in respect to crop production, coverage and yield of the crops";* the major findings are as follows:

(a) The purpose of this objective is to explore the possible (statistical) relationships between rainfall and temperature changes with changes in the principal four crops, in terms of changes in output (total production), coverage of the crop and yields. This analysis uses the respective data sets at the district level (13) within the reference study area, between 1970s and 2000. The climatic data, which is station (point) based has been averaged for the respective districts. Simple correlation coefficients and bi-variate regressions were carried out for generalisation purposes. The seasonal analysis has also been carried out for Maha (NE Monsoon) and Yala (SW Monsoon) seasons, wherein the reference segregated production, coverage and yield data and segregated seasonal average rainfall and temperature data has been used.

(b) A variety of socio-economic as well as technological factors are important considerations, along with the role played by bio-physical and climatic elements. The study area (of Sri Lanka) that has been under investigation, samples all the three major agro-climatic areas of the country. But, most farming practices are under rain-fed conditions (particularly, the plantation crops). Therefore, the influence of climate change, especially increasing temperature as well as falling precipitation conditions are likely to have much more pronounced influence on the areal coverage of (rain-fed) crops, whether rice or other plantation crops, which in turn will impact the total out-put of each of the crops. The yields are governed by several socio-economic, technological and farm management practices and are relatively less governed by climatic factors alone, though by no means immune to climatic influences.

(c) The impact of temperature increases associated with decline rainfall has also regional influences, i.e., on the wet zone, the intermediate zone and the dry zone regions in varied degrees. The impacts have been the strongest in dry zone areas, but the other zones have not been immune to the influences. For example, there has been pronounced declines rubber areas and output (wet zone). Tea areas in Wet zone are more affected than probably in the intermediate zones (the Central Highland areas), because of failures of SWM and temperature peaks during NEM and the SIM periods. The coconut areas are confined to the coastal areas, particularly on the west coast and it appears there are serious problems with drying of coconut plants and significant yield decline (These are all in rain-fed conditions).

(iv) The fourth objective of the present study is to study the response of varied farming communities to perceived threats of climate change and its consequences. The major findings are as follows:

(a) The perception and adaptive strategy study of the three farming communities indicate invariable unanimity of the recognition by farmers that both the rising temperatures and uncertain rainfall pattern including changes in seasonality have all contributed to their misery, declining incomes and living standards, growing indebtedness. Many opt to move out of the present farming practices by switching to other crops. Many look for greater Government support system and relief and crop insurance system.

(b) The condition of the rice farmers in the Dry zone, especially calls attention. The farmers are either small or marginal and their incomes meagre. The increasing temperature conditions in the last two decades combined with decreasing rainfall during the principal growing season (North East Monsoons) and especially, the uncertainty and unpredictability have been adding to their misery. The crop coverage is seriously affected and since most of the farmers are tied to only farming their conditions worsen by the day. The rainfall long-term predictions (our estimations) show further decline in rainfall year after year, at a rate of about 14 mm per year and this is likely to further aggravate the situation.

9.8 Limitations of the Study:

(i) One of the major limitations of the study refers to non-uniformity of data for all the principal crops both in terms of the units of reference (districts) as well as yearly availability of data. Only for rice standardised data is available season-wise for all the districts from 1968-69 to 2000-01. For tea, the data on area coverage is over a 10 year period and the coverage is not by district, but by High, Medium and Low grown areas (altitudinal distribution). There is also no conformity of data to the agro-climatic zones, since the zonal boundaries cut across district boundaries.

(ii) Sri Lanka study suffers from the lack of suitable crop models for assessing the impact of climate change. There is a need for crop models for paddy, tea, rubber and coconut, which would require further micro-technical data that was unavailable during the current study.

(iii) The forecasting method used was quite simple due to lack of data on both other climatic parameters as well as access to some global data which could be incorporated in more sophisticated modelling in climate change itself.

9.9 Recommendations:

The following recommendations are made in light of the study as above:

(i) In light of very strong indications of climate change not only over the study region but for the whole of Sri Lanka and also the forecasts on increasing temperature and declining precipitation conditions in coming decades, model programs could be developed for agricultural crops. The green revolution techniques have to be modified through research to make major crops cultivation sustainable.

(ii) Effective water supply (like, extension of irrigation works into dry regions and water harvesting systems) and management systems are recommended be in placed with a degree of urgency. Even feasibility of trans-basin diversion schemes could be explored to counter climate change impacts by increasing the water availability in the dry zone. Better water management systems could be introduced by strengthening the institutional base to manage water resources economically and increase the efficiency of irrigation by adopting sprinkler irrigation methods and drip irrigation system. A project can be started to test the efficacy of small reservoirs for regulating the base river flow also feasible. This will increase crop diversification and cropping intensity.

(iii) There is a need for revising the existing agricultural policy taking into account the climate change impacts. These need strong action plan prepared for implementing the agricultural policy. Particular attention should be placed on for high droughts resistant crops varieties and the development of irrigation water management practices especially in the drought prone areas.

(iv) Sri Lanka present agricultural land use system is bedevilled with problems such as stagnant level of agricultural out put, decline in farm incomes and widening social problems. The response strategy in the agricultural sector has to focus on the potential for diversifying agricultural production and the food habits of the people. A comprehensive approach to rice cultivation is necessary. The dependence of rice and wheat has to be reduced and other crops less susceptible to droughts could be promoted like, yams, tubers and other food crops. The elements of such a strategy should include development of rice varieties with high yields which are droughts resistant and use less water, agricultural practices which use less water, sound water management systems, cultivation of alternative crops, and conversion of uneconomic rice lands into other high value uses. In long term the introduction of agricultural systems, which are less dependants upon the monsoon cycle may be necessary. This may require changes in cropping pattern, agricultural systems, cultural practices, as well as perceptions and attitudes of farmers. Changes in crop varieties, new agricultural systems and cultural practices such as mixed farming, inter-cropping, dry farming and other similar systems have been advocated to deal with theses problems.

(v) It is also essential that adequate funds are provided for conducting research to address the impacts of climate change on agriculture, particularly in development of drought resistant crop varieties, development of cropping pattern suitable to agro climatic zones and enhanced research on climate and crop simulation models to reach ideal conditions.

(vi) There is also the need to promote rained farming and the efficient utilisation conservation of water through development integrated farming system in relation to climate change.

(vii) Finally, there is the need to create community awareness and farmers education on climate change and its possible hazards and in the manner different farming communities could possibly cope with the changing conditions and prepare themselves. No doubt, much of this requires a proactive position of the Government and the district administrations to enable the farming communities to come to terms with the risks involved in their chief occupations and livelihood system.

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