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A Study of Climate Changes in the Coastal Region
(Special Reference on Paddy Production in Ampara District)

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Abstract

Agriculture is a vital sector in Sri Lanka as it plays key role in GDP, export income and total employment. This sector contributes 7.42 percent and 15 percent to GDP and export income in Sri lanka, respectively, and also it provides employment to about 26.1 percent of the labour force exceeding the contribution of any other single sector (Central Bank of Sri Lanka, 2017). Agricultural production is vulnerable to variation in climate, which affects almost all the regions in the Universal. Using a collective cross-sectional data from major paddy producing regions in Ampara and Sri Lanka, the responsiveness of paddy production to average temperature and rainfall variation was analyzed. This study purposes to examine the relationship between rainfall and paddy production. Samplings from 100 farmer's households had been gathered by questionnaire survey as primary data and the secondary data. Rainfall data of 135 years and 20 years / 40 seasons paddy cultivation data has been utilized to analyses the result. As the result, the study finds that through the 3, 5 years moving average had shown high drier seasons of the years. The paddy production was very high in Maha season but this was very low in Yala season because of the rainfall variability. Paddy yield under various climate change scenarios. Both average temperature and rainfall have concave, non-monotonic effects upon paddy production, which implies that variations in growing climate are likely to have negative effects on paddy production. It was found that modest increases in average temperature and variation in rainfall had only a small effect of unclear sign, but increases in average temperature beyond 2.01^{0}C were likely to have strong negative effects on paddy production. For example, 3.08^{o}C increase in average temperature individually or in combination with changing rainfall can lead to approximately 32% yield drop in Sri Lanka and 26% in study areas of paddy production.
Keywords: Agriculture; Meteorology; Paddy; Production; Climate

Introduction

In many parts of the world, species and ecosystems may experience climatic conditions at the limits of their optimal ranges or beyond. Predominantly, extreme events such as floods, hurricanes, heat waves and droughts have been analyzed in terms of the major impacts and costs for society. Hence, agricultural production is vulnerable to variation in climate and which affects almost all the regions in the world. In particular, there are serious implications of climatic variation on livelihood in tropical Asia because many of the world's poor are houses in the region and they produce food for their subsistence under a prevailing tropical climate. At the beginning of the 21st century, many countries in South Asia remained under-developed or developing despite varied socio-cultural and economic histories. Since then, the severity of the impact of climatic variation in these economies has been significant. Records show that extreme weather incidences cause one third of losses in agricultural and allied sectors in these economies (FAO, 2016).

The Food and Agriculture Organization (2015) has estimated that, in developing countries, agriculture industries absorbed 23% of the damages from all-natural disasters including drought and flood during 1990-2015. Of the total damage to agriculture, 39% has been in the crops sub-sector. In developing countries, the total economic losses in the crops sub-sector were shown to be US$ 15 billion during 1990-2015. Approximately 71% of the total damage was due to floods and drought (Food and Agriculture Organization, 2015).

The agricultural sector in Sri Lanka occupies a prominent role in the economy, ensuring food supply and alleviating rural poverty, with its original focus on food crop sector priorities (Central Bank of Sri Lanka, 2017). Sri Lanka claims self-sufficiency in paddy production owing to conductive government policies and technological advancement in the paddy industry. Paddy serves as a staple food for people in the country and contributes to 7.42 % of the country's agricultural GDP where 23.8% of the population is employed in agriculture (Central Bank of Sri Lanka, 2017).

The distribution of rainfall in the country shows that paddy is a seasonally produced food crop in Sri Lanka. The cultivated paddy is considered semi-aquatic plant grown under controlled water supply. The source of water supply and degree of flooding are the original environmental factors determining paddy crop yield, among many other inputs. However, extreme weather incidences in Sri Lanka have been very frequent during the last five years and have created uncertainty in reaping a worthy harvest. The extreme weather conditions destroy not only the crop yield but also the entire infrastructural network in paddy farming. Because of the severe drought in decades, for example, the total paddy production reduced by 39% and the area harvested dropped by 32%. It is clear the paddy production in Sri Lanka is highly sensitive to changing climatic conditions, where the production is often connected to risk and uncertainty. Therefore, this study was undertaken to assess the impact of short-run climatic variation on paddy production in selected locations of a dry wet lowland using Ampara coastal areas as a case study.
The annual rainfall varies from 864 mm to to 2984 mm (120 years data) distribution, which has sight variation throughout the district. The most of the rain is being received during the month of October to February and it is both inter-monsoon and North East monsoon types. The mean annual rainfall values on the eastern slopes are less than 3,500 mm and the lowest are in the northwest (Chandrapala, 1966). Climate change has become a major concern to human society because of its potentially deleterious impact worldwide. It poses especially significant threats to sustainable development in developing countries, which have fewer resources and are more vulnerable (Munasinghe, 2001).

Paddy, the basic food of Sri Lanka, is the most important source of employment and income of the rural population. During 1940's the country produced only 45 percent of the total requirement of paddy with a population of only 7 million and the country is now at 90 percent self-sufficiency with 20 million populations. During the past decade, this has varied between 85% - 98% (Thiruchelvam, 2001). Thus, there is growing concerns that the global warming would affect the productivity of paddy crops (Tao et al, 2002). The two seasons for paddy cultivation are Maha and Yala. Maha is the seven-month period from September – March and Yala, the five-month period from April to August. As such, Yala gets its rainfall from the second half of the first inter-monsoon and most of the Southwest monsoon, whereas Maha depend mainly on the rainfall from the Northeast monsoon and the second inter-monsoon (Fernando, 2000).

It is the single most important crop occupying 26.1 percent (0.77 /million ha) of the total cultivated area in Sri Lanka. On average 542,556 ha are cultivated during Maha and 249,123 ha during Yala making the average annual extent sown with paddy to about 791,679 ha. About 1.7 million farm families are engaged in paddy cultivation island-wide. Trend in extent, production and average yield of paddy, 2007- 2017 in figure – 01. Sri Lanka currently produces 2,383,153 tons of rough paddy annually and satisfies around 97% of the domestic requirement. Paddy provides 48% total calorie and 43% total protein requirement of an average Sri Lankan (Department of Census and statistics, 2017).

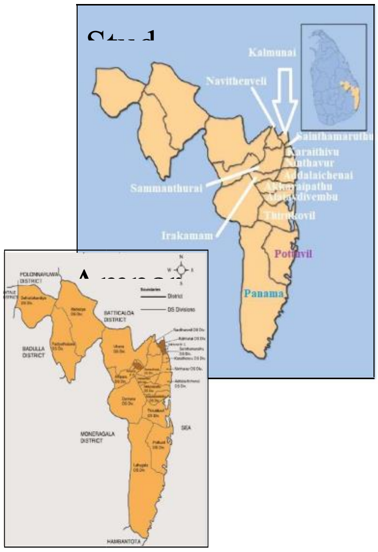
Most of the government support programs and interventions on paddy cultivation sector are focused in these areas, which also makes it an important area for research and development activities. Climate and agriculture both are highly interrelated. Agriculture is highly dependent on the climatic factors. The climatic factors as well as other factors that are determined by climate cause vulnerability of agriculture and agricultural production.
The estimated paddy production for 2017 Maha season was 1,473,832 MT. This is about 33% increase compared with the previous (2016, Maha - 2902693MT) Maha season. The Ampara district produces about 10% of the national requirement of the paddy. Paddy cultivation under major and minor irrigation facilities and rain fed basis during Maha Season. Many paddy varieties are cultivated in Ampara district. Paddy is cultivated in both Yala and Maha seasons in Ampara district and highest yield was recorded in Maha season. Total sown paddy area in the district during 2014/15 Maha season was 83,133 ha and the extent sawn in 2015 Yala season was 65,793 ha. The total paddy production target of both seasons was 617,000 metric tons. The extent and production of paddy in both seasons are presented in following tables – 1.0.

The highest production of 368,748 MT of paddy was estimated from Ampara District. Paddy production in Ampara District was accounted for about 12% of paddy production of the country. The contribution to the total paddy production of the country from Pollonnaruwa, Kurunegala, Batticaloa, Hambantota and Anuradhapura districts were estimated as 11%, 8%, 7%, 7% and7% respectively during the 2013/2014 Maha season.

Amparai District has many agriculture activities such as Paddy cultivation, Vegetables, and other crops. Paddy cultivation is the major plantation for farmers in this district. Their basic economy and food is mainly depending on paddy production. Amparai District has good climate, well irrigation and soil structure for paddy production. The study area's paddy cultivation is also affected by the rainfall fluctuation and the other hand without enough irrigation water. Due to this, they leave the paddy cultivation in the middle of this period. There was lots of researches and publishing done about this issue. These problems lead to number of problems in paddy production and human life. It is a major problem in primary economic activities.

Study Area

District of Ampara is located in south east of Sri Lanka and belongs to Eastern Province. Ampara district covers area of 4,415 sq. km of surface and 193 sq. km of water area.



The mean temperature is 30°C. Highest temperature is 36°C. The lowest temperature is 24°C during December and January periods. The Ampara district is situated in the dry zone of the country and received an annual rainfall of 1400mm mainly during North-East monsoon season. The district experiences dry season from March to September and the rainy season from October to February. Ampara district consists of 20 divisional secretariats and selected study areas consist of 15 agrarian service centers.

Historically Ampara district is a significant landmark to contribute for the national economy of the country. As it was the major region to produce grain for the ancient kingdom, British rulers also supported financially to develop the irrigation sector in the region to ensure higher performance of agriculture. The contribution to national GDP by Ampara district is about 3.2% which grows by about 6.0% per annual. Timely rain and availability of water will be one of the main critical factors for the increased domestic production by the district, as the agriculture is still the main contributory sector.

Objectives

- To identify the climate change (change in weather factors) in study areas
- To find out change in the paddy production yield in study areas
- To examine the relationship between the climate change and paddy production yield in study areas

Methodology

In the collection of necessary information and data for the study, the researcher depends on both qualitative and quantitative data from both the primary and secondary sources. Approximately, ranging between 10-20 farm households in each of the production regions in a single cropping season have created an unbalanced pseudo panel for 1940 - 2000. The panel (unit of analysis is an individual farmer) has 15 successive cropping seasons consisting two cropping seasons within a single year (Maha-major season and Yala-minor season). Sampling method has been used to collect primary data. Hundred samples have been collected by Questionnaire survey. These 100 samples were distributed to different stakeholders as follows; Development Officer-20, Irrigation officials-15, Farmers-50, Public-15 and Field observation has been done in the paddy area. Direct interview; questions will be prepared and discussed with individuals and group of people based on the study focus.

These informal direct interviews would be conducted with men and women from different group of people throughout the research process. The Direct interview methods will be used to gather primary information criteria for the selection of individual and group interviewee has been based on farmers, government officials and non-government officials.

The secondary data has been collected from several organization. Population data from Department of Census & Statistics of Sri Lanka, Rainfall and temperature data from Meteorological Department, Paddy production of Amparai District from Department of Agriculture, Irrigation Report, Annual performance report of Amparai, images, and published research reports utilized to the study. Data were sourced on farm inputs and weather parameters (for 1955 - 2017) respectively Ampara agrarian services office and from weather station pottuvil of Sri Lanka. Paddy production in eleven production regions (Chavalaikadai, Kalmunai, Irakkamam Navithenveli, Malwathai Sammanthurai, Sainthamaruthu, Karaithivu, Ninthavur, Addalachenai, Akkaraipatthu (West), Akkaraipatthu (East), Alayadivembu, Thirukkovil, Thambiluvil, Komari, Pottuvil, Panama) were considered for the analysis. 60 years' rainfall data (1957 - 2017) from meteorological station of Pottuvil, Amparai and 20 years (20 years maha seasons + 20 years yala seasons = 40 times seasons) paddy cultivation data (1997 – 2017) and (20 years maha seasons + 20 years yala seasons = 40 times seasons) paddy production yield data (1997 – 2017) from Department of Agriculture has been utilized the analyze the result. Accurate statistical methods have been used to find the variability on rainfall trend and paddy production trend that includes trend analysis, 3, 5 years moving average of Standard deviation. Correlation analysis is used to analyze the water level a statistical analysis method that statistically measures the extent and the nature of the relationship between two variables. Correlation is concerned with describing the strength of the relationship between two variables by measuring the degree of "scatter" of the data values. In this study, the correlation co-efficient analysis is undertaken to find out the relationship between the rainfall and paddy production in the study area.

Results and Discussion

The area cultivated in paddy by each farm was included as an independent variable (extent) since we recorded production as our dependent variable. Quantity of seed paddy (seed), total NPK_2(fertilizer) and labour hours for a single season were calculated. We were unable to obtain data on other farm inputs such as tractor hours and number of agrochemicals used to control pests in paddy. Therefore, a total cost on tractors and total cost on weedicides for a single season were used as proxy variables to represent power use and chemical use.

How paddy production is affected by climatic when all the other farm inputs are present. We simulated paddy production under various temperatures and rainfall projections, because the directions as well as the magnitude of changes in weather variables imply different production levels. This is of use for planning future paddy production under different climatic conditions with varying rainfall and temperature. Subsequently, we estimated a multi-variant normal to the variables of interest (temperature and rainfall). The simulations were conducted as follows. Thus, we were able to obtain estimates of how average production levels are likely to fluctuate under both standard climatic variation and those induced by climate change. The overall results suggest that the average paddy production is higher in the absence of natural climatic variation.

For the simulation exercise, predicted values in the Equation 1 were used as the base case. We simulated future climatic conditions under four scenarios

- temperature increase by 2^0C,
- temperature increase by 4^0C
- rainfall increase by 50% and
- rainfall decrease by 50%, in comparison to the base-case scenario (Table 02).

From the results of the simulation exercise, we calculated the projected yield change due to changing climatic scenario using the expected levels of yield. The yield changes were reported for all possible individual variations for temperature as well as for rainfall while the combined effects were reported only for significant yield changes (Table 02).

According to the results, all the weather variables indicated a significant effect on paddy production and the coefficients were of the expected sign. The relationship between temperature or rainfall variables with production is quadratic. In addition to weather variables, all the farm inputs were positive and indicative of a high level of statistical significance on paddy production. Therefore, we can infer that area cultivated, number of seed, fertilizer quantity, labors. input as well as tractor and weedicide use can increase paddy production significantly. Production in Maha season is favorable as this shows an additional production potential of 11% compared to Yala season. Therefore, we conclude that production in Maha is greater to that of Yala. With the time effects, compared to the paddy production in 2017, lower production was reported in 1970 - 1990, due to the drought in the respective year period. Relatively from 1990 to 2017, production years recorded a bumper harvest perhaps due to favorable weather. Region dummies suggested that, relative to Karaithivu, Ninthavur and Navithanveli regions, all the other regions significantly produce high paddy volume. The theoretical base for the simulation exercise was adopted from Jensen's Inequality predictions which provide a powerful tool for predicting some direct effects of environmental variance in biological systems (Ruel and Ayres, 1999). Jensen's inequality implies that environmental variance (i.e.Change in temperature or rainfall) can have important and predictable biological consequences that cannot be inferred from average environmental conditions. When the response function is nonlinear, environmental variance will consistently elevate or depress the response (Roitberg and Mangel, 2016). Thus, the projected response would follow a concave relationship against the variation in rainfall or temperature as shown in Figure - 02. Figure 02 suggests the non-linear response behavior of log of production to variation in average temperature or rainfall. When average temperature increases, log of production increases up to until the average temperature reaches 29.5^{0}C and it decreases thereafter. Similarly, log of production is maximum when rainfall is ranged from 1500-2000 mm/season. Based on the above discussion, we present the simulation results in two composite panels in Figure 2; individual effects in panel A, B and combined effects in panel C, D. The panel A illustrates the individual effect of average temperature change on paddy production whereas panel B suggests the yield response for rainfall change. The combined effect for both the average temperature and rainfall are given in panels C and D. In terms of average temperature changes, according to panel A, a severe production loss was observed at a 4^{0}C rise in average temperature while the 2^{0}C average temperature rise did not cause a substantial production loss. As shown in panel B, the rainfall changes by 50% did not imply a notable drop in production from the baseline. However, the combined effect of a 4^{0}C average temperature rise with a 50% change in rainfall resulted in a significant drop in production (panel D).

Among these four simulated scenarios, a notable production loss3 is reported when average temperature is increased by +4^{0}C and rainfall by 50%. Therefore, we can conclude that, the production is severely affected with the increase of average temperature by +4^{0}C. However, the scenarios with a rainfall change of 50% did not indicate a major impact on paddy production.

Paddy Production Yield and Climate Changes

The above simulation analysis produces the expected yield levels and direction of yield change at different climate scenarios.

Subsequently, we calculated the percentage yield change from the base case scenario to derive a quantitative measure to depict the effect of climatic variation. Table-04 summarizes the yield changes compared to the baseline yield level at different climatic scenarios, for individual average temperature and rainfall changes as well as for the combined weather scenarios. It is important to note that there are noted regional variations in the production loss while we only present a summary of the island-wide effect.

Firstly, individual weather effects were analyzed. At the baseline condition, the predicted yield is 2,459.58 kg/ha. A significant reduction in this yield, which is approximately 30%, is seen when the average temperature is increased by 4^0C from the baseline in the simulation exercise. This is mainly because of bio-physical reasons such as paddy plants inability to withstand adverse temperature regimes and a loss in fertility occurring as heat is generated through average temperature increases (Morita et al., 2001).

However, the projected yield did not show a reduction when average temperature is increased by 2^0C. Studies have proven that the small change in average temperature can sometimes increase paddy yield at a tropical climate (Satake and Yoshida, 1978; Morita et al., 2001; Peng et al., 2004). The simulation exercise for rainfall variation did not result in a substantial impact on paddy production as in the case of temperature. The yield drop due to 50% increase in rainfall is only 2.48% while the drop from to 50% decrease in rainfall is only 0.18%. Several reasons can account for this observation. Unlike average temperature, farmers can regulate water levels in paddy fields depending on the rainfall distribution. Moreover, wide spread use of irrigation and drainage mechanisms currently in place can assure water availability in paddy fields against rainfall variations. Therefore, rainfall variation appears to have less impact on production.

In addition to the individual effects given above, we simulated combined effects for temperature and rainfall conditions using the hypothetical scenarios (Table - 04). The combined effect of a 4^0C average temperature rise with a 50% rainfall increase may cause 32.13% damage in paddy yield. However, the combined effect of 4^0C average temperature increase and decrease in rainfall by 50% can reduce paddy yield by 27.57%. Hence, we conclude that the combined effect of different climatic conditions would produce more severe results than that of individual effects. In summary, climate smart cropping strategies will be of timely importance for sustained production against climate variation.

Annual Rainfall Changes

The trends of annual rainfall were deviated in this area, 1994 had being 3092mm as a high rainfall of the years and 1968 had being 853mm as a low rainfall of the years. However, the rainfall was not being below 800mm in between these periods. The rainfall was from 2000mm to 3000mm in the years 1871, 1898, 1911, 1913, 1914, 1927, 1931, 1933, 1936, 1957, 1965, 1966, 1984, and 2000, and above 3000mm of rainfall was obtained in 1994 and 2000, we have faced heavy flood during this period. Some period was obtained below 1000mm of rainfall in 1889, 1909, 1968, 1980. This was caused to the drought in the study area. In other periods, the rainfall was in between 1000mm to 2000mm, many years were obtained.

Standard Deviation for Rainfall (MM)

The annual rainfall varies from 864 mm to 3081 mm (146 years' data) distribution, which has sight variation throughout the district. The most of the rainfall is being received during the month of October to February and it is both inter-monsoon and North East monsoon types.

The Figure - 07 clearly explains the changes of rainfall variability. There were 14 dry seasons and 14 wet season. The long term of dry season was occurred from 1870 to 1895 for 16 years and the long terms of wet season were occurred from 1956 to 1967 for 12 years. The first wet season was being from 1896 to 1900 for 5 years and the first dry season was being from 1870 to 1895 for 16 years.

The Figure 08 shows that the selected 146 years' rainfall, there were 11 dry season and 11 wet season. The long term of dry season was occurred from 1871 to 1895 for 25 years and the long terms of wet season were occurred from 1922 to 1936 for 15 years. The first wet season was being from 1871 to 1895 for 25 years and the first dry season was being from 1922 to 1936 for 15 years. The rainfall seasons are imbalanced in each other. Nonetheless, we had experienced the long-term Rainfall in 5 years Moving Averages that the selected 146 years rainfall, there were 11 dry season and 11 wet seasons. The long terms of dry season were occurred from 1871 to 1895 for 25 years and the long terms of wet season were occurred from 1922 to 1936 for 15 years. The first wet season was being from 1871 to 1895 for 25 years and the first dry season was being from 1922 to 1936 for 15 years.

Identification of positive and negative rainfall years

Observational rainfall data from 1980 to 2017 were divided into 5 categories as extremely below, below normal, normal, above normal and extremely above by comparing the data with 30year average rainfall data. Main meteorological stations observational data were considered for the analysis and they were plotted according to above categorization. Five positive and five negative rainfall years were identified accordingly (Fig 09 and Fig 10).

Paddy Production in Study Areas (1980 – 2017)

According to the Figure:11 & 12, the paddy production was very high in Maha season when compare with Yala season. The yield was very high above 100,000mt in 1983, and 1985. During the period of 1988, 1991, and 1997 were very less yield produced in Maha season. The main reason for this, it got very less rainfall in these periods and even the pre and post-civil war is another reason for the less production.

Paddy Production and it's running mean & Average Rainfall (MM) – Yala

In the Yala season, less amount of production had produced by the farmers because, they could not get the sufficient water for the cultivation. The major reason for this, the less rainfall was registered during this period. According to the Figure 12, The highest production is from 1983 to 1995 and the good development was started after 1981 when compare with past years. In the Maha season, Paddy Production and it's increasing from year 1952 - 1983 but after 1984, it's decreasing. According to the Figure 13, The highest Average Rainfall (MM) is from 1952 to 1976 and but after 1977, it's decreasing. In the Yala season, less amount of production had produced by the farmers because, they could not get the sufficient water for the cultivation. The major reason for this, the less rainfall was registered during this period. The highest production is from 1983 to 1995 and the good development was started after 1981 when compare with past years.

Paddy Production and it's running mean & Average Rainfall (MM) – Maha

According to the Figure 15, the paddy production was very high in Maha season when compare with Yala season. The yield was very high above 1850,000mt in 1984, and

1998 and it was very low above 250,000mt in 1953. During the period1952-1982, paddy production is increasing in smoothly from 1952 (250,000mt) to 1982 (600,000mt). According to the Figure 16, The highest Average Rainfall (MM) is in 1958 and 1985 Average Rainfall is 1600mm from 1952 to 1979, but after 1979, Average Rainfall trend is below 1600mm and its suddenly increase and decreasing year by year.

Correlation Analysis

Table - 06. Comparative View of Maha and Yala seasons Paddy production (mt) and Rainfall in Amparai 1980 – 2017. At 95%, confident level the Table 05 illustrates that there is negative correlation between Rainfall and Yala season paddy production, according to the Table 06 the correlation value is 0.335 and which is significant at the level of 5% because the p value (0.053) is greater than the significant level of 0.05. According to the correlation for rainfall helps to test the production here the significant P value is less than the 0.05 significant levels therefore the alternative or null process can be accepted.

This paper analyzed the effects of changing climatic conditions on paddy production in Coastal Areas of Ampara District. Using a pooled-cross section data collected from 1965 to 2017, Simulation results were conducted for the expected value of production under different assumptions about future climatic conditions. It was found that modest increases in average temperature and variation in rainfall had only small effects of ambiguous sign, but increases in average temperature beyond 2^{o}C degrees were likely to have strong negative effects on paddy production. For instance, 4^{o}C increases in average temperature individually or in combination with changing rainfall can lead to approximately 30% yield drop in production. The primary channel for this effect appears to be via increasing temperature. Perhaps due to the widespread use of irrigation/drainage infrastructure, variations in rainfall seem less important for output. In terms of policy, our results highlight the ability of climate change to threaten the stability of paddy production in sub-continental Asia. Finding ways to ensure food security appears to be an important priority. Further the fact that output seems more sensitive to rising average temperature can help to guide scientific research in the production of crops/varieties that are more robust to these particular phenomena. co-efficient analysis is undertaken to find out the relationship between the rainfall and paddy production in the study area.

The contribution of rainfall for paddy production takes a major role in the world. Rainfall differs in every area of Sri Lanka. It varied from 864mm to 3081mm distribution which has sight variation throughout the district. According to the 3 years' standard deviation moving average, there were 14 dry seasons and 14 wet seasons, the first wet season was being for 5 years from 1896 to 1900 and by the 5 years standard deviation moving average, the first wet season was being for 25 years from 1871 to 1895.

The paddy production was very high during the Maha season because of the high rainfall and this is low in Yala season by the less rainfall. The yield was very high above 100,000mt in 1983, and 1985. During the period of 1988, 1991, and 1997 were very less yield produced in Maha season. The main reason for this, it got very less rainfall in these periods and even the pre and post-civil war is another reason for the less production.

According to the correlation analysis, both positive and negative impacts were identified. There is a strong positive relationship between rainfall and Maha season production, the correlation p value is 0.002 is less than significant level of 0.01. There is a negative relationship between rainfall and Yala season production, the correlation p value 0.053 is greater than the significant level of 0.05. As a result, rainwater harvesting, making the proper irrigation system, improving the traditional agricultural practices are the suggestion to get more yield from Yala season. Overall analysis, there are strong and negative relationship between paddy production and climate change (rainfall).

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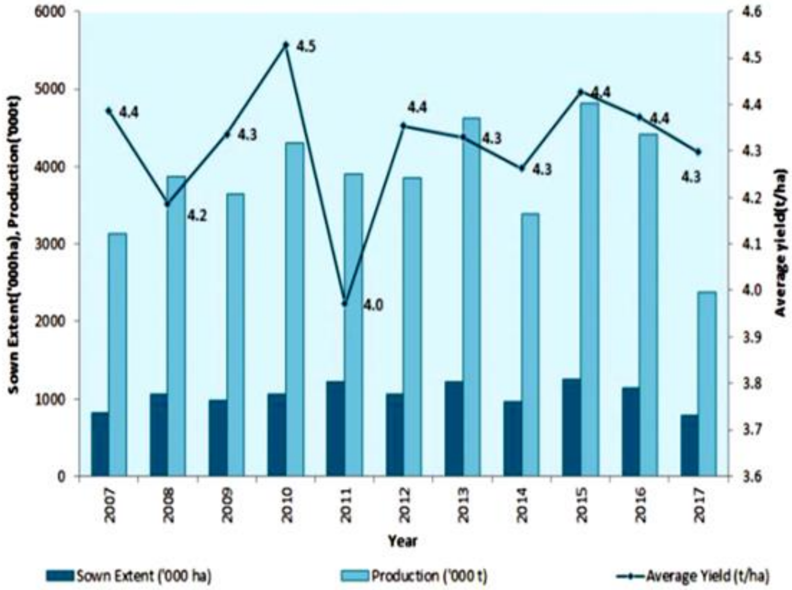


Figure 1. Trend in extent, production and average yield of paddy, 2007- 2017

Table 1.0: Extent sown (ha) and production (Mt) of paddy cultivation during Maha and Yala season

Year	Extent (ha) Maha	Production (Mt) Maha	Av: Yield Mt/hc	Extent (ha) Yala	Production (Mt) Yala	Av: Yield Mt/hc
2004/2005	60,737	243,191	4.0	56,324	256,551	4.6
2005/2006	62,715	273,932	4.4	55,036	256,824	4.7
2006/2007	51,803	244,031	4.7	53,787	255,935	4.8
2007/2008	64,490	299,533	4.6	60,168	283,081	4.7
2008/2009	69,979	337,390	4.8	46,227	214,941	4.6
2009/2010	69,861	358,274	5.1	59,255	275,913	4.7
2010/2011	70,819	126,409	1.8	61,904	287,675	4.6
2011/2012	71,877	345,264	4.8	60,864	270,027	4.4
2012/2013	82,921	314,015	3.8	64,403	297,229	4.6
2013/2014	81,940	368,748	4.5	44,377	199,265	4.5
2014/2015	83,133	307,661	3.7	65,973	309,335	4.7

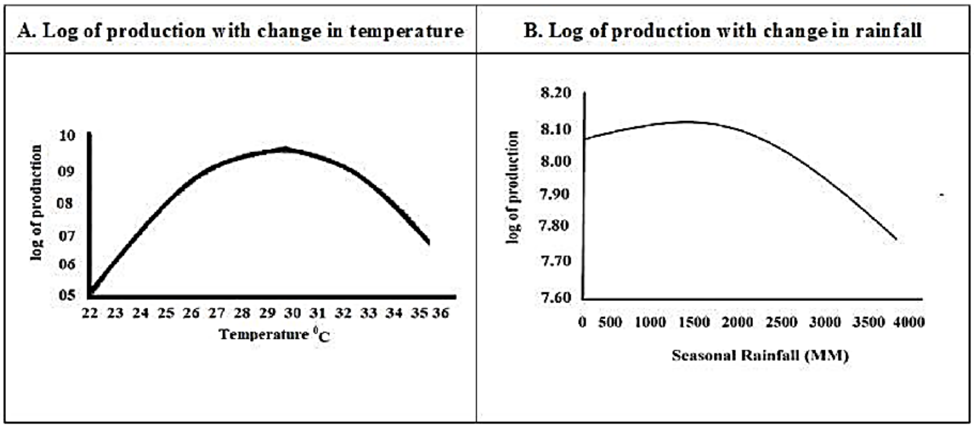
Table: 02 The definitions of the variables used in the study are given below.

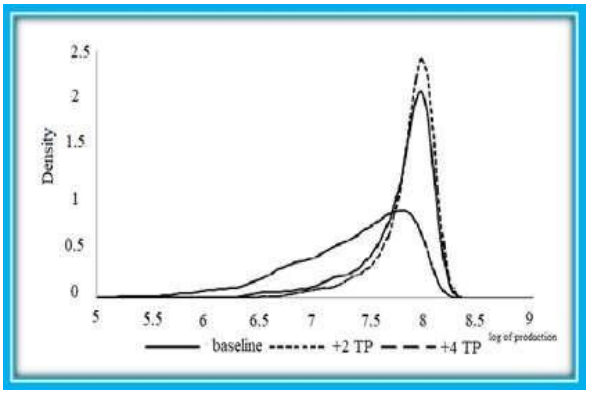
Category	Variable	Description	Source
Dependent variable (Y π)	Rice production	Total rice production by the farmer in time (kg/season)	DOA
Weather variables	Temperature (jt T)	Seasonal average air temperature(0C)	DCS
	Rainfall (jt RF)	Seasonal total rainfall(mm)	DCS
	Relative humidity (day)	Seasonal average relative humidity of the daytime (%)	DCS
	Relative humidity (night)	Seasonal average relative humidity of the nighttime (%)	DOA
Control variables (farmer inputs) (it x)	Extent	Area cultivated (ha/season) DOA	DOA
	seed	Quantity of seed paddy (kg/season)	DOA
	fertilizer	Quantity of NPK fertilizer (kg/season)	DOA
	labor	Quantity pf total labor input (Man day's/season)	DOA
	tractor	Rental cost on total labor input (LKR*/season)	DOA
	Weedicide	Cost of weedicides (LKR*/season)	DOA
Dummy variables	Year (t P)	Reporting year (2000 is the base year)	DOA
	Region (D1)	Cultivated region (coastal areas of Ampara is the base case)	
	Season (D2)	Cultivated season of the year (yala season is the base case)	
• Note : LKR* - Sri Lanka Ruppees			

Name of A.S.C	Major	Minor	Rained	Highland	Total
Sainthamaruthu	950	0	0	0	950
Chanakudiruppu	532	226	25	5	788
Kalmunai	1710	0	0	0	1710
Neelavanai	0	591	0	74	665
Ninthavur	6803	0	0	550	7353
Palmmunai	2410	0	1114	204	3728
Akkaraipatthu (East)	7683	215	3668	480	1246
Karaithivu	1367	0	0	17	1384
Thambiluvil	2645	1466	6401	3289	13801
Lahugala	738	334	473	100	1645
Potthuvil	4277	1770	7132	700	13879
Addalaichenai	4708	0	468	468	5644
Panama	1150	750	230	2000	4130
Akkaraipatthu (West)	9878	0	746	0	10624
Komari	0	1200	1194	350	2744
Malwathai	10512	0	619	310	11441
Sammanthurai	8876	0	325	600	9801
Chavalaikadai	9588	402	200	250	10440
Irakkamam	4255	500	250	400	5405
Total	**110132**	**9061**	**33614**	**39549**	**192356**

Table: 03 Particulars of agricultural lands in study areas

Figure 02. Performance profile with temperature and rainfall variations





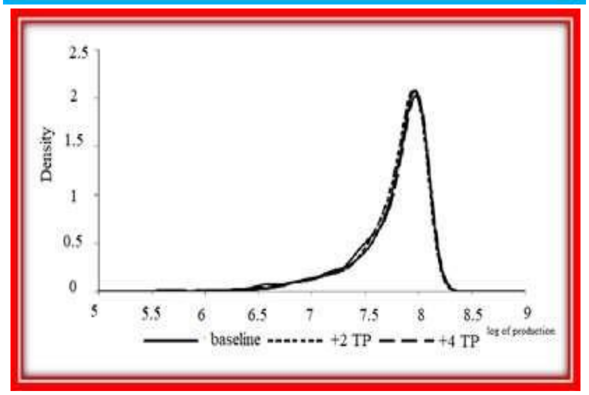
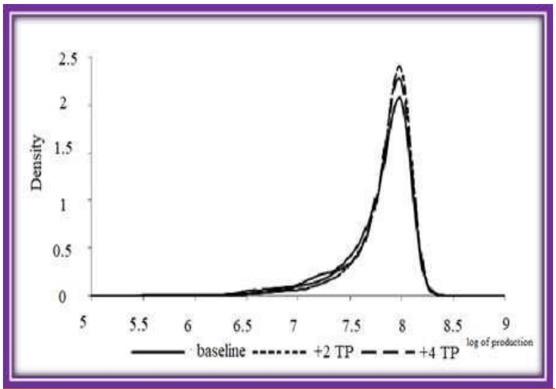


Figure 03. Temperature effect: Temperature change by +20C and +40C

Figure 04. Rainfall effect: Rainfall change by ±50 %



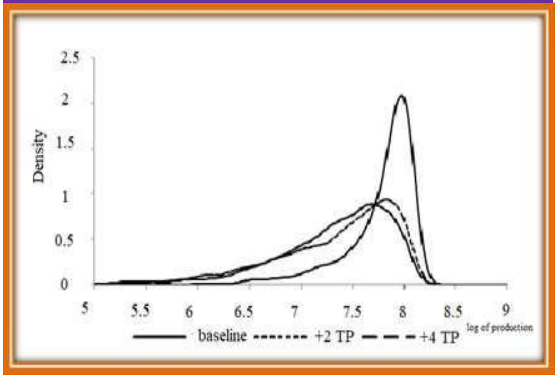


Figure 05. Rainfall effect change by +20C and +40C Rainfall change by ±50% : Combined effect (+2TP and RF change) Temperature at +20C and Rainfall change by ±50%.

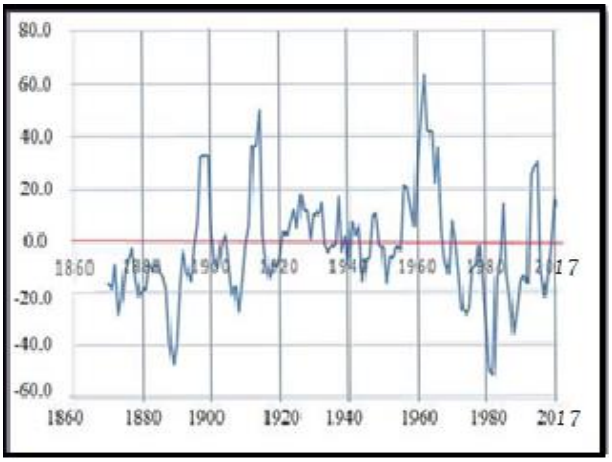
Figure 06. Combined effect (+4TP and RF change) Temperature at +40C and Rainfall change by ±50%

Table -04. Percentage yield change from the baseline in different climate scenario.

Scenario	Baseline Average Yield (kg/ha)	Yield Change* (%)
Baseline	2,459.58	
Individual effect –Average temperature		
2^0C increase	2,600.12	5.71
4^0C increase	1,727.75	-29.75
Individual effect - Rainfall		
50% decrease	2,455.15	-0.18
50% increase	2,398.56	-2.48
Combined effect		
Temperature increase by 4^0C &		
Rainfall <u>increase</u> by 50%	1,669.21	-32.13
Temperature increase by 4^0C &		
Rainfall <u>decrease</u> by 50%	1,781.57	-27.57

Note: * Yield change compared to the predicted value of base case

KALAM -International Research Journal
Faculty of Arts and Culture
South Eastern University of Sri Lanka
Volume X Issue 2, 2016



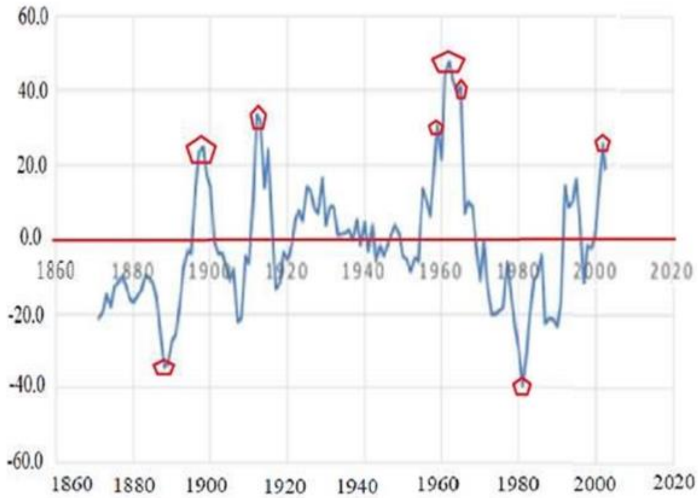


Figure 07. Rainfall in 3 years Moving Average

Figure 08. Rainfall in 5 years Moving Average

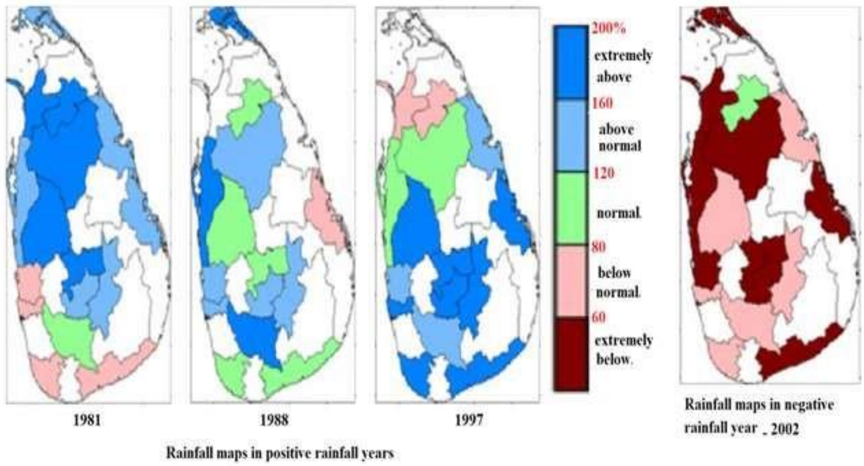


Figure - 9. Rainfall pattern in 1981, 1988, and 1997(Positive). Figure - 10. Rainfall pattern in 2002(Negative).

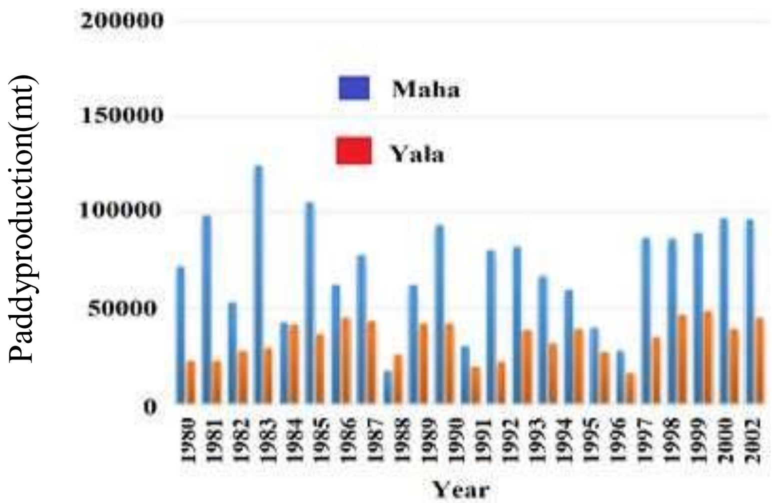


Figure : 11. Paddy production (mt) in Amparai 1980 – 2002

Figure 12: Paddy Production, Imports and Average Yield Source: Based on Central Bank of Sri Lanka, Annual Report, 2018

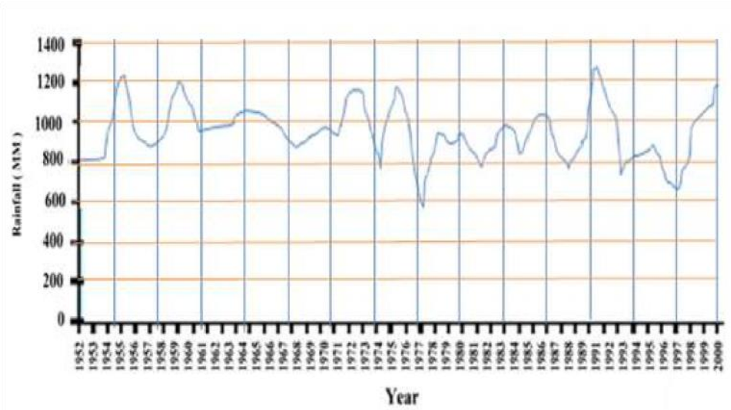


Figure.13 Average Rainfall (MM) – Yala

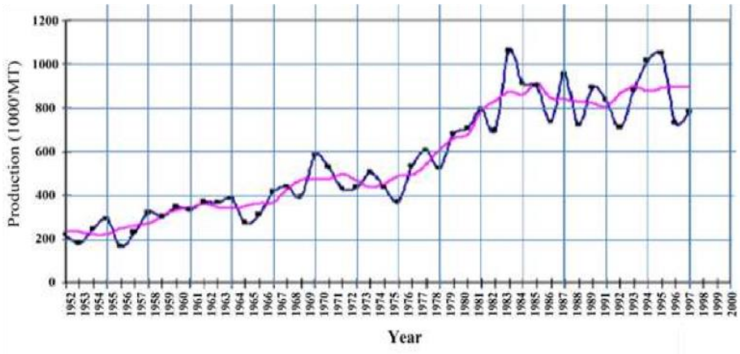


Figure : 14.Paddy Production and it's running mean – Yaha (the pink line shows the running mean)

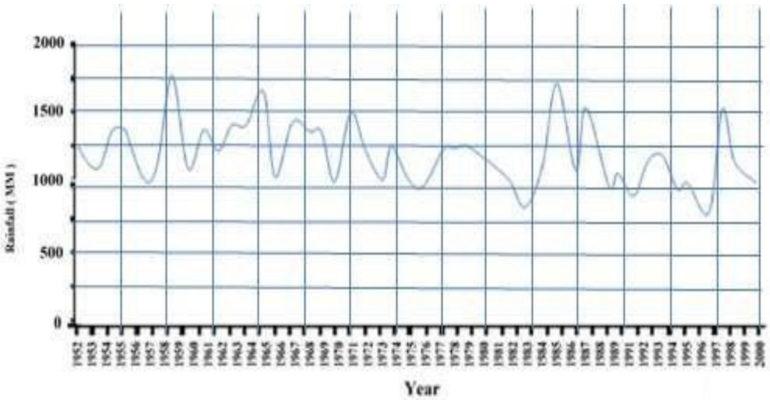


Figure.16 Average Rainfall (MM) – Maha

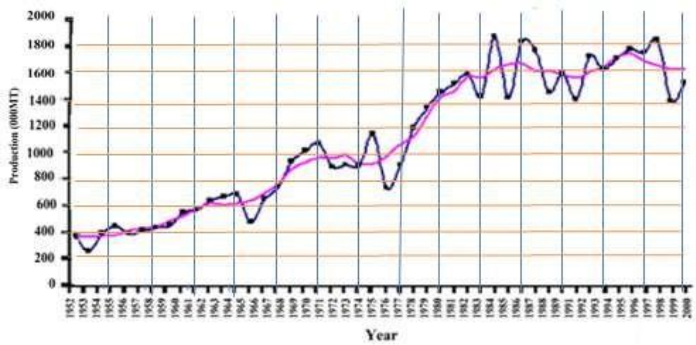


Figure : 15.Paddy Production and it's running mean – Maha (the pink line shows the running mean)

Table : 05 Paddy production(mt) & Rainfall(MM) - Maha

Correlations			
		Rainfall	Maha Season
Rainfall	Pearson Correlation	1	.510**
	Sig. (2-tailed)		.002
	N	34	34
Maha Season	Pearson Correlation	.510**	1
	Sig. (2-tailed)	.002	
	N	34	34

**. Correlation is significant at the 0.01 level (2-tailed).

Table : 06 Paddy production(mt) & Rainfall(MM) – Yala

Correlations			
		Yala	Rainfall
Yala	Pearson Correlation	1	.335
	Sig. (2-tailed)		.053
	N	34	34
Rainfall	Pearson Correlation	.335	1
	Sig. (2-tailed)	.053	
	N	34	34