A Statistical Analysis of Rainfall Variability and Paddy Production Trend in Batticaloa District, Sri Lanka

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Abstract

Paddy production, in the district of Batticaloa, in Sri Lanka, experienced severe challenges due to the rainfall variability in the recent past. The main objective of this paper is to assess the rainfall variability and to identify the relationship between paddy production and rainfall, by means of statistical analysis. Rainfall variability was analyzed using the data of 100 years from 1918 to 2017, of Batticaloa district and the relationship of variables was identified using the data of 40 years from 1978 to 2017. This study adopted a trend analysis using nonparametric and parametric econometric techniques to evaluate the relationship between paddy production and rainfall using EViews 9.0 software. The model was evaluated using Ordinary Least Square (OLS) technique. Results revealed that the annual and seasonal rainfall showing a significant increasing trend. After 1957, rainfall had fluctuated with high variability and rainfall intensity had increased in some years, resulting in flood hazard. On the other hand, dry weather had resulted in long drought condition. Based on the regression results, positive relationship between rainfall and paddy production in Maha season was identified and it is also statistically significant at 1% confidence level. A unit increases in the rainfall in Maha season would increase the paddy production by 0.05 times. Moreover, the rainfall in Yala season negatively correlated with paddy production in Batticaloa. However, it is not statistically significant.

Key words: *Climate, Paddy, Rainfall, Trend, Variability*

I. INTRODUCTION

Climate change and climate variability have greater impact on the agriculture sector, food security and nutrition and millions of livelihoods (FAO, 2017). However, these impacts are varied with space and time. Even though, it is a global phenomenon, developing countries are more vulnerable to impacts of climate change as they are subject to high level of vulnerability and lack of capacity to mitigate the effects of climate change (Ali et al, 2017). FAO (2017) states that "beyond 2030, the impacts of climate change on the productive capacity of the agricultural sectors and thus food security will become increasingly severe in all regions".

In Sri Lanka, variability in climate in association with extreme weather events is to increase. In that way, Sri Lanka, being an agriculture nation, is exposed to increased risk of the impacts of climate changes. Thus, problems associated with food security have ended up becoming a matter of vital importance for all. It encountered many challenges due to several climate induced issues which includes decline in agricultural productivity, food loss, and lack of livelihood resilience among rural poor and increased undernourishment and malnutrition (Esham et al. 2018). Thus, it poses threats to the important livelihood option in most part of the region in the country which is considered to be a major contributing factor in developing the rural economy.

Even though many climatic factors determine the paddy cultivation in Sri Lanka, rainfall and temperature are most important climatic parameters that influence on the paddy production significantly in Sri Lanka. Because, potential impacts of climate change like temperature increases and precipitation changes will affect the crop directly (Joshi et al, 2011). It has been confirmed by the past studies that variability in rainfall and temperature as a major threat to paddy production in Sri Lanka. The influence of these factors on paddy production therefore should not be underrated. In particular, variability in rainfall poses more impacts on crop yield, productivity, and quality as it is crucial for paddy cultivation in association with rainfall pattern.

Sri Lanka, being a tropical country, receives rainfall from two distinct monsoons and inter-monsoon seasons. Thus, Sri Lanka has four climatic seasons and two main crop production seasons. These two prime monsoons (South-West and North-East Monsoons) are responsible for distinct cropping seasons known as Yala and Maha. Karunathilaka et al, (2017) emphasizes that, the seasonal rainfall indicates an increasing trend during the first-inter monsoon, second-inter monsoon and north-east monsoon seasons at a majority of the stations.

Burt & Weerasinghe, (2014) pointed out that, "reliability of rainfall continues to be of great importance to a large fraction of the population and a lack of rainfall at the start of either monsoon season can threaten crop yields and force farmers to change their cropping practices". In particular, natural calamities like drought and flood conditions also are due to the changes in rainfall, which is considered as the most important climatological parameter (Swan et al, 2015).

Flood situation intensively affects the growing period and harvesting stage and bring greater loss to production. Jayawardene et al (2015), states that drought and flood contribute significantly to the reduction in paddy cultivation, which is one of the fundamental crops in Sri Lanka. Yoshini & Suppiah, (1984) too stated that droughts and floods experienced in Sri Lanka resulted in much crop losses in paddy production.

By analyzing the information and projected change, Climate Change Secretariat (CCS) of Sri Lanka suggests that a gradual increase in ambient air temperature, changes in the rainfall distribution pattern, increase in frequency and severity of extreme weather events are the three major changes experienced by country (CCS, 2016). Lokuhetti & Zubair, (2016) state in their study, Sri Lanka was much warmer from June 2015 until December 2016 than long-term historical average (1900 - 2004) but comparable to recent average temperatures. "An extended period of dry weather (the worst drought in 40 years to hit Sri Lanka) affected large swathes of cropping land across the country throughout 2016" (FAO, 2017).

There is real risk of crop failure prevailing during dry years (Burt & Weerasinghe, 2014). When compared to the previous paddy production of Yala season 2016, a substantial downward trend by 608,071 Metric Ton (40%) was identified in 2017 Yala season (Department of Census and Statistics, 2018). *"*The reason for the downward movement of paddy production could be: the lack of sufficient water facility for paddy cultivation due to dry climate condition prevailed during Yala season 2017, which also led to paddy cultivation to be done to a limited extent, which resulted in a lower average paddy yield than the expected amount and also considerable harvest loss being reported in some districts" (Department of Census and Statistics, 2018).

As a result of agriculture failures being caused by various climatic reasons, paddy farmers tend to encounter more risk where their socio-economic and psychological context is concerned as they are equipped with the lower adaptive capacity to cope with changing climate. Thus, it is essential to identify the trend, pattern and relationship of rainfall variability and paddy production.

II. PROBLEM DEFINITION AND OBJECTIVE

The Eastern province in Sri Lanka, being an important paddy producer, plays a prominent role in the rural livelihood development in the region. The province consists of three districts namely Trincomalee, Ampara and Batticaloa. Irrigation water has been the major source of agricultural water both in Trincomalee and Ampara districts while Batticaloa district mostly depends on rain fed agriculture. Moreover, the principal professions of the people living in this district are agriculture and fisheries. Therefore, the variability in rainfall causes more intense impacts to this district than others. It is well evident from past studies that thousands of livelihoods, which entirely depend on paddy cultivation, face significant challenges due to the recent impacts of climate change in the district.

In the recent decades, Batticaloa district experienced adverse impacts, either by drought or flood disasters. Therefore, paddy farmers in Batticaloa are exposed to unexpected challenges caused by extreme weather events resulting in flooding and extended effects of drought condition. Adverse climate conditions and problems associated with the low selling price of paddy are the most important problems encountered by the paddy farmers in the Eastern Province (*Vhurumuku et al. 2012).*

In a study carried out by Elankumaran (2003) it was found that rainfall variability causes disastrous damage to crop production in the Batticaloa district. Food security assessment report of 2011 based on the Northern, Eastern and North-Central Provinces states that intensified rainfall in December and January in 2011 resulted in heavy flood and severe damages to crops and other impacts such as displacement, limited accessibility in Batticaloa district (Petersson et al. 2011). This report also states that a livelihood migration towards non-agricultural labor occurred in the same year due to severe flood impacts (ibid).

In 2016 alone people affected by drought is 20,474 and by flood is 3172 (Batticaloa District Secretariat, 2016). In 2017, people affected by drought are 81,005 which consists of 24,129 families (ibid). Similarly, about 28,416.4 acres of cultivation square were affected by drought in the same year. In this background, identifying the rainfall variability in this district is very imperative to face the future challenges in paddy production and for planning process in relevance to rainfall variability in Batticaloa district.

III. STUDY AREA

The study area Batticaloa located in the Eastern part of Sri Lanka. The total extent of Batticaloa district with inland water is 2624.19 km^2 (Batticaloa

District Secretariat, 2017). It lies in dry-agro-ecological zone of Sri Lanka which receives rainfall from NE rainfall from December to February, and the rest of the year, the district experiences dry weather condition. Mean annual rainfall in dry zone is less than 1,750 mm with a distinct dry season from May to September (CSS, 2015).

Average annual rainfall of Batticaloa district is 1200 mm and rainy weather prevails in this district from November to February (Batticaloa District Secretariat, 2017). Silva et al, (2013) states that "the coastal area of Batticaloa, directly faces the monsoonal winds and the littoral drift, is oriented from the southeastern to the northwestern directions due to the configuration of the mainland and the continental shelf". Most part of the year dry weather prevails in this district. As the district experiences long spell of dry weather, the average annual temperature remains at 32ºC. From June to September the district experiences dry season.

IV. METHODOLOGY

The main objective of this paper is to assess the rainfall variability and to identify the relationship between paddy production and rainfall in Batticaloa district by means of statistical analysis. Rainfall variability was identified by analyzing 100 years' monthly rainfall data from 1918 to 2017. The relationship between paddy production and rainfall were identified using monthly data of 40 years during the period from 1978 to 2017.

Data of monthly rainfall and rainy days of Batticaloa district were collected from the meteorological department of Sri Lanka. Paddy production data were obtained from the agricultural census of Sri Lankan government and the reports of District Secretariat, Batticaloa. The seasons considered in this study were climate seasons such as (two principal monsoon and two inter-monsoon seasons) and agricultural seasons (Yala and Maha).

This study adopted trend analysis using nonparametric and parametric econometric techniques to evaluate the relationship between paddy production and rainfall in Batticaloa using EViews 9.0 software. Microsoft Office Excel is used for basic trend analysis and to visualize the graphs. The model was evaluated using Ordinary Least Square technique (OLS) and the results were visualized using graphs, figure and tables using EViews 9.0 software and Microsoft Office Excel. Graphical method includes confidence ellipse and kernel fit curve and many other graphs to elaborate the relationship of variables. The model was evaluated using OLS technique to find out the relationship of variables. The OLS regression analysis used the following equation to evaluate the rainfall variability and paddy production in Batticaloa District.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + u$$

Where, Y denotes Paddy production, X_1 denotes rainfall during Yala season, X_2 denotes rainfall in Maha season and u denotes the error term of the regression.

V. RESULTS AND DISCUSSION

A. *Trend and rainfall variability*

The analysis of 100 years' rainfall data from 1918 to 1917 identified several findings in rainfall variability and trend with relevant to annual, monthly and seasonal rainfall in Batticaloa district. Results revealed that, the annual total rainfall in the study area fluctuates over the period of time. Fig 1 shows the trend of annual total rainfall in the study area. Based on the annual total rainfall trend, second half of this century has received higher rainfall than the first half. Moreover, the study area experiences a high amount of annual total rainfall (above 2500 mm) in some years (3581mm in 2011, 3080 mm in 1994, 2897 mm in 1963) while very low (below 1000 mm) in some other years (865 mm in 1968, 922 mm in 1983, and 990 mm in 1980). The lowest rainfall received by the study area for the last hundred years is 865 mm in 1968 while highest rainfall recorded in 2011 as 3581 mm. This is the ever recorded highest rainfall in the century in Batticaloa district.

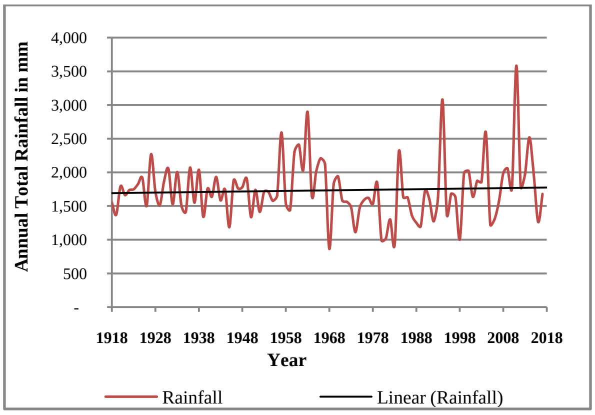

Fig 1: Annual Total Rainfall from 1918 – 2017

The trend of the rainfall clearly revealed that rainfall highly fluctuated in the later part of the century (1957 to 2017) with a high variability than the first part (1917 – 1956). In the first part, rainfall varies between 1186 mm to 2269 mm with a range of 1083. The standard deviation is 232.94 mm and the mean annual total is 1699.5 mm in this period. In turn, the rainfall experienced by the study area the latter part varies from year to year and results in combination of dry climate and intense rainfall. Rainfall in this period, ranges between 865 mm to

3581 mm with a range of 2716. Mean annual total rainfall is 1752.67 mm and the standard deviation is 525.72 mm. Thus, the study reveals that the rainfall mean, range and standard deviation of annual rainfall have increased by two folds with high levels of variability in the recent decades.

Similar to the above findings, Karunathilaka et al, (2017) in their study revealed that the eastern region of the country has shown an increasing trend in rainfall over the last half century, while western, northern and south-western region and central hill of the country have shown a decreasing rainfall trend during the same period. As like the annual total rainfall monthly and seasonal rainfall also show an important pattern in this district. Fig 2 and 3 shows mean monthly rainfall and seasonal rainfall from 1918 to 2017 for Batticaloa station respectively. As shown in the box plot (Fig 2), study area receives more rainfall in the beginning and the latter part of each year. This monthly wise variation is based on the climatic seasons belongs to the study area.

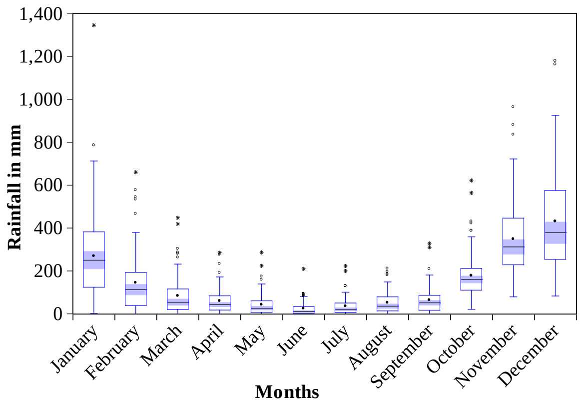

Fig 2: Mean Monthly rainfall from 1918 – 2017 in Batticaloa District

According to the last 100 years of annual data, study area receives high rainfall from the North-East monsoon next to Second Inter monsoon. North East monsoon is very much significant and lasts longer and therefore month of December recorded higher rainfall than other months. It starts in mid or end of November and becomes intensified rain in December as shown in the Fig 2.

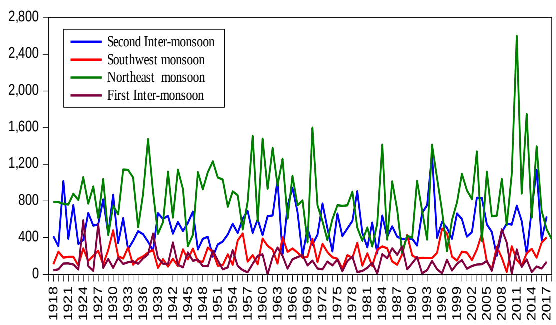

Fig 3: Seasonal rainfall variability of Batticaloa District

The first Inter monsoon season brings lowest rainfall to the study area next to South West Monsoon. Thus, the period starting from March to September monthly rainfall is recorded as low. Among this, lower rainfall has been recorded in June. Therefore, the dry period prevails in the middle part of the year, usually during the Southwest monsoon season. Following this season, wet periods which start as the second inter monsoon season, bring a considerable amount of rainfall for this district. These patterns are mostly decided by the number of rainy days and the intensity of rainfall. Accordingly, Fig 4 shows the trend of rainy days from 1978 – 2017 by agricultural seasons in this district. Similar patterns are evident in number of rainy days as well.

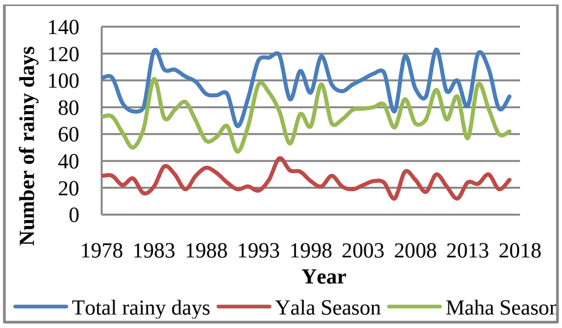

Fig4: Trend of rainy days Yala and Maha seasons based on 40 years data from 1978 - 2017

Fig 4 shows rainy days are fluctuating over the period of time. According to the analysis, which was based on the data of 40 years of rainy days, a significant increasing trend was identified in Maha season and annual total rainy days. Moreover, there is a gradual decrease in rainy days was identified with fluctuation in Yala season. During the last 40 year period only 18 years have recorded more than 100 rainy days and 7 years (1979, 1984, 1994, 2000, 2004, 2011 and 2015) have recorded as with 116 rainy days. Highest annual total rainy days (131 days) have recorded in 1984 while lowest rainy days (72 days) recorded in 2016. It is noted that in this year Batticaloa district experiences severe and prolonged drought condition. Thus, this year alone about 20,474 people were affected (District Secretariat, Batticaloa, 2016).

B. Trend of Paddy Production in the Study Area

In Batticaloa district paddy cultivation is predominantly undertaken in two main seasons of Sri Lanka. The Maha and Yala **are** the major cultivation season in Sri Lanka, Maha is falling between October and March and Yala is a minor cultivation season depends on irrigation water extends from April to September**.** Similarly, in Batticaloa district too Maha is the major season when cultivation occurs in this district. Cultivation in Yala is very limited as this season depends on irrigation water. According to the statistics of Maha 2016⁄17 season, Batticaloa district placed in 5th place in district wise paddy production.

The total extent of paddy cultivated for the Yala season in Batticaloa district is 24,211 hectares which is 10% of the total sown extent of paddy cultivation during this season (Department of Census and Statistics, 2018). The total paddy cultivated area during the Maha season 2017/2018 in this district was about 64,796 at all schemes (ibid). Table 1 below shows the gross extent sown acres of paddy cultivated and gross extent harvested at all schemes in the district.

TABLE 1: Paddy Production in Batticaloa District

Type	Gross extent sown acres (Acres)	Gross extent harvested (Acres)
Major scheme	49,678	43,954
Minor scheme	8,395	6,446
Rain fed	97,200	40,695
All scheme	155,273	91,095

Source: Data obtained from District Secretariat, Batticaloa

As shown in the Fig 5 the analysis clearly shows that the paddy production in Batticaloa district shows a significant increasing trend in Maha and Yala seasons. The total paddy production trend of Batticaloa district is predominantly depends on the paddy production of the Maha season rather than Yala. The shape of the curve of total paddy production trend shows a similar pattern as paddy production in Maha.

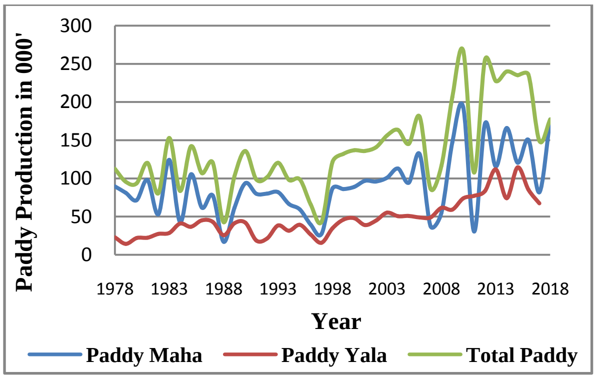

Fig 5: Paddy production by seasons based on 40 years data from 1978 - 2017

C. *Relationship of Paddy Production and Seasonal Rainfall in Batticaloa District*

The Fig 6 shows the relationship of variables (rainfall and paddy production) in Batticaloa District. The regression line of Kernel Fit and confidence ellipse curve shows a relatively positive relationship among these variables at 5% confidence level and this relationship was evaluated using the parametric approach to confirm its variability.

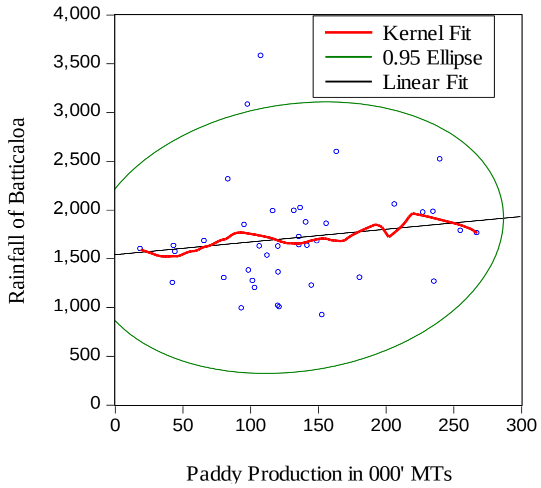

Fig 6: Relationship of Paddy production and Rainfall in Batticaloa District (Estimated, 2018)

Relationship of seasonal rainfall (Rainfall in Maha and Yala) and paddy production in Batticaloa District illustrated in the following figure 7 with the support of Kernel fit curve for the period 1978 to 2017. Rainfall in Maha is positively related with paddy production in Batticaloa and rainfall in Yala is negatively related with the paddy production for the same period.

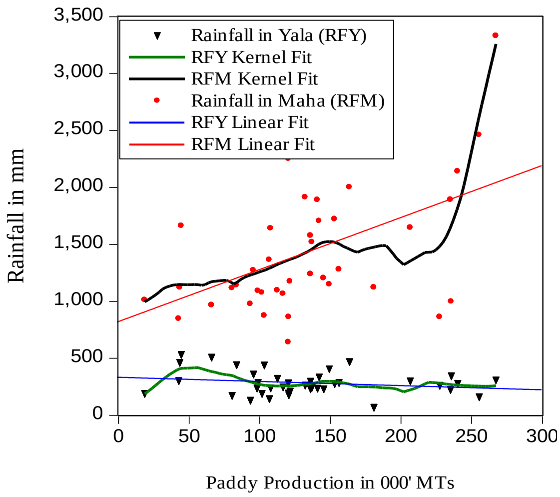

Fig 7: Relationship of Paddy production and seasonal rainfall in Batticaloa (Estimated, 2018)

1. Unit Root Test:

The variables were examined unit root test using ADF technique and presented in the following table 2. As per the result, all the variables were stationary at a level and significant at 1% confidence level too. Hence, this paper adapts OLS technique to evaluate the relationship of variable and presented in the table 3.

TABLE 2: Augmented Dickey Fuller (ADF) Test

Variables	t Statistic	p value	Status

Paddy Production	-3.69	0.008*	I(0)
Rainfall in Maha	-5.43	0.000*	I(0)
Rainfall in Yala	-5.91	0.000*	I(0)
Note: * denotes a significant level at 1%			

Source: Estimated, 2018

2. OLS Regression Result

The relationship between the variables such as paddy production and seasonal rainfall in Batticaloa District evaluated using an ordinary leased square (OLS) and the result shows that rainfall in Maha season is positively related with paddy production even at 1% significance level (Table 3). A unit increase of rainfall in Maha would increase the paddy production by 0.05 times. Rainfall in Yala is negatively correlated with paddy production in Batticaloa district, but it is not statistically significant. This model is significant because the F statistic of the model is significant at 1% confidence level.

TABLE 3: OLS Regression Result

Variables	Coefficient	p value
Constant	86.69***	0.01
Rainfall in Maha	0.05*	0.00
Rainfall in Yala	-0.10	0.20
F Statistic	7.21*	0.00
R^2 - 0.28, Adjusted R^2 - 0.24		
Note: * denotes 1%, ** denotes 5% and *** denotes 10% significance level		

Source: Estimated, 2018

$$Y = 86.69 - 0.10X_1 + 0.05X_2$$

Where, Y denotes Paddy production, X_1 denotes rainfall in Yala season and X_2 denotes rainfall in Maha season.

3. Test of Model Stability

The evaluated OLS model was tested using various tests to confirm the stability. There are many statistical techniques to test the model specification. In this study, evaluated OLS model was tested using Ramsey RESET test, Jarque-Bera error normality test, heteroskedasticity test and CUSUM test. The result of the tests mentioned above has summarized in Table 4 below.

TABLE 4: The Results of Diagnostic Tests

Test	Stat.	Prob.	Decision
Ramsey RESET test	0.7	0.40	Model specified correctly
Jarque-Bera (Normality test)	1.5	0.45	Error Normally distributed
Heteroskedasticity Test 1.Breusch-Pagan-Godfrey	0.00	0.99	No heterokedasticity
2. White Test	0.10	0.99	No heterokedasticity
Note: * denotes 1%, ** denotes 5% and *** denotes 10% significance level			

Source: Estimated, 2018

4. Ramsey RESET Tests:

The Ramsey Regression Equation Specification Error Test (RESET) is tested the specification of independent variables. This omitted variable test, namely Ramsey RESET test was employed to find out whether there are any more variables to be added to validate of analysis or the included variables to be specified as square or cube format. The hypothesis of the Ramsey RESET test is as follows,

H_0: The model is correctly specified
H_1: The model is not correctly specified

The F statistic of the Ramsey RESET test is 0.70 with a probability of 0.40 which means that the null hypothesis of the RESET test specified above cannot be rejected at the 5% confidence level. Hence, the model developed in this study is correctly specified and there is no more square or cube form of independent variables to be added.

5. Jarque-Bera Error Normality Test:

The following Fig 8 clearly displays a histogram and descriptive statistics of the residuals, including the Jarque-Bera statistic for testing normality. The Fig 8 shows as bell-shaped and the Jarque-Bera statistic is not significant at 5% confidence level (JB t stat is 1.56 and p value is 0.45). Hence, the used model is specified correctly as per the Jarque-Bera test statistic.

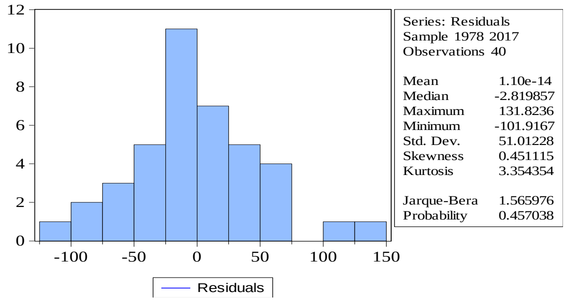

Fig 8: Jarque-Bera Histrogram of error term
(Estimated, 2018)

6. Heteroskedasticity Test

Variation of error term over the specified time period is simply called heteroskedasticity which means that the error term is not normally distributed and varies time to time. The Breusch-Pagan-Godfrey test result of the analysis summarized in the table 4 is 0.00 with a p value of 0.99 which means that the null hypothesis cannot be rejected at a 5% confidence level. Hence, the error has not heteroskedasticy and it is homokedastically varies over the specified time period.

7. CUSUM Test:

The CUSUM test is based on the cumulative sum of the recursive residuals. This option plots the cumulative sum together with the 5% critical lines. The test parameter finds instability if the cumulative sum goes outside the area between the two critical lines. The Fig 9 clearly shows that the model fitted within the confident level line. Hence, the model used for the analysis is best based on the CUSUM test (Fig 9).

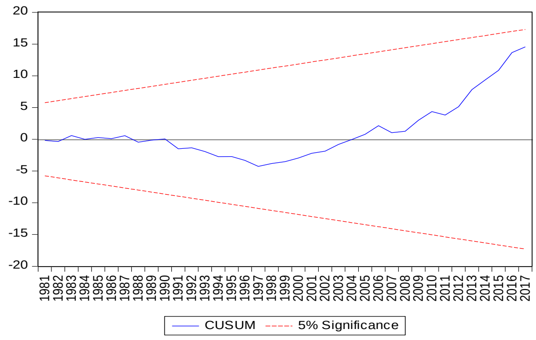

Fig 9: CUSUM test for Regression (Estimated, 2018)

As summarized above, all the tests were confirmed that the model specified is correct and the result explored above is statistically significant to conclude the findings. In addition, according to moving average technique the model has forecasted the paddy production in Batticaloa (Fig 10).

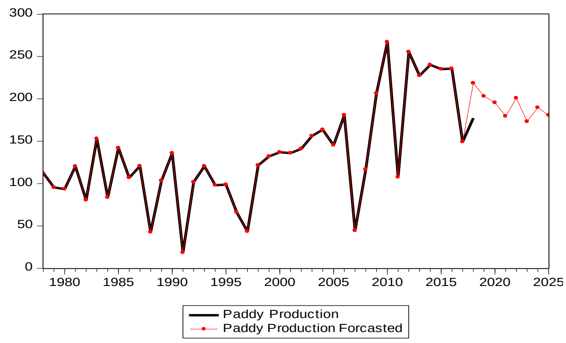

Fig 10: Forecasting of Paddy (Estimated, 2018)

The actual line based on paddy production shown up to 2017/2018 Maha and thereafter the forecasted line drew using e-views software. It shows that the forecasted paddy production also varies over the time period.

VI. CONCLUSION

The main objective of this paper is to assess the rainfall variability and to identify the correlation between paddy production and rainfall using statistical analysis. Based on the results of analysis of 100 years data from 1918 – 2017 of Batticaloa, the annual total rainfall and seasonal rainfall shows a significant increasing trend. After 1957, rainfall in this district fluctuated with high variability and rainfall intensity also increased in some years, which resulted in flood hazard and in turn dry weather resulted in long drought condition. The frequency and intensity of this situation have increased due to the instability of rainfall pattern. Consequently, the paddy production in this district faces significant fluctuation. Statistical analysis revealed a positive relationship between rainfall and paddy production in Maha season and it is also statistically significant at 1% confidence level. Thus, a unit increase in the rainfall in Maha season would increase the paddy production by 0.05 times. Also, the rainfall in Yala negatively correlated with paddy production in Batticaloa, but it is not statistically significant.

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