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Full Length Research Paper

The impact of rainfall variability on rice production in Region Six- Guyana

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Guyana's climate is characterized by seasonal variations in rainfall; the premise on which the cropping cycle of rice was established. However, strong tendencies of rainfall to deviate from its normal seasonal pattern have often resulted in large losses in the rice sector. This research examined the effect of rainfall variability on rice production, with specific reference to area sown, yields and area harvested for the period 1988 – 2007 in Region Six, Guyana. Correlations of rainfall with area sown, area harvested and yields revealed an inverse relationship between rainfall and these variables and a weak positive relationship between rainfall during the vegetation and reproductive periods and yields. For yields the order of influential magnitude was variations in years, crop, and area. Further, the results of the regression analysis have shown that variations in rainfall accounted for 85-90 percent of the observed fluctuations in area harvested, yields and area sown. The effect of rainfall on rice production was exacerbated by access to farming equipment and access to and management of irrigation and drainage facilities.

Keywords: climate variability, rice, climate change vulnerability, rice production, Guyana

ACRONYMS

ANOVA: Analysis of Variance
GDP: Gross Domestic Product
GRDB: Guyana Rice Development Board
IRRI: International Rice Research Institute
ITCZ: Inter-convergence Zone
FAO: Food and Agriculture Association of the United Nations
USDA FAS: United States Department of Agriculture, Foreign Agriculture Service
GLSC: Guyana Lands and Survey Commission

1 INTRODUCTION

Rice is a cereal food which forms an important part of the diet of many people worldwide, especially in tropical Latin America, and East, South and Southeast Asia. It is regarded the second most consumed cereal grainworldwide (Statista, 2020; Van Nguyen and Ferrero, 2006). Guyana is the seventh largest rice producer in the Latin America and Caribbean region (IRRI, 2016; USDA FAS, 2016). Since the introduction of rice production to Guyana by the Dutch in the 18th Century as a mere staple food for African slaves, rice has assumed a dominant position in Guyana's economy (Ishmael, 2005). This industry now accounts for approximately 3.3% of Guyana's annual GDP and 20.5 % of GDP within the agricultural sector (Holder, 2019). It also provides employment for approximately100,000 Guyanese, including farmers, millers and exporters (Rampertab, 2001). Following extensive empoldering along Guyana's coast, rice production expanded allowing for cultivation in five of Guyana's ten administrative regions.

Rice production in Guyana follows the marked seasonality of rainfall to which it has adapted. However annual variability in rainfall continues to threaten the industry. This is usually of greater consequence during extreme weather episodes or phenomena. Rice farmers often report great losses following periods of excess or deficits of rainfall. For Guyana, shortfalls in production result in domestic shortages, often reflected in higher domestic prices and reductions in foreign revenue.

Therefore this research sought to assess the extent to which changes in rainfall has affected rice production in Region Six. Specifically the research assessed the exposure of Region Six to shifts in rainfall patterns over the period 1987-2007 and to determine the sensitivity of Guyana's rice production to rainfall variability. It is expected that the results of this study will be used in identifying appropriate strategies to combat short and long term effects of rainfall variability on the rice industry.

1.1 Background

The field component of this research was conducted in the coastal district of Region Six represented on the maps below (*see Figure 1-1*). Region Six is one of ten administrative regions and one of five rice-growing regions in Guyana. With approximately 48,000 acres of rice lands, this region is regarded the second largest contributor to Guyana's rice industry; accounting for twenty four percent of the

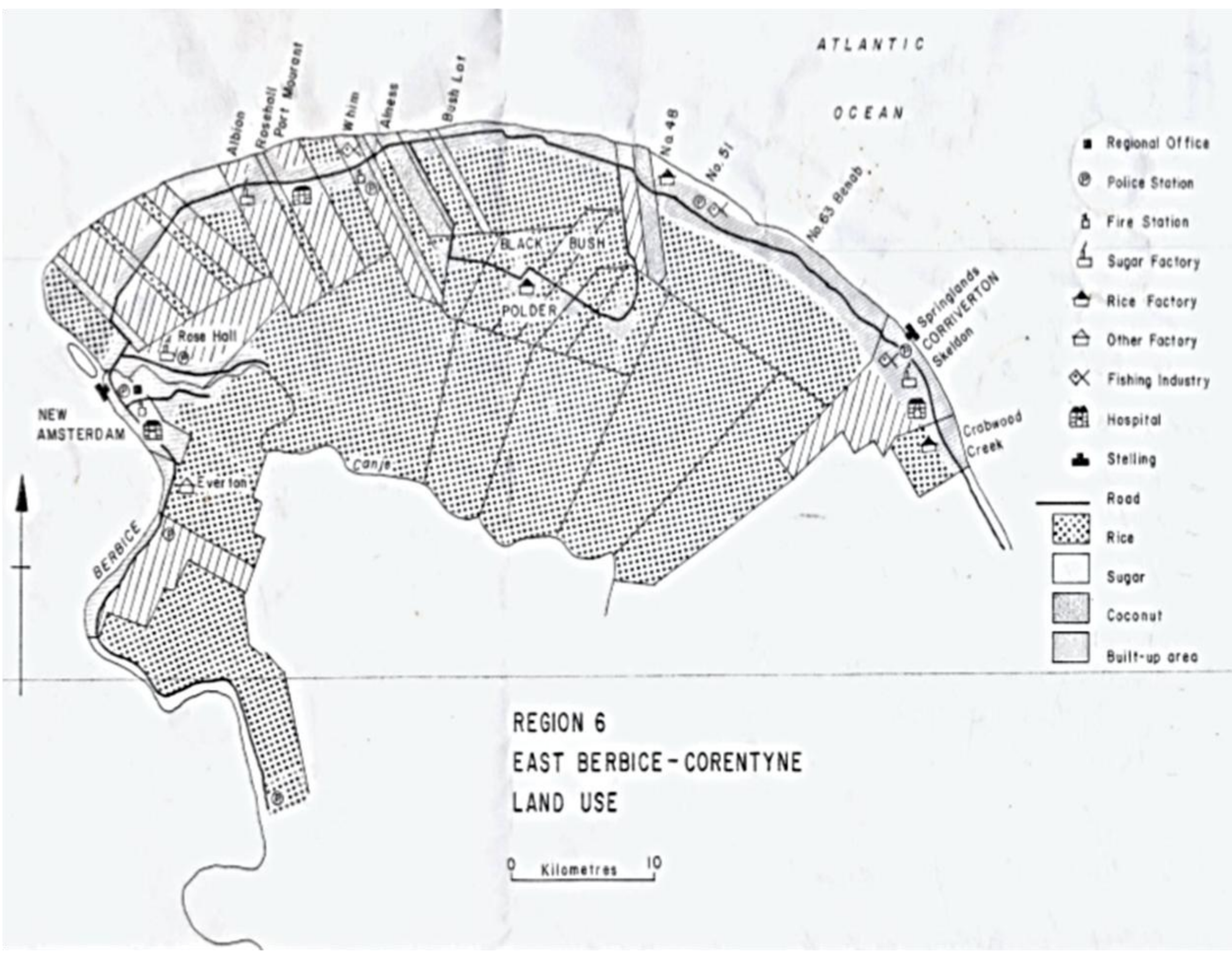

Figure 1-1: Land use Map of Study Area
Source: University of Guyana, 2008

industry's total annual output (GLSC, 2004 and FAO, 2002). This region comprises five rice–growing areas or districts, namely - Crabwood Creek, Borelamb-East Bank, Gibraltar – Number 51, Number 52- Number 74 and Black Bush Polder. Of the five districts, Black Bush Polder outputs the largest amount of agricultural products. The remaining four districts are regarded collectively by the Guyana Rice Development Board as the Frontlands.

2 LITERATURE REVIEW

2.1 Rice Production

In most rice-growing countries, rice is usually grown as a lowland (wetland) crop. Under this system, land is either prepared wet or dry but water is always held on the field by bunds. About 30% of the world's rice is grown as rainfed lowland and about 45% as irrigated lowland. Land preparation is done in two stages, the first of which involves the burning of all shrubs, stumps, straw and all unwanted materials. Burning of the shrubs is usually hindered if the conditions are wet. The next stage is the actual ploughing of the land, which is also referred to as cut. Usually the field is ploughed (or cut) two times; the first while the lands are dry; the other under wet conditions (2" above the highest spots).

However, for both rainfed lowland and irrigated lowland rice, the raising and handling of seedling and plant density are generally similar. Rice seeds are soaked in water for 24 hours, then kept warm for 48 hours and may be broadcasted by hand or sown by means of a case seed drill while the disk is still in suspension in the water. The water is then drawn off until germination occurs; after which the field is kept in a flooded condition at a height not exceeding four inches until two to four weeks before harvesting. Inadequate supply of water during this period could severely affect the development of seedlings.

There are five distinguishable stages of rice plant development for transplanted rice (Prathumchai *et al.* 2018). If the rice is sown directly (broadcasted), the first two stages are combined (Food and Agricultural Organization). The vegetation stage, includes the sowing of rice and tillering. The duration of this phase varies from 35-40 days. Approximately forty percent of the water requirement for rice growth is utilised during this period (Table 2-1).

The next stage is the reproductive stage, known commonly as the mid-season stage. It commences from panicle initiation to flowering stage. This stage extends for 45 to 50 days. Approximately 30 percent of total water requirement for growth is utilised during this period. According to Brouwer, Prins and Heibloem (1989b) this stage of rice growth is most susceptible to water shortages. The final stage is the ripening stage. During this stage the least quantity (5%) of water is required. This stage lasts approximately 30 days. Some authors have grouped the last two stages under the reproductive stage, thereby culminating the rice development stages into two stages (Table 2-1:).

Table 2-2: Irrigation water management in paddy

Stages of growth	% of total water requirement (approx.)
Main field preparation	20
Planting to Panicle initiation (PI)	40
P.I to **flowering**	30
Flowering to **maturity**	5

Source: Agropedia, 2009

2.2 Culture of Rice Production in Guyana

In Guyana, more than 90 percent of rice is grown in lowland irrigated systems and the remaining in lowland rainfed systems (FAO, 2002). Rice planting patterns in both systems follow the marked seasonality of rainfall. In a typical year, the first crop, also known as the larger (50-65%) crop is sown in January – February (United States Department of Agriculture, 2017) (*see Table 2-2*). This is preceded by land preparation from December – January. The second crop is planted between the months May-June, following land preparation in March – April (United States Department of Agriculture, 2017). It has been the custom to refer to the first crop as the main or spring crop whilst the second crop is referred as the autumn crop. Nowadays, it is customary for two crops to be planted on the same land per year (. However, in earlier days this was not the

Table 2-3: Rice planting schedule in Guyana

	Land preparation months	Vegetative growth period	Reproductive growth period	Harvesting
Spring Crop	December - January	January - February	March - April	March - May
Autumn Crop	April - May	May - June	July- August	September - November

Source: United States Department of Agriculture, 2017

case. In Berbice, there was one crop per year and cattle was allowed to graze for the remainder of the year.

The irrigated lowlands of Guyana are supported by an elaborate empolder system which addresses the twin problems of drainage and irrigation. Earthen river dams which were constructed to impede the flow of water from rivers in the upper reaches of the interior, also serve as water reservoirs to supplement rainfall in agricultural areas. This is supported by a drainage and irrigation network comprising canals, sluices and kokers which are used to transport irrigation water to farms during dry seasons and to remove excess water from the land during rainy seasons. However these systems were only designed to supplement natural weather conditions, of which farmers are expected to make the best use (Naraine, 1981). This means that farmers supported by irrigated systems are required to take advantage of natural irrigation as much as may be possible.

Rice is produced on small (10 to 30 acres), medium (31-59 acres) and large scales (more than 59 acres) by rural farmers of predominantly East Indian descent. East Indians took to rice cultivation following the end of the indentureship period in 1917 (Mangru, 2013). Therefore, for many farmers, rice cultivation is not only a means of livelihood, but also a way of life.

2.3 Guyana's Rainfall Pattern

Guyana is dominated by a "tropical humid climate" (Daniel, 2001). The alternating wet and dry seasons, is the primary characteristic of our climate. According to Koppen's climatic classification system Guyana can be divided into two climatic regions, Ami-tropical rainy climate and Awi-tropical Savannah climate (Cleare, 1961).

Most of Guyana, including its coast, is included in the Ami-tropical rainy climatic region. In this climatic regime annual rainfall distribution shows a "bimodal" pattern (Guyana Hydrometeorological Service, 2008). This pattern is as a result of the annual meridional migration of the Inter Tropical Convergence Zone (ITCZ). The northward movement of the ITCZ generally brings heavy rainfall between mid-April and the ending of July, with a major peak rainfall in June (Guyana Hydrometeorological Service, 2008). This is called the primary wet season. During the southward migration of the ITCZ, a second wet season is observed between mid-November and the ending of January with peak rainfall in December. The periods in between are often referred to as primary dry (long) season and secondary (short) dry season respectively (Khan, 1998). Cleare (1961) in evaluating the climate of British Guiana over a seventy six-year period found the average annual rainfall total for Berbice, Demerara and Essequibo to be 81.35", 95.33" and 101.36" respectively.

Based on 100 years of data, Potter (1970) noticed complete 45-year cycles of annual rainfall which comprised short cycles of four years. These year-to-year variations of precipitation cause droughts in some years and floods in others (Cleare, 1961). For instance, he noted that in 1972 the first wet season began abruptly on April 18 and ended early but slowly, whilst the second dry season was extremely dry. The second wet season began abruptly on October 27, one month ahead of average time, and its short duration produced extremely low rainfall from December 1972 to April 1973, resulting in a serious drought (Potter, 1970).

3 METHODOLOGY

Monthly rainfall data solicited through the Guyana Hydrometeorological Service were obtained for the period 1988 – 2007. Rice production data was collected for the corresponding period from the Guyana Rice Development Board (GRDB).

The rainfall analysis that follows involves data from 32 rainfall stations in Region Six, selected for consistency and length of rainfall records, spatial distribution and proximity to rice growing areas. Rainfall data from the selected stations were used to create an "all-region 6" rainfall index for each month. Using the indices, annual, monthly and seasonal rainfall variations were then computed. The year 1990 was excluded from the rainfall analysis as a result of substantial discrepancies and or regularities in the data.

The effects of rainfall on rice production were analyzed using correlation and regression analyses, as well as an analysis of variance. Whilst correlation was used to test the association of rainfall with the various processes of rice production, the source of the variability in rice production were tested through regression analysis and analysis of variance models (ANOVA). Simple multiple linear regression models modelled rice production (number of bags) as the response variable. Rice Production was regressed upon a combination of the following regressor (independent) variables: Area Planted, Area Harvested, Total Rain Fall, and Yields. Total rainfall was divided into four rice production phases corresponding to Land Preparation, Vegetative Growth, Reproductive Growth, and maturation-harvest. Two to four regressor variable models were run using regression procedure and options in the statistical analysis Software Package of MINITAB (MINITAB Inc., 1994).

4 RESULTS

4.1 Rainfall Variability in Region Six

In the first instance the statistical mean annual rainfall for the period was used as the estimated "normal" annual rainfall for the area. Based on this methodology, five years recorded above normal rainfall (1989, 1990, 2005, 2006 and 2007); nine years recorded below normal rainfall (1991, 1992, 1994, 1997, 1998, 2000, 2001, 2002 and 2003) and six years recorded normal or close to normal rainfall (1988, 1993, 1995, 1996, 1999 and 2004) (see Figure 4-1).

In the second methodology for calculating variability of rainfall from the normal, a normal-range was calculated based on the interval plus and minus one standard deviation from the mean. Annual rainfall that exceeded plus one standard deviation from the mean or upper range were regarded extremely wet years whilst years with rainfall below minus one standard deviation from the mean were regarded extremely dry years.

The standard deviation interval was useful in highlighting anomalies or extreme rainfall events. Three years recorded rainfall above the upper interval. These are 1989, 1996, 2000 and 2007. These years were identified based on Oceanic Niño Index (ONI)as "moderate" - "strong" La Nina years (Null, 2020). In 1992, 1997 and 2003 rainfall below the lower interval was recorded. These years are consistent with "moderate" – "very strong" El Nino years based on Oceanic Niño Index (ONI)(Null, 2020). During "Weak" La Nina and El Nino years "significant" above or below normal rainfall was not recorded.

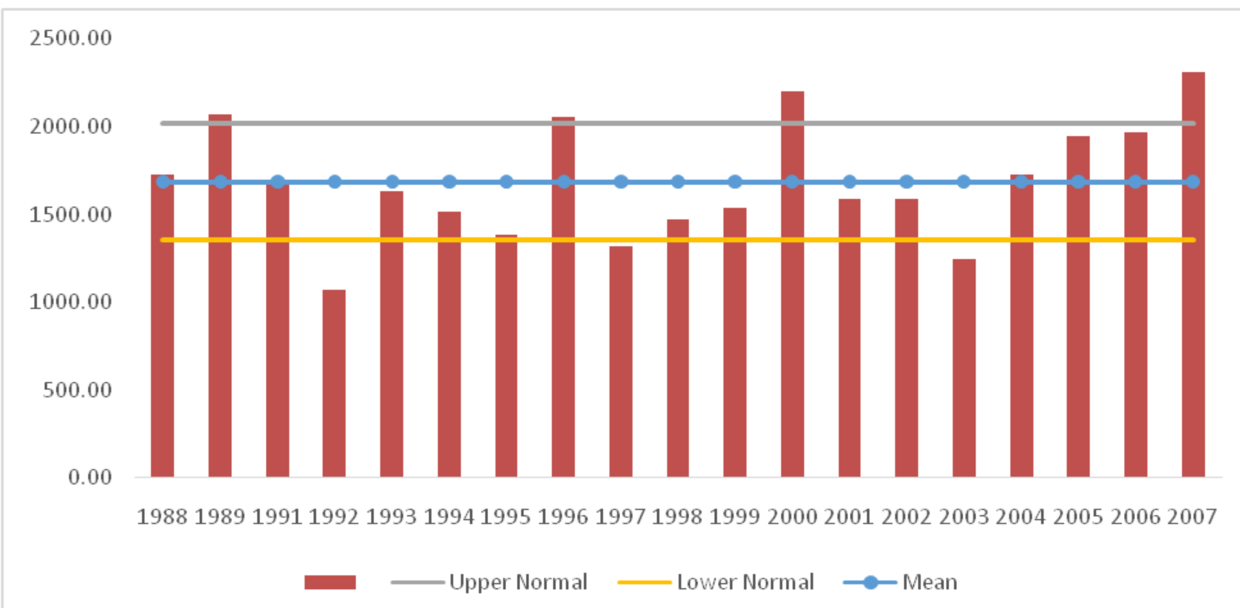

Figure 4-1: Average annual rainfall in Region Six for the period 1988- 2007

Despite some variability in annual rainfall was observed during the period, overall the analysis indicates that rainfall during the period was normal and no significant difference was found between mean rainfalls for years in this study. This was concluded following a single-factor Analysis of Variance to test the null hypothesis that there is no difference in the mean rainfall for the years 1988 – 2007 at a significance level of 0.05. The analysis returned a P-value of 0.45 therefore, the null hypothesis cannot be rejected at the significance level of 0.05 (see Table 4-1). In addition, the F-value (1.00) is less than the F-critical value (1.65), therefore

Table 4-1: ANOVA Single Factor: Annual Rainfall in Region Six 1988 – 2007

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	166361.6	18	9242.3138	1.00832565	0.451635	1.65341
Within Groups	1915694	209	9166.0009			
Total	2082056	227				

we have no evidence to reject the null hypothesis. The results suggest that there is no significant difference in mean annual rainfall for the years 1988 – 2007. It was therefore concluded that the variability in mean rainfall between the years 1988-2007 was not significant.

4.2 Effect of rainfall on Area sown

The relationship between rainfall during land preparation and area sown was tested using the Pearson's Correlation Coefficient. The correlation coefficient (r) was calculated to be – 0.2 and – 0.4 for the first and second crops, respectively (*see Table 4-2*). This suggests the possible existence of an inverse relationship between rainfall during land preparation and area sown(acreage) for both first and second crops. That is, higher rainfall during land preparation stage decreases the acreage prepared. This observed relationship is stronger during the second crop. This result was supported by farmers, an estimated twenty percent of whom indicated that excess rainfall hindered their preparation often resulting in delayed sowing.

Table 4-2: Correlation Analysis Rainfall Vs Area Sown

	Parameters	**Correlation Coefficient**
Area Sown	Rainfall during land preparation vs area sown for the first crop	-0.2
	Rainfall during land preparation vs area sown for the autumn crop	-0.4

The regression model indicates that rainfall during land preparation accounted for 85-88% of the observed variations in area sown annually in the Frontlands and Black Bush Polder Area (Tables 4-3 and 3-3). Of the four periods of rainfall, land preparation, vegetative, reproductive and harvesting, the model suggested that rainfall during land preparation was most influential in determining acreage sown, accounting for 64-76% of the observed variation in acreage sown over the period 1988-2007.

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Table 4-3: Regression Analysis for the Frontlands

	Rainfall during land preparation (r^2)	**Rainfall during vegetative growth (r^2)**	**Rainfall during reproductive growth (r^2)**	**Rainfall during harvesting (r^2)**
Area Sown (85%)	76.3	22.3	0.1	1.4

Despite many farmers practice dryland and wetland land preparations, the latter is often hindered by huge depressions in the land created by combine harvesters during their reaping operations. Therefore, farmers must allow their land to dry for several weeks, and level it again before the land is prepared under wet conditions. If heavy rainfall persists during the period of land preparation, farmers are not allowed to carry out the first stage of land preparation which requires dry conditions. This situation, according to the Drainage and Irrigation Board, is a regular setback to farmers in Region Six. In 2008 alone, insufficient rains accounted for 8,000 acres of rice land left uncultivated whilst 200 acres of rice were unharvested as a result of excess rainfall (Mahdu, 2019). Often, if weather conditions are unfavourable, farmers plant later in the crop period when the conditions are optimal for land preparation. Therefore, more importantly than the area sown, rainfall during land preparation affects the scheduling of crops resulting in many farmers sowing during off-season periods. Consequently, approximately 50 percent of farmers currently sow during months traditionally unsuitable for cultivation.

Market conditions, especially prices, often drive farmers to cultivate their land despite less than encouraging conditions for land preparation. This may hide the resultant impact and possible variations in area sown that may have resulted from rainfall. Farmers who have sown despite less than optimal rainfall conditions for land preparations have reported lower yields.

4.3 Effects of rainfall on Area Harvested

To assess the association between rainfall and area harvested mean rainfall for these months March – May and August- September was correlated with percentage of area (acres) harvested for the corresponding periods of the First and Second crops. In each instance the Calculated Pearson's Correlation Coefficient returned was -0.1.This indicates that a weak inverse relationship existed between rainfall and area harvested for both crops (*see Table 4-4*). Whilst the correlation coefficient is miniscule, the results support the observation that higher rainfall during the harvesting period results in lower acreages harvested.

Table 4-4: Regression Analysis for Black Bush Polder

	Rainfall during land preparation (r^2)	Rainfall during vegetative growth (r^2)	Rainfall during reproductive growth (r^2)	Rainfall during harvesting (r^2)
Area sown (88.4%)	64.0	30.7	2.9	2.3

Further area harvested was regressed upon rainfall during land preparation months, rainfall during vegetative growth months, rainfall during the reproduction growth months and rainfall during harvesting months. The models for the Frontlands and Black bush Polder Area accounted for 87.5 – 90% of the observed variation in area harvested, suggesting that rainfall accounted for approximately 88-90 percent of annual observed changes in rice production (*see Table 4-5 and 4-6*).

Table 4-5: Correlation Coefficient rainfall vs area harvested

	Parameters	Correlation Coefficient
Area harvested	Annual rainfall during harvesting vs Percentage of Area Harvested for the autumn crop	-0.1
	Annual rainfall during harvesting vs percentage of Area harvested for the Spring Crop	-0.1

Table 4-6: Regression Analysis for the Frontlands

	Rainfall during land preparation (r^2)	Rainfall during vegetative growth (r^2)	Rainfall during reproductive growth (r^2)	Rainfall during harvesting (r^2)
Area Harvested (87.5%)	78.9	18.5	0.4	2.2

The magnitude of influence were in the order of rainfall during land preparation, rainfall during vegetative growth, rainfall during harvesting and rainfall during the reproductive growth. The model suggests that rainfall during land preparation resulted in the most substantial impact while rainfall during reproductive growth the least impact on area harvested in a particular year. Rainfall during harvesting period accounted for 2-3% of the observed fluctuations in acreage harvested. Narine (1981), pointed out that the occurrence of excess rainfall during harvesting, leads to difficulty in maneuvering machinery in the field, which can lead to many acres of rice left un-harvested. This phenomenon, referred to as lodging, tend to affect some varieties of rice more than others. In some cases up to 50% of a farmer's crop may be left un-harvested (Guyana Rice Development Board, 1997).

During periods of heavy rainfall, impassable access dams frequently impede access of machinery and labour to rice fields since most access roads are primarily clay. This restriction often delayed harvesting and resulted in higher production costs for farmers who must seek alternative modes of transportation to transfer their crop from the field. Boats, which are the usual alternative to combine harvesters, are on the average, capable of carrying only thirty bags per trip. For a farmer with several hundred bags of paddy this method of transportation may prove to be very costly.

Poor rainfall conditions is also often exacerbated by inadequate harvesting machinery. Farmers rely on limited number of tractors to carry out land preparation and combine harvesters. Farmers are therefore forced to wait on the available of the necessary equipment, resulting in greater lodging of the crop.

The difference in the effect of rainfall on acreage harvested in the Frontlands and Black Bush Polder area (*see tables 4-6 and 4-7*) may be the result of disparities in drainage infrastructure between these two areas.

Table 4-7: Regression Analysis for Black Bush Polder

	Rainfall during land preparation (r^2)	**Rainfall during vegetative growth (r^2)**	**Rainfall during reproductive growth (r^2)**	**Rainfall during harvesting (r^2)**
Area harvested (88.9%)	62	30.7	4.3	3.0

Table 4-8: Correlation Co-efficient - Rainfall vs Yields

	Parameters	**Correlation Coefficient**
Yields	Annual rainfall during harvesting vs Yields for the Spring Crop	-0.2
	Rainfall during harvesting vs yields for the autumn crop	-0.08
	Rainfall during reproductive growth vs yields	0.2
	Rainfall during vegetative growth vs yields	0.08

4.4 Effects of rainfall on rice yields and rice production

Mean rainfall during the three most popular months for harvesting among respondents and yields (bags/acre) for both first and second crops were correlatively assessed for the corresponding periods. The Calculated Pearson's Correlation Coefficient reflected statistically negative weak relationship between rainfall during the harvesting periods and yields (*see table 4-8*). The results suggests that increases in rainfall during harvesting results in lower acreages harvested. As indicated in table 4-8, the correlation coefficient between yields and rainfall during vegetative and reproductive growth stages in both cases returned a weak positive (0.2 and 0.08 respectively)suggesting that higher rainfall during the vegetation and reproductive stages of rice growth results in higher yields – all other factors remaining constant. This relationship was stronger during the reproductive stage emphasizing the need for irrigation during the reproductive growth stage of the plant.

This is supported by literature which indicates that at the onset of panicle initiation i.e. as the plant transitions between the vegetative and reproductive stages and during "active reproduction", water demand is usually critical. Inadequate water supply at this stage affects both productivity and grain fertility (De Datta, 1981). Since water is necessary for the development of grains, the plant is only allowed to produce the number of grains for which water is supplied. Insufficient rainfall will therefore lead to lower numbers of grains per panicle, resulting in lower yields.

Additionally, farmers in Region Six reported that insufficient rainfall during the reproductive stage, resulted in high incidences of paddy bug disease and the

the commencement of the reproductive stage, insufficient rainfall creates the conditions necessary for the proliferation of panicle blast in the rice plant. Infection of the panicle neck node, called neck blast or rotten blast, is believed to be the most destructive symptom of the blast disease. This disease causes the neck of the panicle to break, with subsequent grain shattering, resulting in lower yields.

Incidence of paddy bugs during the grain filling (reproductive) stage is also correlated with inadequate irrigation. Nymphs and adults bugs feed on the endosperm at milk and dough stages, while the adult bugs inject enzyme to predigest cellulose ($C_6H_{10}O_5$) and in the process contaminate the grains with fungus that causes grain discoloration. "Panicles attacked by the paddy bugs result in wind grains, malformation and discoloration. Consequently, there are lower yields, quality and brittleness, which result in increased breakage on milling" (Guyana Rice Development Board, 2016). More than half of the farmers indicated that they were affected by high occurrences of" wind grains".

The regression analysis model accounted for 89-90 percent of the observed variations in yields and total rice production. Rainfall during land preparation and rainfall during the vegetation stage accounted for approximately 94 % of the observed variation in yield. Rainfall during the reproductive and harvesting stages accounted for 0.7 to 7 percent of the variations in yields and production (*see Tables 4-8 and 4-9*).

Table 4-9: Regression Analysis for the Frontlands

	Rainfall during land preparation (r^2)	Rainfall during vegetative growth (r^2)	Rainfall during reproductive growth (r^2)	Rainfall during harvesting (r^2)
Yield (89%)	81.3	17.9	0.2	0.5
Production (87%)	62.3	31.8	5.1	0.7

In the ANOVA Table from the General Linear model analysis for yields, variation in precipitation had an effect on yields, although of the smallest significant influence (0.08%) (*see Table 4-10*). Years, district, and crop accounted for a greater proportion of this variation.

The variation (4%) accounted for by "crop period" is believed to be a result of the differences in length between the first and second crops. Additionally, it is reported that a larger number of farmers sow during the first crop as opposed to the second crop.

Another source of variation in yields was area or district, which was responsible for 19 percent of the variations in yields (Table 4-11). Among the outstanding differences highlighted with respect to districts, was in relation to infrastructure, particularly for irrigation and drainage. Approximately 80 percent of farmers have access to irrigation systems in Region Six. Of these farmers, more than 50% of the respondents reported that many times access to this irrigation resource was restricted. A smaller percentage (~ 10%) of farmers utilised drainage trenches for irrigation whilst the remaining farmers (~10 percent) rely solely on rainfall for irrigation

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Table 4-10: Regression Analysis for Black Bush Polder

	Rainfall during land preparation (r^2)	Rainfall during vegetative growth (r^2)	Rainfall during reproductive growth (r^2)	Rainfall during harvesting (r^2)
Yield (90%)	63	30.7	3.5	2.8
Production (90%)	61.9	30.6	4.8	2.8

Table 4-11: ANOVA for Yields

	Crop Period	Area/ District	Rainfall	Years
Yield	4	19	0.08	76.02

early onset of blast disease. During panicle initiation,

The drainage network includes sluices and mechanical drainage pumps. The mechanical drainage components (system) are designed to accommodate 1.5” of rainfall in 24 hours. Areas with access to gravity drainage, drain at a much lower rate owing to the flat topography of coastal lands. Therefore, areas served by gravity drainage are more prone to flooding. Nevertheless, it is believed that many floods could be abated with better monitoring of sluices by their operators. In many instances sluice gates are opened too late or closed too early resulting in unnecessary accumulation of water on the land.

5 CONCLUSION

The research concluded whilst variability in mean annual rainfall during the period was not statistically significant, 35 percent of the years during the period recorded rainfall above and below the interval +/- one standard deviation from the mean rainfall. These years coincided with “moderate” to “very strong” El Nino and La Nina. Less fluctuations were observed during “weak” El Nino and La Nina years.

Several models accounted for approximately 87-89% of the variations in production, yields, area harvested and area sown in Region Six, Guyana. Therefore the models were able to account for a significant proportion of the variations in production and support the observation that rainfall variability impacts rice production. In all cases the coefficient for rainfall phases were consistently miniscule. The coefficients for area harvested and area sown were negative, suggesting that increases in rainfall during the corresponding months negatively impacts area sown,acreage harvested and yields. The correlation coefficients for yields during the vegetation and reproductive stages were positive which suggests that increases in rainfall during these stages positively impacts yields. Despite weak correlation coefficients were returned, in all cases the results supported observations regarding the relationship between rainfall and each of the parameters tested.

Despite the study establishes a relationship between rainfall and area sown, area harvested and yields, regression and ANOVA models have highlighted that rainfall does not account for 100 percent of the observed variation in these parameters. The study has identified several non-climatic, anthropogenic factors that may account for a proportion of the variation in rice production that is often attributed to rainfall. These includeaccess to and management of irrigation and drainage systems, selected rice varieties and access to equipment.

A small percentage (10-15%) of fluctuations were unaccounted for by the models. This suggests that 10-15 percent of fluctuations in rice productions may be unrelated to rainfall.

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7 APPENDICES

7.1 ANOVA: Single Factor Average Annual Rainfall in Region Six Guyana

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
1988	12	1727.50667	143.95889	12820.25923
1989	12	2069.04424	172.42035	3656.957129
1991	12	1669.275	139.10625	5918.656096
1992	12	1070.72381	89.226984	2289.397472
1993	12	1630.74429	135.89536	3445.00014
1994	12	1517.35143	126.44595	4057.732515
1995	12	1384.80113	115.40009	10464.61168
1996	12	2053.98634	171.16553	18474.20031
1997	12	1318.34702	109.86225	10280.16619
1998	12	1472.6076	122.7173	6734.154828
1999	12	1539.43104	128.28592	5440.246406
2000	12	2197.61729	183.13477	17623.44075
2001	12	1589.78014	132.48168	12104.36521
2002	12	1590.38171	132.53181	7881.38411
2003	12	1244.01937	103.66828	8143.184593
2004	12	1726.7336	143.89447	7252.810892
2005	12	1946.72211	162.22684	8409.368919
2006	12	1964.86505	163.73875	19197.23205
2007	12	2307.56163	192.2968	9960.849153

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	166361.6	18	9242.3138	1.00832565	0.451635	1.65341
Within Groups	1915694	209	9166.0009			
Total	2082056	227				

7.2 Analysis of Variance for regression models

7.2.1 Dependent Variable: Production

The regression equation is

Production = 168 Yield – 2.09 Rainfall – 0.1 Area Sown + 265 Area Harvested

191 cases used 145 cases contain missing values

Predictor Nonconstant	**Coef**	**Stdev**	**t-ratio**	**P**
Yield	168.0	215.9	0.78	0.437
Rainfall	-2.092	3.305	-0.63	0.527
Area Sown	-0.14	48.14	-0.00	0.998
Area Harvested	264.92	60.86	4.35	0.000

S=9255

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	1.65612E+11	41402908672	483.35	0.000
Error	187	16017975296	85657624		
Total	191	1.81630E+11			

Source	DF	SEQ SS
Yield	1	1.63385E+11
Rainfall	1	1447072
Area Sown	1	602668032
Area Harvested	1	1622907008

7.3 Analysis of Variance General Linear Models

7.3.1 Dependent Variable: Bags

Source	DF	Sum of Squares	F Value	Pr> F
Model	67	6823014073078	42.45	0.0001
Error	243	582955283030		
Corrected Total	310	7405969356108		

R-Square0.921286
c.v. 11.06753
Mean Bags 442,551.326

Source	DF	Type III SS	F Value	Pr > F
Rainfall	1	5446025481	2.27	0.1332
Year	19	1892532837636	41.52	0.0001
District / Area	1	1058886012690	441.39	0.0001
Crop	1	56994955021	23.76	0.0001
Production	3	3054944866	0.42	0.7356
Year and Crop	13	1341715505672	43.02	0.0001
Year and Group	14	756775248165	22.53	0.0001