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Assessing flood effects on rice farming and the efficacy of climate-smart practices for agricultural resilience in region 5, Guyana

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Abstract

This study investigates the effects of the 2021 flood on rice farmers in Region 5, with a focus on losses incurred during the end of the first crop and the onset of the second crop of that year. The study also proposes climate-smart agricultural (CSA) strategies to enhance resilience in the region.

Region 5, situated on Guyana's low coastal plain approximately three meters below sea level, is highly vulnerable to natural disasters such as flooding. In May and June 2021, Guyana experienced unprecedented rainfall, resulting in the most severe flood event in over two decades. This flood, classified as Level 3, led to widespread damage in Region 5, including the destruction of crops, livestock, homes, and infrastructure, largely due to overtopped and breached conservancy dams, high tides, and inadequate drainage systems.

Field data were collected using the farmer register provided by the Guyana Rice Development Board (GRDB). Losses were categorized into three primary types: (i) Harvesting Loss, (ii) Sowing Loss, and (iii) Land Preparation Loss. These were verified by a technical team from the Ministry of Agriculture, including GRDB Extension Officers. Results showed that June 2021 recorded over 500 mm of rainfall, leading to catastrophic flooding. The greatest losses occurred in the sowing category, with 6,932 acres affected across 187 farmers. This was followed by land preparation losses (3,516 acres; 53 farmers) and harvesting losses (2,137 acres; 53 farmers). The total estimated economic loss amounted to GYD $668,885,000.

Given the increasing risks posed by climate change, the adoption of climate-smart agricultural practices is critical. Recommended strategies include: eliminating the burning of paddy straw, cultivating flood-tolerant rice varieties, and adhering strictly to GRDB agronomic guidelines.

Keywords: Climate change, climate-smart practices, flooding, impact, paddy, harvest, sowing, land preparation, resilience

1. Introduction

Disasters are often conceptualized as the result of an interaction between extreme environmental phenomena and vulnerable human populations. This perspective underscores the critical role of socio-economic and political conditions in shaping human vulnerability and determining the extent to which populations are affected by environmental hazards [31]. Over the past four decades, natural hazards including droughts, floods, storms, tropical cyclones, and wildfires, have led to substantial human casualties and losses in livelihoods, in addition to severe damage to economic infrastructure, social systems, and the environment [22].

The economic toll of natural disasters has escalated significantly, with costs increasing approximately fourteen-fold since the 1950s. Globally, the annual financial burden attributed to such disasters is estimated at between US$50 billion and US$100 billion. In China alone, data from the Ministry of Civil Affairs indicate an average annual loss of approximately US$12 billion, with an estimated 200 million individuals affected each year. Projections suggest that by 2050, natural disasters could claim up to 100,000 lives annually and result in global economic losses exceeding US$300 billion per year [20].

Global land use patterns reveal that about 70% of land is allocated to agriculture, forestry, and rangelands, with 12% used for arable and permanent crops, 31% for forests and woodlands, and 27% for permanent pasture [30]. Nations worldwide have experienced significant economic repercussions due to natural disasters. For instance, in 2017, economic losses from natural disasters totaled approximately US$210.1 billion (49% above the historical average) according to the Centre for Research on the Epidemiology of Disasters [2].

The increasing frequency and intensity of extreme weather events, driven by global climate change, now pose serious threats to global agricultural systems. Anthropogenic climate change has already had measurable negative effects on crop production. Between 1961 and 2017, global warming linked to human activities has led to an average decline of 5.3% in yields of three major staple crops, mainly: maize (5.9%), wheat (4.9%), and rice (4.2%) [28].

Moreover, the annual impact of various natural disasters has shown an upward trajectory. Arid zones have expanded globally over the past 60 years and are projected to increase by 10% by the end of the 21st century compared to the 1961 to 1990 baseline [10]. Droughts alone account for nearly half of all losses associated with climate-related disasters [44].

China, due to its extensive and varied topography, is particularly susceptible to natural hazards. From 1990 to 2018, the Asia-Pacific region experienced an increase in flood events, with China among the most severely impacted countries [21]. Approximately 69% of China's land area is mountainous or hilly, where nearly 45% of the population resides. In addition to climate-induced events, geological hazards such as earthquakes and landslides have inflicted considerable damage, a situation exacerbated by increasingly frequent tectonic activity. Vulnerable populations, especially those in poverty, bear the brunt of these disasters [39]. These adverse effects have been especially pronounced in underdeveloped regions, where future climate change is projected to intensify the challenges, undermining sustainable development [26].

In recent decades, the global scientific community has placed growing emphasis on the consequences of human-induced climate change. Of particular concern are the impacts on food security and agricultural productivity, including access to, availability of, and stability in food prices [8]. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) confirmed with high confidence the detrimental effects of climate change on crop yields. Agriculture is acutely sensitive to climatic variations, which include fluctuations in average conditions across spatial and temporal scales beyond individual weather events. Notable drought events in 1997 and 2016 exemplify how climate variability manifesting as floods, droughts, or storms, can severely disrupt national economies that depend heavily on climate-sensitive sectors [18].

In many parts of the world, agriculture is already under pressure due to rising temperatures, more variable precipitation, prolonged dry spells, intensifying extreme weather events, rising sea levels, and the salinization of arable soils and freshwater resources. These factors collectively threaten the viability of traditional agricultural practices, forestry, and fisheries, necessitating urgent adaptation strategies [19].

In the context of Guyana, the country's geographical coordinates, approximately 5°N latitude and 59°W longitude, place it just north of the equator. Its climate is characterized by two distinct rainfall regimes: the northern coastal zone influenced by maritime conditions, which experiences bimodal rainfall peaks, and the more continental Rupununi Savannahs in the southwest, which exhibit a single wet and dry season. The country experiences two primary rainy seasons from November to January and from May to July, and two dry seasons, typically occurring between September to October and February to March. The average annual rainfall is approximately 1,890 mm, among the highest in the Caribbean region.

According to the United Nations Framework Convention on Climate Change (UNFCCC), Guyana is expected to experience increased rainfall and rising temperatures during its rainy seasons. Given that the Coastal Plain lies roughly three meters below sea level, the country's agricultural activities are particularly vulnerable to spatial and temporal variations in precipitation [15].

In May 2021, Guyana experienced higher than normal levels of rainfall across the country. This led to what was described as the worst flooding in Guyana for over 20 years. In June 2021, it was reported that all communities across Guyana were severely affected included communities in Region 5. The flood caused damage to homes, loss of crops and livestock, displacement of families and damage to buildings. The flood occurred due to continuous heavy rainfall which resulted in the overtopping or breach of conservancy dams which was compounded with high tides and poor drainage capacity.

Most of Guyana's agricultural activities take place on its Coastal Plain where it is approximately 3 meters below sea level and is vulnerable to natural disaster such as flood, therefore, the findings of this study will highlight the impact of flood on cultivated rice in the villages of Region 5. The study will discuss the use of Climate Smart Agriculture Practices for Resilience in the Region.

The general aim of this study was to determine the impact of flood on cultivated rice and the use of climate smart agriculture practices for resilience in Region 5, Guyana. The specific objectives which guide this study are as follow: (1) To determine the economic and social impact of flood on cultivated rice in Region 5, Guyana. (2) To use climate smart agriculture practices in rice cultivation in Region 5, Guyana.

1. 2. Methodology

2.1 Study location

The present study is geographically centered on Region 5 (Mahaica-Berbice), as illustrated in Figure 1. This administrative region is located along the northern coast of Guyana, bounded by the Atlantic Ocean to the north, East Berbice-Corentyne (Region 6) to the east, Upper Demerara-Berbice (Region 10) to the south, and Demerara-Mahaica (Region 4) to the west. Geographically, Region 5 spans from the eastern bank of the Mahaica River to the western bank of the Berbice River, encompassing a total area of approximately 1,472.47 square miles (3,813.67 square kilometers). The region is characterized by three major physiographic zones: The Low Coastal Plain, the Hilly Sand and Clay Belt, and the Hinterland Forested Region. With an estimated population of 50,000 inhabitants, Region 5 plays a critical role in Guyana's agricultural sector, being the largest rice-producing area in the country. More than 110,000 acres of land are under rice cultivation, with cropping occurring biannually.

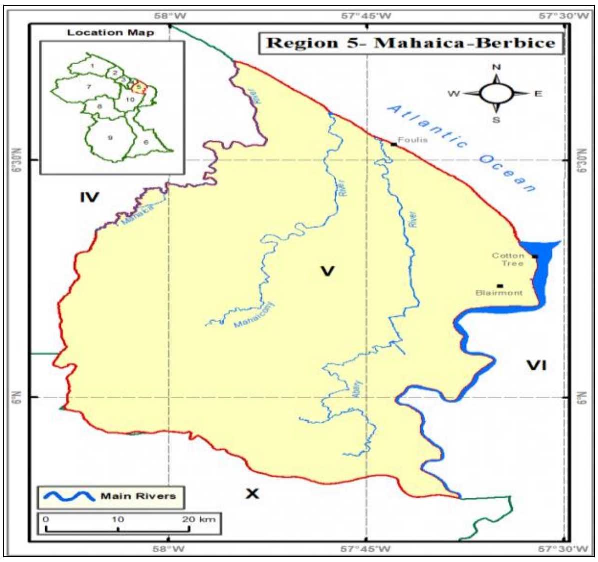

Fig 1: Location of study: region 5 (Mahaica-Berbice)

2.2 Data collection

2.2.1 Farmers register

The farmers' register was obtained from the Guyana Rice Development Board and was used to ascertain the farmers in Region 5 who were affected by the 2021 flood. The Farmer's Register is the main tool used in this study, it is a document that contains information and statistical results of a farmer such as location of the farm, ownership information, information on the farming activities and production quantities, among others [13].

2.2.2 Harvesting data

Harvesting refers to the process of gathering mature rice crops from the field and can be performed either manually, using tools such as sickles and knives, or mechanically, employing equipment like threshers or combine harvesters. Key activities involved in paddy harvesting include cutting, stacking, handling, threshing, cleaning, and transportation. Irrespective of the method employed, it is critical to maintain optimal grain quality and minimize post-harvest losses during these operations. The implementation of appropriate harvesting techniques is essential to maximize grain yield while reducing physical damage to the grains and preventing deterioration in quality [13].

2.2.3 Land preparation data

Effective land preparation is a critical agronomic practice to optimize rice field conditions for planting. Properly prepared fields facilitate weed suppression, promote nutrient recycling, and create a friable soil matrix conducive to transplanting or a level surface ideal for direct seeding. The spectrum of land preparation techniques ranges from zero or minimal tillage, aimed at reducing soil disturbance, to intensive puddling, which disrupts soil structure to enhance water retention. Initial preparatory activities typically commence after the previous harvest or during the fallow period, serving both to enhance soil fertility and to manage weed populations. The standard sequence of operations generally includes: (1) ploughing to till, aerate, and invert the soil; (2) harrowing to disintegrate soil clumps and incorporate organic residues; and (3) wet harrowing, raking, and leveling under flooded conditions to create a uniform seedbed [13].

2.2.4 Sowing data

Broadcasting refers to the uniform distribution of pre-germinated seeds over a well-prepared field, typically carried out manually or using aircraft. This is followed by water release into the field approximately three days post-sowing. Timely sowing in a properly prepared field facilitates rapid and uniform crop establishment, which enhances yield potential and improves competitiveness against weeds, pests, and other biotic stressors. The optimal sowing period is influenced by several factors, including geographical location, cultivar characteristics, climatic conditions, water availability, and the anticipated harvest schedule. Additionally, synchronized planting within a two-week timeframe across adjacent fields is recommended to reduce the incidence of insect pests, diseases, avian predation, and rodent damage [13].

2.2.5 Categories of data collected from farmers

The following are some categories of data collected by farmers:

1. Data on Harvesting loss of paddy for the first crop of 2021 [13].
2. Data on sowing loss of paddy for the second crop of 2021 [13].
3. Data on land preparation but did not sow paddy for the second crop 2021 [13].

The data on losses for the various categories were verified by using the farmer's register after the flood waters had receded from the rice fields and dams were accessible. The verification team consisted of extension officers and technical personnel from various Governmental and Non-Governmental bodies [13].

Data were collected from affected farmers of each category through various means such as field visit, face to face contact, telephone conversation, contact farmers, drone images etc.

2.2.6 Data analysis

The collected data were verified by the various Governmental agencies then they were tabulated according to Villages in the Region to show the number of farmers, acreage loss (by acre) and the value of loss. These data were tabulated and then placed on graphs and tables using Microsoft Excel 2016.

3. Results and Discussion

3.1 Global rice production

Rice is the most widely produced crop on the planet, ranking second only to wheat in terms of harvested area [33]. India and China have the largest rice-growing areas, with 39.6% and 36.0% respectively. According to the FAO (2013) [9], Africa produces a significant amount of rice, about 15.08 million tons on an area of 10.23 million acres, accounting for roughly a third of the world's total rice production. Rice is necessary for human nutrition since it is a significant source of carbohydrates and, also contributes protein to the diet. Rice has 6.8% protein, 78.2% carbohydrates, 0.5% fat, and 0.6% mineral content, hence it is generally utilized as a staple food [34]. Over half of the world's population relies on the crop to supplement their diet. China and India are the two leading producers, accounting for more than half of the global total, with just over ten (10) countries responsible for 85% of global rice production; except for Brazil (all the other leading producers are based in Asia).

In developing countries, the agriculture sector absorbs 23% of the total damage and losses. Between 2005 and 2014, approximately USD $93 billion was lost in crop and livestock production due to natural hazards and disasters. The number and frequency of recorded natural disasters, along with the associated impact and damage to livelihoods and economies (local and national), are increasing significantly. Natural disasters often destroy critical agricultural assets and infrastructure, disrupting production cycles, trade flows and livelihoods means. This affects food security and causes additional disruptions throughout the value chains. Such disasters may slow overall economic growth, especially where agriculture and food production still account for a large share of gross domestic product and employment [7].

Historically, Guyana earned the designation of the “breadbasket of the Caribbean” due to its substantial production of rice and sugarcane, which supported both domestic consumption and export. Agriculture remains a cornerstone of Guyana’s economy, with most activities concentrated within the Low Coastal Plain, an area that comprises approximately 5% of the nation’s total landmass. Among agricultural commodities, rice holds particular prominence; it is produced locally for domestic consumption and represents the leading export crop on international markets.

The cultivation of rice in Guyana dates back to the early 18th century when it was introduced by Dutch settlers. In 1738, the Dutch Governor of Essequibo, Laurens Storm van Gravesande, officially introduced rice cultivation to supplement the diets of enslaved laborers on sugar estates. Since then, rice has evolved into the most vital component of the nation’s agricultural sector.

Currently, rice production constitutes the largest agricultural industry in Guyana, forming a critical foundation of the national economy and serving as a staple food for the population. The sector plays a significant role in sustaining rural livelihoods, with over 170,000 families deriving direct or indirect benefits from rice-related activities. Notably, paddy production has shown a marked increase over the past decade, peaking in the First Crop of 2019 with a record output of 525,649 metric tonnes at an average yield of 6 tonnes per hectare.

3.2 Challenges for rice cultivation in Guyana

Over the past three to four cropping cycles, rice cultivation on Leguan Island has witnessed a significant decline, with many fields being abandoned due to increasingly erratic weather patterns. The traditional practice of rice farming has become progressively challenging, compelling many farmers to seek alternative livelihoods. These difficulties, primarily linked to climatic instability, have introduced a high degree of uncertainty in agricultural planning, as farmers are unable to predict future conditions with confidence. The prevailing perception among the farming community attributes these changes to climate change. Persistent and unseasonal rainfall has led to frequent crop failures, placing numerous farmers in financial distress [13].

In response to these challenges, younger farmers in particular have begun to diversify their income sources. Some have transitioned to livestock and cattle rearing, converting previously cultivated rice lands into pasture. Others have adopted intercropping practices, such as planting bananas alongside rice, in an effort to mitigate crop losses. Similar trends have been observed in Berbice, specifically in Regions Five and Six, regarded as two of the country's major rice-producing zones, which have also experienced reduced productivity due to unfavorable weather conditions. According to the President of the Guyana Rice Producers Association (GRPA), the sector has recorded some of its lowest yields in recent years, primarily due to excessive rainfall [13].

In Berbice, persistent and unusually intense rainfall over the past three years has hindered timely land preparation, thereby disrupting planting schedules. The resultant waterlogged conditions have prevented many farmers from harvesting their crops or preparing the land for subsequent cycles. Traditionally, rainfall in the months of April and October is not typical; however, in recent years, precipitation during these periods has become frequent and prolonged. This shift in climatic conditions has led to a marked reduction in rice production. For instance, in the first crop of 2021, only 180,000 acres out of a total of 235,000 acres were cultivated, as reported by the GRPA [13].

The severity of the weather in early 2021 left many farmers unable to reinvest in their fields due to financial constraints, further compounding the decline in production. Moreover, rice millers have encountered challenges in maintaining existing markets or securing new ones, as uncertainties in supply affect contractual obligations. Although certain rice varieties, such as GRDB15 and G98-196, exhibit greater resilience to climate-related stressors, many farmers continue to prefer high-yielding cultivars like GRDB16 and GRDB10, despite their lower tolerance to adverse climatic conditions [13].

3.3 Impact of floods on the agriculture sector in Guyana

One of the most significant flood events in Guyana’s recent history occurred in January 2005, impacting approximately 275,000 individuals, an estimated 37% of the national population and resulting in economic losses valued at USD 465 million, equivalent to 60% of the national GDP. Intense and prolonged rainfall led to elevated water levels within the East Demerara Water Conservancy (EDWC), approaching the critical breach threshold of 18 meters. A breach of this magnitude would have posed a catastrophic risk to the structural integrity of the dam wall.

A comprehensive socio-economic assessment of the 2005 flood revealed widespread damage, particularly within the agricultural sector. The most affected administrative areas included Regions 3 (West Demerara/Essequibo Islands), 4 (Demerara/Mahaica), and 5 (Mahaica/West Berbice), with Region 4 alone accounting for 55% of total losses, followed by Region 2 (23%) and Region 5 (19%). Substantial damage was recorded across key agricultural subsectors, including sugarcane, rice, livestock, and a wide range of crops such as fruits, vegetables, tubers, and herbs. This event acted as a catalyst for national reforms, prompting the implementation of proactive strategies and policy frameworks focused on vulnerability reduction, many of which were developed in collaboration with international development partners.

Since the 2005 disaster, Guyana has experienced several additional extreme rainfall events resulting in significant flooding in the years 2006, 2008, 2010, 2011, 2013, 2014, 2015, and 2021. According to the United Nations International Strategy for Disaster Reduction (UNISDR), the floods of 2006 and 2008 affected approximately 135,000 people, with cumulative economic damages from the 2006 and 2010 events reaching USD 183.7 million. Historical records indicate the occurrence of approximately 834 emergency and disaster events since April 1973. Flooding in Guyana is typically triggered by a combination of high-intensity precipitation, riverine overflow, sea swells, overtopping or failure of sea defenses and conservancy dams, and synergistic effects of high tides and rainfall [37].

Data from a Human Services Organization indicate that the May-June 2021 floods impacted over 29,300 households across more than 300 communities. Rainfall in May 2021 alone was recorded as the second-highest in the country over the past four decades. Guyana experiences a bimodal rainfall regime, with a long wet season from April to August and a shorter wet season spanning December to early February. However, in southern regions such as the Rupununi (Region 9), the short wet season is often absent. Annual precipitation averages approximately 90 inches (2,290 mm) in Georgetown and 70 inches in the Rupununi Savannas.

Climatic variability in Guyana is strongly influenced by the hydrological behavior of large tropical river systems, notably the Amazon and Orinoco Rivers. These fluctuations affect not only precipitation patterns but also tropical agricultural productivity and economic activities. Unlike some regional counterparts, Guyana's contribution to deforestation remains minimal, ranking among the lowest globally [25]. The majority of Guyana's population resides along a narrow coastal strip, which is situated between the Atlantic Ocean to the north and inland water retention systems such as the conservancies to the south. This coastal belt is protected by sea defenses and 10-12-foot-high dykes, which enclose extensive floodplains that serve as critical water reservoirs during the dry season [40].

From December 2020 onward, Guyana has experienced persistently excessive rainfall with little to no interruption between the major and minor wet seasons. Meteorological projections anticipate that these atypical precipitation patterns will persist through August. As of late May 2021, sustained rainfall has led to widespread inundation of coastal areas, including the capital, Georgetown, as well as interior regions such as Pomeroon and Bartica, where riverine flooding has occurred. The severity of flood impacts varies across administrative regions: Regions 1, 3, 4, 8, and 9 are classified as Level 2 (moderate impact with limited coping capacity), while Regions 2, 5, 6, 7, and 10 are classified as Level 3 (severe impact with inadequate coping mechanisms).

Region 5 is home to the Mahaica-Mahaicony-Abary (MMA) Conservancy, constructed in 1985 by partially damming a floodplain situated between the Mahaicony and Berbice Rivers. This is the largest conservancy in the country, with a storage capacity of 609 million cubic meters (hm³) and covering a reservoir area of 808 km². The MMA Conservancy constitutes Phases 1 and 4 of the Mahaica-Mahaicony-Abary Agricultural Development Authority (MMA/ADA) project, which was designed to enhance agricultural productivity through improved irrigation and drainage infrastructure. Upon completion of Phases 2 and 3, the system will support over 450,000 acres of agricultural land. Currently, the MMA/ADA region contributes approximately 50% of national rice production, 30-35% of livestock production (primarily cattle), and 10-15% of national sugar output [36].

3.4 Economic and social impact of flood on cultivated rice in region 5

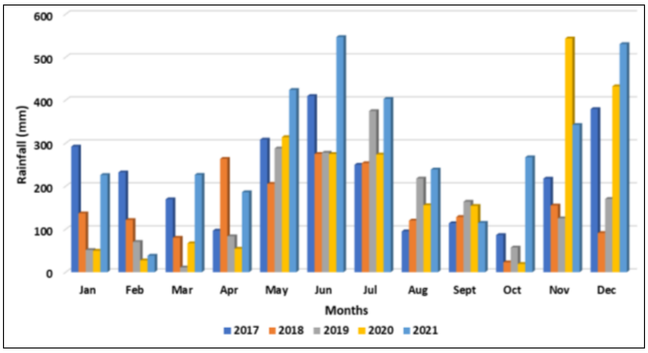

Fig 2: Rainfall for the coastal regions of Guyana from 2017 to 2021

In Guyana there are two rainy seasons for the year, May/June and November/December. The data represented on Figure 2 revealed that majority of rainfall from 2017 to 2021 occurred during the two rainy seasons. In the first rainy season the rain starts off in April, peaks in June and ends off in July/August, while the second rainy season starts off in November, peaks in December and ends off in February the following year. In the year 2021 the highest amount of rainfall occurred in the month of June with over 500 mm.

Since December 2020, Guyana has experienced unusually high levels of rainfall, with no discernible dry period between the June rainy season and the typically shorter wet season, which generally concludes in February. Meteorological forecasts indicate that these atypical and intense precipitation events are likely to persist until at least August. Beginning in late May, persistent heavy rainfall led to widespread flooding across the coastal regions, including Region 5. In the hinterland, areas such as the Pomeroon and Bartica also received substantial rainfall, contributing to elevated water levels in major river systems, including the Pomeroon, Cuyuni, and Mazaruni rivers. The extent and severity of flooding varied by region. Based on national assessments, the flooding in Regions 1, 3, 4, 8, and 9 was categorized as Level 2, indicating moderate impact, whereas Regions 2, 5, 6, 7, and 10 were designated as Level 3, reflecting more severe and widespread inundation.

Table 1: Paddy losses at harvesting stage

Rank	Villages	Number of Farmers	Paddy Loss (Ac)	Avg. Loss (Ac)	Value (GYD$) (Million)
1	Abary Creek	14	619	44.2	49,520,000
2	Von Better	5	369	73.8	15,520,000
3	Tiger Ranch	6	283	47.2	22,640,000
4	Hopetown	10	151	15.1	12,080,000
5	Pine Ground	5	151	30.2	12,080,000
6	First Savannah	5	127	25.4	10,160,000
7	Easu & Jacob	3	117	39.0	9,360,000
8	Macouba	6	115	19.2	9,200,000
9	Water Dog Creek	2	80	40.0	6,400,000
10	Cottage	3	63	21.0	5,040,000
11	Wash Clothes	3	27	9.0	2,160,000
12	Little Biaboo	1	19	19.0	1,520,000
13	Quackoo Dam	2	16	8.0	1,280,000
Total		65	2137	32.9	156,960,000

As depicted on Table 1, in the first crop of 2021, harvesting usually commence around the middle of March and ends around the first week in May. The data in the table above show that sixty-five (65) farmers' loss their paddy at the harvesting stage which accounted for two thousand one hundred and thirty-seven (2,137) acres. Most of the paddy loss during the harvesting stage came from Abary Creek which amounted to fourteen (14) farmers and six hundred and nineteen (619) acres. Villages such as Von Better and Tiger Ranch are considered to be remote areas and are mostly consisted of large scale farmers, the data showed that for both villages there were eleven (11) farmers who loss six hundred and fifty-two (652) acres of paddy during the harvesting stage. Villages such as Wash Clothes, Little Biaboo and Quackoo Dam had little loss mainly because most of the farmers in those areas would have harvested their paddy on time. The total loss at the harvesting stage has an economic value of one hundred and fifty-six million nine hundred and sixty thousand Guyana Dollars (GYD $156,960,000).

Table 2: Paddy losses at sowing stage

Rank	Villages	Number of Farmers	Paddy Loss (Ac)	Avg. Loss (Ac)	Value (GYD$) Millions
1	Tiger Ranch	8	1591	198.9	38,915,000
2	Little Biaboo	17	583	34.3	37,895,000
3	Abary Creek	17	577	33.9	37,505,000
4	Bush Lott	9	539	59.9	35,035,000
5	Bara Bara	7	499	71.3	22,935,000
6	Hope Town	3	470	156.7	21,950,000
7	Wash Clothes	19	408	21.5	21,570,000
8	Mortice	7	382	54.6	24,430,000
9	New Providence	5	296	59.2	19,240,000
10	Third Point Abary	7	254	36.3	16,510,000
11	Champagne	11	211	19.2	13,715,000
12	Pine Ground	3	210	70.0	13,650,000
13	Handsome Tree	8	140	17.5	9,100,000
14	De Hoop	17	132	7.8	8,580,000
15	Strathcampbell	9	122	13.6	7,930,000
16	Easu & Jacob	7	108	15.4	7,020,000
17	Big Biaboo	3	107	35.7	6,955,000
18	# 10 Village	13	87	6.7	5,655,000
19	Libion	3	70	23.3	4,550,000
20	First Point Abary	3	44	14.7	2,860,000
21	#28 Village	1	25	25.0	1,625,000
22	Flora Garden	2	23	11.5	1,495,000
23	Ranch Dam	2	18	9.0	1,170,000
24	Foulis	2	16	8.0	1,040,000
25	Quakoo Dam	3	14	4.7	910,000
26	# 41 Village	1	6	6.0	390,000
Total		187	6932	37.1	362,630,000

As shown in Table 2, in the second crop of 2021, broadcasting (sowing) of paddy usually commences around the middle of May and finish at the end of June. Although a substantial amount of water is required for land preparation, sowing and establishment of the paddy crop (rice crop), if it is not managed in a timely manner, farmers are likely to lose the crop at an early stage. In the table above a total of six thousand nine hundred and thirty-two (6,932) acres of paddy sown were loss for the second crop 2021 due to the flood. Tiger Ranch which is considered to be a remote area, consisted of large scale farmers and a total of one thousand five hundred and ninety-one (1,591) acres among five (5) farmer's loss their paddy at the sowing stage. Although areas such as Bara Bara, Hope Town and Mortice had small numbers of farmers, these areas were ranked 5, 6 and 8 respectively in the table with regards to the acreage loss. Villages that ranked from 21 to 26 in the table had minimal loss because they are located closer to the sea and had rapid drainage. The total loss at the sowing stage has an economic value of three hundred and sixty-two million six hundred and thirty thousand Guyana Dollars (GYD $362,630,000).

Table 3: Land prepared but did not sow

Rank	Villages	Number of Farmers	Land Prepared but Not Sow (Ac)	Avg. Loss (Ac)	Value (GYD$) Millions
1	Bush lot	11	528	48	23,760,000
2	Onverwagt	6	512	85	23,040,000
3	Von Better	1	400	400	10,000,000
4	Mortice	8	334	42	15,030,000
5	Foulis	4	320	80	14,400,000
6	Tiger Ranch	3	315	105	13,375,000
7	Bara Bara	3	295	98	13,150,000
8	Big Biaboo	2	250	125	11,250,000
9	Wash Clothes	5	199	40	8,955,000
10	Weldad	3	129	43	5,805,000
11	Gordon Table	2	126	63	5,670,000
12	Pine Ground	3	55	18	2,475,000
13	De Hoop	2	53	27	2,385,000
Total		53	3516	66	149,295,000

Land preparation is important to ensure that the rice field is ready for planting. This includes (i) ploughing (till) or dig-up, mix, and overturn the soil; (ii) harrowing to break the soil clods into smaller mass, and (iii) harrow the soil in water, rake and leveling the field. As displayed on Table 3, the second crop of 2021, a total of three thousand five hundred and sixteen (3,516) acres of rice land were prepared by fifty-three (53) farmers. However, due to the intense flood during that period, these farmers could not have proceeded to sow their paddy, as such this was considered as a loss for them. The data from the table above shows that Bush lot village has the highest acreage with five hundred and twenty-eight (528) acres of land prepared but didn't sow with eleven (11) farmers. This was followed by Onverwagt village with five hundred and twelve (512) acres prepared but did not sow with six (6) farmers. Von Better which is a remote area had one farmer who prepared four hundred (400) acres but couldn't sow it due to the persistent flood. Although Tiger Ranch had 3 farmers who prepared their land for sowing it ranked 6 out of 13 because of its large acreage prepared (315 acres). The total loss in this category has an economic value of one hundred and forty-nine million two hundred and ninety-five thousand Guyana Dollars (GYD $149,295,000).

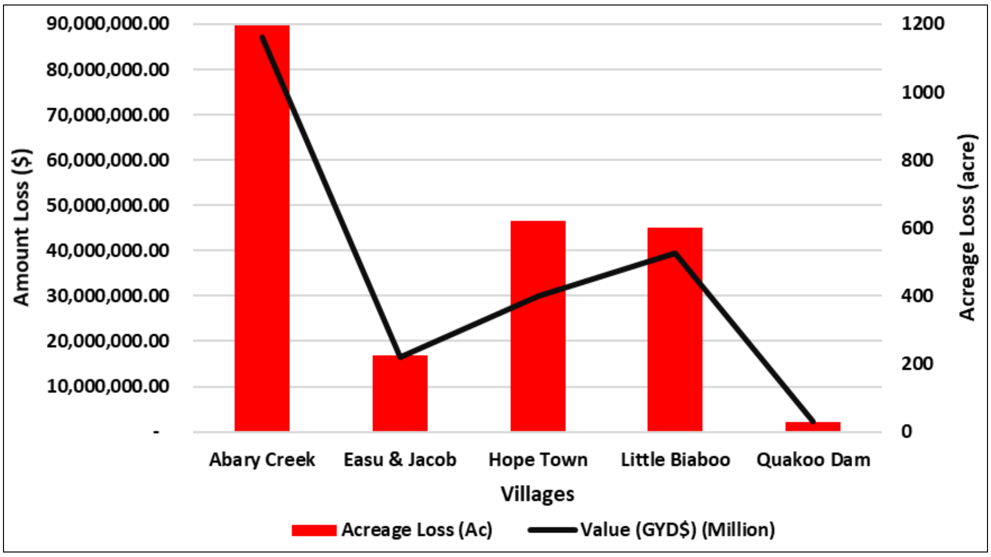

Fig 3: Combination of harvesting and sowing losses (acre)

During the flood there are farmers who loss paddy in more than one category. Figure 3 above is showing a total of seventy-seven (77) farmers loss paddy during the harvesting and sowing stage which sums up to two thousand six hundred and seventy-four (2,674) acres. Figure 3 further revealed that Abary Creek had most losses from both categories (1,196 acres' loss) followed by Hope Town with 621 acres' loss then Little Biaboo with a total of 602 acres. The total loss for both categories have an economic value of one hundred and seventy-five million and forty thousand Guyana Dollars (GYD $175,040,000).

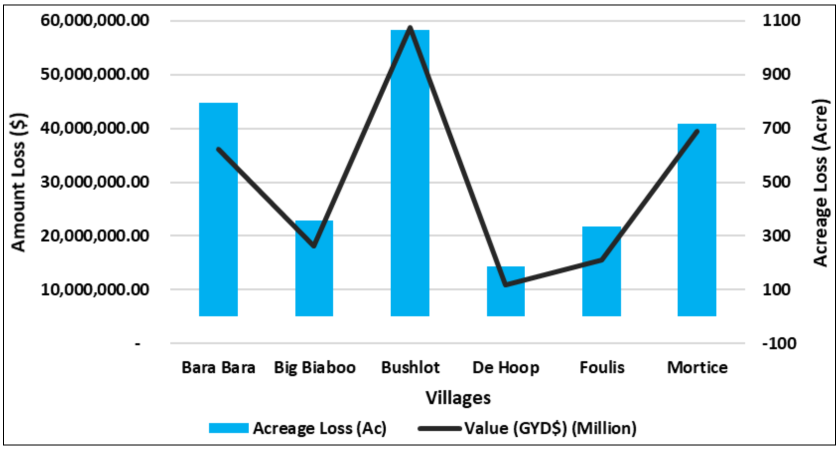

Fig 4: Combination of sowing and land preparation losses (acre)

Figure 4 above shows farmers who lost their paddy after sowing and farmers who prepared their land for sowing but couldn't sow due to the flood. Bush lot village was mostly affected in both categories with a total of one thousand and sixty-seven (1,067) acres followed by Bara Bara village with a total of seven hundred and ninety-four (794) acres been affected. De Hoop village was least affected in both categories with only one hundred and eighty-five (185) acres been affected. The total loss for both categories have an economic value of one hundred and seventy-eight million nine hundred and fifty thousand Guyana Dollars (GYD $178,950,000).

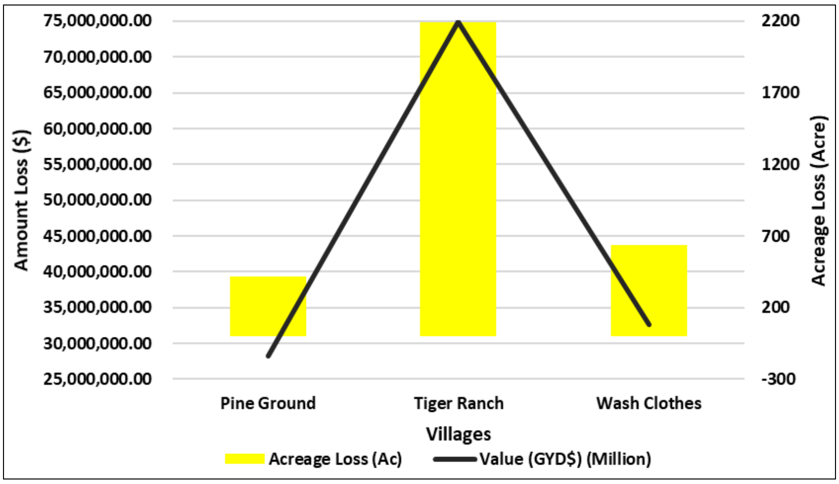

Fig 5: Combination of harvesting, sowing and land preparation losses (acre)

Figure 5 above show the villages where there were losses in all three categories that is harvesting, sowing and land preparation. In this combination, Tiger Ranch was reported to have majority of the losses with a total of two thousand one hundred and eighty-nine (2,189) acres followed by Wash Clothes with a total loss of six hundred and thirty-four (634) acres then followed by Pine Ground. The total loss for all three categories has an economic value of one hundred and thirty-five million eight hundred and twenty thousand Guyana Dollars (GYD $135,820,000).

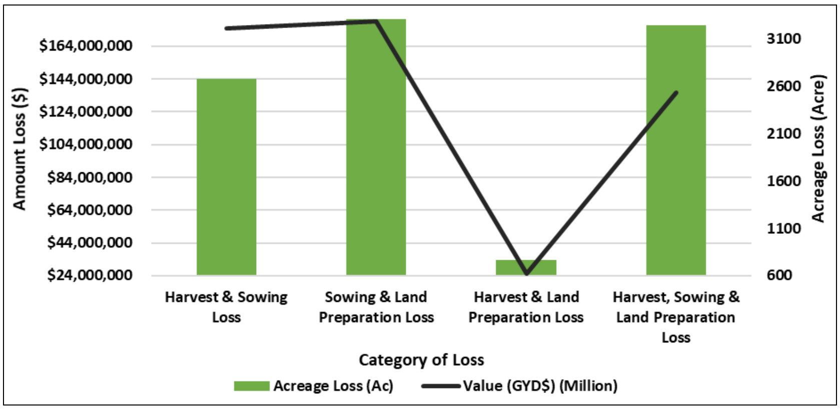

Fig 6: Total acreage loss from the various combination of categories

Figure 6 above highlights the total acreage loss from the various combination of categories. Sowing and land preparation loss was recorded to be the most with a total of three thousand four hundred and fifty-five (3,455) acres. This was followed by harvesting, sowing and land preparation loss with a total of three thousand two hundred and thirty-nine (3,239) acres. Harvesting and land preparation loss was recorded to be the least with a total of seven hundred and sixty-nine (769) acres. These various combinations of the different categories of acreage loss have an economic value of five hundred and fifteen million three hundred and thirty thousand Guyana Dollars (GYD $515,330,000).

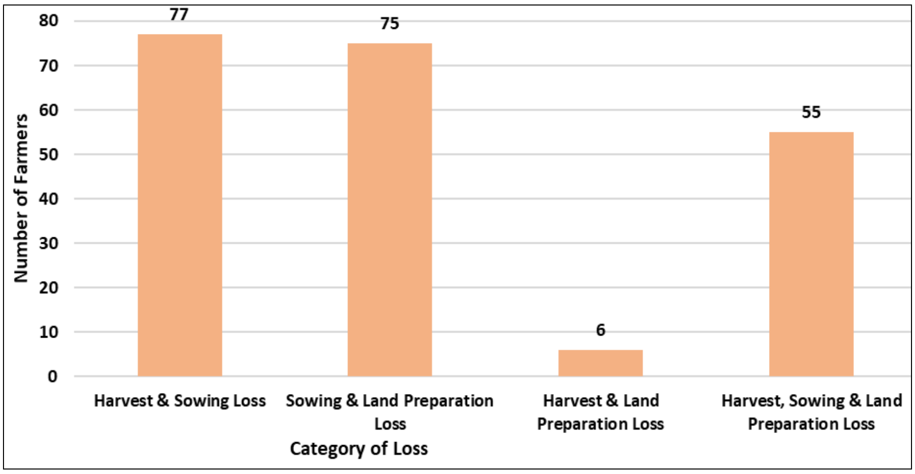

Fig 7: Number of farmers' experience losses from the various categories

Figure 7 above shows a total of two hundred and thirteen (213) rice farmers experienced losses in the various combinations of the different categories. A total of seventy-seven (77) rice farmers experienced losses at harvesting and sowing, while a total of seventy-five (75) of them experienced losses at sowing and land preparation. The combination of all three categories, a total of fifty-five (55) rice farmers experienced losses, while only six (6) of them experienced losses at harvesting and land preparation.

3.5 Global trend of climate related challenges

In 2020, Ethiopia encountered multiple climate-induced challenges, notably desert locust infestations and extensive flooding. The desert locust outbreaks primarily affected the northeastern regions, including Tigray, Wollo, and Afar, as well as the southeastern zones such as Dire Dawa and Hararghe. Concurrently, continuous heavy rainfall led to significant flooding across the Fogera plain, a key rice-producing area, and low-lying parts of the Afar region. Between June and September, the Fogera plain experienced severe inundation resulting from the overflow of the Rib, Gumara, and other tributaries feeding into Lake Tana and the Abay (Blue Nile) River.

The flooding in Fogera was exacerbated by several structural and management deficiencies, including: (i) poor maintenance and regulation of irrigation channels; (ii) the absence of flood-control infrastructure within the districts of the plain; and (iii) the lack of integrated watershed management strategies such as afforestation, terracing, and other upstream flood mitigation measures. Furthermore, inadequate flood-risk assessment and emergency response planning contributed to the scale of damage. Approximately 16,000 farming households were impacted, with an estimated 9,000 hectares of agricultural land submerged. According to local agricultural and disaster response authorities, the affected households can be categorized into two groups: those who lost both their homes and agricultural fields (including rice and other crops), and those whose losses were limited to farmland [1].

In Pakistan, a major producer of rice and cotton, severe monsoon rains and flooding have similarly devastated agricultural systems. These events have not only damaged current crop yields but also pose a significant threat to the upcoming wheat planting season, particularly in the context of already constrained global wheat supplies. The 2022 floods, the worst in over two decades, have resulted in the deaths of over a thousand individuals and displaced millions. Damage to key export crops has diminished food availability and foreign exchange earnings, increasing the need for food imports and placing further strain on global commodity markets. Data from Gro's Climate Risk Navigator for Agriculture indicates that cumulative rainfall between June 1 and August 30 was 161% above the 10-year national average [14].

As a result of the floods, Pakistan's rice production for the 2022-2023 marketing year was revised downward to 8.3 million metric tons, significantly lower than the previous year's 9.1 million tons. Export projections were also adjusted, with 2021-2022 exports estimated at 4.5 million tons (a record), and a slight reduction to 4.2 million tons for 2022-2023. Despite the natural disaster, rice exports in the first half of 2022 expanded across traditional markets, including Africa, the Gulf States, and the European Union, with China experiencing the highest growth. Domestic rice consumption is projected to increase to 4.3 and 4.6 million tons for 2021-2022 and 2022-2023, respectively, due to post-pandemic resurgence in social gatherings. However, the 2023-2024 wheat planting season is expected to be adversely affected by the floods [38].

Similarly, Thailand's rice sector has suffered from flood-related disruptions during the 2022-2023 marketing year. The U.S. Department of Agriculture's Foreign Agricultural

Service (FAS) reported a slight decline in expected rice output from 20 million to 19.9 million metric tons, primarily due to flooding in the northeastern provinces. Typhoon Noru, which struck on September 29, triggered extensive flooding in the Chao Phraya, Chi, and Mun River basins, impacting approximately 84,998 hectares of main-season rice crops, about 18% of the total planted area. While the Chao Phraya basin experienced limited damage due to early harvesting, rice fields in the Chi and Mun basins, still in critical reproductive and ripening stages, are being closely monitored for further losses [38].

In India, the rice-growing season typically begins before the monsoon in June and continues through the harvest in September. India produces roughly 90 million tons of rice annually, including 4 million tons of Basmati. The eastern region contributes nearly one-third of this output. By August 17, 2022, rice cultivation had reached 27.84 million hectares, slightly below the 28.13 million hectares reported during the same period in the previous year. Nevertheless, monsoon-related flooding inflicted significant damage on rice and maize crops, particularly in eastern India. In Punjab, an estimated 139,000 hectares (approximately 5% of the total 3 million hectares) of paddy fields were affected due to excessive rainfall in September 2022. Similarly, in Haryana, unseasonal rains impacted nearly 20% of the 1.3 million hectares under paddy cultivation [17].

Brazil is also facing considerable climate variability, with the Amazon and semi-arid caatinga regions in the northeast experiencing a 40% reduction in rainfall, while the southern and southeastern regions observed a 30% increase. These shifts are expected to significantly impact agricultural productivity in ecologically critical zones such as the cerrado savanna and the Pantanal wetlands. Despite early signs of declining productivity, particularly in crops such as coffee, soybeans, and maize, there is limited farmer adaptation to these changing climatic conditions. The persistence of monoculture expansion into the Amazon and cerrado, without adequate mitigation strategies, exacerbates the vulnerability of the agricultural sector. Since 2000, productivity declines have been documented, particularly in essential crops like maize, beans, cotton, cassava, and rice. Rising average temperatures are expected to further decrease soil moisture through increased evapotranspiration, severely affecting water-limited regions such as northeastern Brazil. This reduction in crop yields is likely to deepen existing socioeconomic disparities in the country's most underdeveloped regions.

3.6 The use of climate smart agriculture practices for resilience in region 5

Agriculture is inherently dependent on climatic conditions and constitutes a vital component of the economic framework in Region 5 and across Guyana. Projections indicate that climate change will intensify the frequency, duration, and severity of hydrometeorological events, along with inducing shifts in temperature extremes relative to present norms throughout the 21st century. While certain positive outcomes of climate change on agriculture may arise, primarily through enhanced crop productivity due to increased atmospheric carbon fertilization, these potential benefits are contingent upon stable water availability and the absence of prolonged flooding. In scenarios where such conditions are not met, climate change is anticipated to exert a predominantly adverse effect on agricultural productivity.

Moreover, the increasing temperature trends, in the absence of adaptive protective measures, are likely to diminish yields under traditional farming systems. This is particularly concerning given the geographic vulnerability of Guyana's low-lying coastal plain where the majority of agricultural activity occurs, lying approximately 2.4 meters below sea level. Region 5, along with other coastal areas, faces recurrent flooding risks stemming from excessive rainfall and failures in sea defense infrastructure. Given these challenges, there is a critical need for Region 5 and the wider Guyanese agricultural sector to adopt climate-smart agricultural practices. Such adaptive strategies are essential to mitigate the adverse impacts of climate change and to safeguard food security and rural livelihoods.

3.6.1 Flood tolerance variety

Flooding can adversely impact rice cultivation at any developmental stage, ranging from early germination to maturity. These events may occur as transient flash floods or as prolonged stagnant inundation. In particular, flooding immediately following sowing significantly reduces germination rates and results in poor crop establishment, especially in direct-seeded systems. Advancements in plant breeding have led to the identification of a key genetic factor conferring submergence tolerance, the SUB1 locus. Specifically, the SUB1A gene, originally sourced from an Indian rice landrace, has been isolated and characterized for its role in enhancing flood resilience. Upon submergence, the SUB1A gene is activated, inducing a quiescent state in the plant. This dormancy mechanism minimizes energy expenditure and facilitates post-submergence recovery once water levels decline, thereby improving survival and yield stability under flood-prone conditions.

3.6.2 System of rice intensification (SRI)

Although considerable progress has been made in enhancing rice production and productivity through conventional farming practices, several persistent challenges remain. A viable approach to further increasing output involves improving yield per unit area within the current cultivated land base. However, the issue extends beyond merely increasing food production; it also encompasses the need to adapt to evolving climatic conditions, particularly water scarcity, and to reduce greenhouse gas (GHG) emissions associated with rice cultivation. Achieving sustainable agricultural intensification, minimizing environmental impacts, and ensuring food security necessitate a transformative shift in rice production systems. One promising alternative is the adoption of the System of Rice Intensification (SRI), which utilizes fewer agricultural inputs including land, seeds, fertilizers, pesticides and significantly reduces water usage compared to conventional methods. Notably, SRI practices also lower fuel requirements for water pumping by approximately 30 liters per hectare.

3.6.3 Soil management

Optimal soil performance is achieved through the implementation of sound management practices that enhance soil health, thereby contributing to increased agricultural productivity and profitability. In rice cultivation, the activity of soil biota plays a critical role by improving soil structure and facilitating nutrient availability through natural nutrient cycling processes. Sustainable rice farming relies on the development of soil conditions that promote efficient nutrient cycling, leveraging biological processes to enhance soil fertility and reduce dependence on synthetic chemical inputs.

3.6.4 Zero burning of rice straws
In Guyana almost four hundred thousand (400,000) acres of rice straw are being burnt annually, the burning of rice straws contributes to air pollution, increase in global warming, destroying soil microorganism and soil degradation etc. The rice straw can alternatively incorporate into the field to add organic matter and other important nutrient such as NPK, it also improves the soil structure and increase beneficial microorganism. Additionally, the rice straw can be baled and use for animal feed purposes.

3.6.5 Soil testing
Soil testing refers to the analytical evaluation of soil samples to determine their nutrient composition, chemical properties, and other key characteristics, such as pH or acidity levels. This process is essential for assessing soil fertility and estimating its capacity to support plant growth, particularly by identifying potential nutrient deficiencies. Soil test results provide critical guidance to farmers regarding the type and quantity of nutrients required for optimal crop production. The recent introduction of high-yielding rice varieties by the Guyana Rice Development Board, characterized by elevated nutrient requirements, has underscored the growing importance of routine soil testing as a critical tool for optimizing nutrient management and sustaining long-term crop productivity [13].

3.6.6 Improve the drainage and irrigation system in region 5
Region 5 has three main rivers that lead to the Atlantic Ocean and none of the three rivers have check sluice at their mouth. Hence there is no control of water movement from in and out of these rivers. When the tide from the Atlantic Ocean is high, there is salt water intrusion into the cultivated system and what makes it more problematic is when there is heavy rainfall and the Ocean water is high, there over tapping on dams etc. causing flooding to cultivated areas resulting in loss and damages to crops and livestock. So, one of the recommendations is to place check sluice at the river mouth and install drainage pumps so when there is high tide and heavy rain fall, there will be a constant drainage thus reduce the stay of flood water on the land for long periods.

4. Conclusion
It the month of May/June 2021 flood had negative impact to villages and rice farmers in Region 5. The flood would have caused direct losses to farmers who had paddy to harvest, also to farmers who would have sown their paddy and to those farmers who would have prepared their land but could not sow. There were farmers who suffered losses from more than one category example fifty-five farmers from Pine Ground, Tiger Ranch and Wash Clothes suffered loss from all three categories (Harvesting, Sowing and Land Preparation Loss). The category of sowing was recorded to have the highest loss with respect to number of farmers, acreage and value of the loss. Although the sowing of paddy was within the recommended period of planting that is May/June, the flood water in some areas took as much as 3 to 5 weeks to recede from the land thus causing the young seedling to rot.

5. Statement of ethical approval
Before conducting this study, a formal request for data to be utilized in this research was submitted to all the necessary entities.

6. Confidentiality of participants
Farmer participants were not required to provide any identifying information, such as their names, signatures, contact numbers, or any details that could trace back to them. No names of any farmers, the location of their farm or any ownership information retrieved from the farmer's register were at no time specified in this study to ensure anonymity and confidentiality.

7. Declaration of competing interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Data availability Data will be made available on request.

8. Disclosure of conflict of interest
The author certify that this submission is original work and is not under review at any other publication. The author hereby declare that this manuscript does not have any conflict of interest.

9. Statement of informed consent
The author declare that informed consent was obtained from all individual participants included in the study. All work utilized in this study was fully cited and referenced so authors of prior researches are given their due credentials for their work.

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