



ASSESSMENT OF THE VULNERABILITY OF JAMAICA'S AGRICULTURAL SECTOR TO THE ADVERSE CONSEQUENCES OF SEVERE WEATHER EVENTS

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Acronyms

CARDI	Caribbean Agricultural Research and Development Institute
CBO	Community Based Organization
CFC	Common Fund for Commodities
CIB	Coffee Industry Board
CLR	Coffee Leaf Rust
CO ₂	Carbon Dioxide
CSGM	Climate Support Group, Mona
DRM	Disaster Risk Management
EU	European Union
ECLAC	Economic Commission for Latin America and the Caribbean
ESSJ	Economic and Social Survey of Jamaica
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GCM	Global Climate Models
ICO	International Cocoa Organization
IICA	Inter-American Institute for Cooperation on Agriculture
JAMIS	Jamaica Agriculture Market Information System
JGGA	Jamaica Greenhouse Growers Association
JP	Jamaica Producers
mm	Millimetre
MOAF	Ministry of Agriculture and Fisheries
NGO	Non-Governmental Organization
NIC	National Irrigation Commission
NMIA	Norman Manley International Airport
OAS	Organization of American States
ODPEM	Office of Disaster Preparedness and Emergency Management
PIOJ	Planning Institute of Jamaica
PGRFA	Plant Genetic Resources for Food and Agriculture
RADA	Rural Agricultural Development Authority
RCM	Regional Climate Models
SIA	Sangster International Airport
STATIN	Statistical Institute of Jamaica
USDA	United States Department of Agriculture
USAID/JBRP	United States Agency for International Development/ Jamaica Business Recovery Programme
UWI	University of the West Indies
WTO	World Trade Organization

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Executive Summary

This report presents the results of an assessment of the vulnerability of Jamaica's agricultural sector to climate variables, with particular focus on the following sub-sectors:

- (i) Selected traditional export crops (Sugar Cane, Banana, Coffee, Cocoa);
- (ii) Domestic Crops (Roots and Tubers and Vegetables);
- (iii) Protected Agriculture; and,
- (iv) Livestock

The assessment methodology included document review; case study documentation; consultations with agricultural professionals, farmers, and agricultural extension officers; and the application of a methodology that assesses the vulnerability of a given sector. The methodology evaluates the sensitivity of the targeted sub-sectors to expected climate signals/stimuli, and potential biophysical and socio-economic impacts and their capacity to adapt to those impacts.

A review of the trends in Jamaica's climate over recent decades shows an increase in temperatures, a decrease in rainfall, and sea level rise. Based on this historical data and extrapolation from global and regional climate models, the report also presents a forecast for the future climate of the island. This includes temperature increases of 2.9° to 3.4°C by the 2080s, a decrease in rainfall, an upsurge in very wet days, an increase in the number of high intensity events (including drought and wind speed associated with hurricanes), and a rise in sea levels.

An analysis of data collected on the impact of hurricanes, storms, floods, droughts, and fires on the agriculture sector shows that the sector is extremely vulnerable to hydro-meteorological hazards and droughts. These events have resulted in losses to the sector running into the billions of dollars, with hurricanes and storms accounting for the bulk of the damage. The most severely impacted regions have been Manchester and St. Elizabeth (domestic crops) and the eastern parishes of St. Mary, Portland and St. Thomas (traditional exports). The vulnerability of the sector to climate events is further exacerbated by marginal production environments and land use; rural population's dependence on agriculture, and scarce resources of farm families.

The assessment of the selected agriculture sub-sectors commences with a review of the vulnerability of the sugar cane industry to the effects of climate variability. The assessment demonstrated that sugar cane is highly sensitive to strong hurricane winds, flooding, and, to a lesser extent, drought, as there is ample irrigation coverage. This vulnerability impacts the lives of many as the industry plays a central role in the rural economy (for example, in Westmoreland, Clarendon, St. Thomas, and Trelawny). The industry is now being encouraged to use cane varieties that can better withstand strong winds.

The banana crop has been found to be more susceptible to effects of high intensity hurricanes than to changes in temperature or rainfall. Additionally, flooding due to excessive rain makes the banana susceptible to outbreaks of black sigatoka disease and root rot. Large acreages of banana production have been destroyed during each of the hurricanes and storms that have affected the island in recent years. The severity of damage from hurricanes and storms resulted in a cessation of banana exports following Hurricane Dean in 2007, causing significant unemployment in banana-producing areas. Banana exports restarted only recently in 2014, and farmers have begun to put resuscitation protocols in place so that harvest of fruits from damaged fields can be achieved within five to nine months.

The strong winds of Hurricanes Ivan, Dean and Sandy, and Tropical Storm Gustav have resulted in severe crop loss for the coffee sub-sector. The crop is also sensitive to drought, to which coffee leaf rust disease is linked. Coffee production employs approximately 100,000 persons at all levels and is an important foreign exchange contributor to Jamaica. Extreme weather event protocols have been established for the sub-sector that include establishment of windbreaks and construction of drains to take water off farms. Protocols have also been established for dealing with coffee leaf rust and research continues for improved protocols.

Over the past decade, cocoa production has suffered from drought, high temperatures, prolonged precipitation and hurricane/storm events, to which the crop is highly sensitive. Small farmers are involved in the industry and loss of cocoa plants means loss of income for them. Stimulated by the strong demand for Jamaican cocoa, a resurgence of cocoa farming activity has included the formation of the Cocoa Growers' Association, which is employing various methods to adapt to climate variability.

The domestic crop sub-sector has suffered significantly from its vulnerability to high winds and flooding associated with storms, and to droughts given the dependence on rainfed agriculture. The impacts have included increased incidences of pests, foliage damage to ginger and turmeric, rhizome rot disease to ginger, high incidence of fungal disease on sweet yam, and outbreaks of blight disease in Irish potatoes. High temperatures have also triggered bacterial and fungal wilts of Irish potatoes. The severe impact on crop yields not only results in loss of livelihood and income, especially in the case of small farming communities, but also poses a threat to food security. The introduction of protected agriculture for selected vegetable crops has so far proven beneficial in terms of vulnerabilities to pests and diseases.

Protected agriculture can help to reduce losses from heavy rainfall and drought events, as well as pests and diseases that prevail on open field production. As such, the technology has created opportunities for additional investment and employment in the sector for the younger generation, business persons, and people seeking more sophisticated farming methods. However, despite the greater resilience of protected agriculture production, recent hurricanes and storms have damaged greenhouse structures and crops. These structures are vulnerable to gusty winds from tropical storms and hurricanes. In preparation for these events, greenhouse farmers are encouraged to roll up the plastic casing to enable wind to move through the structure, but this exposes the crops to the elements. Additionally, technical assistance has been sought for newer structural greenhouse designs that are more resilient to storm force winds.

The assessment of the effects of climate variability on the livestock sub-sector revealed that animals are likely to die if exposed to wind, excessive rainfall and drought. Livestock farmers also suffer from the loss of electricity and water that follows a storm event. Losses in this sub-sector, though less than that of domestic crops, can be significant given the industry's contribution to the livelihoods of many small farmers and households. The capacity to adapt to climate variables is being developed in the livestock sub-sector—for example, through the introduction of new and more resistant varieties of goat and sheep to strengthen livestock production and improved ventilation systems for bird coops.

Conclusions/ Recommendations for the Agricultural Sector and Sub-Sectors

The report provides a list of recommendations for the agriculture sector in general, and others for specific sub-sectors, all of which can help the sector to adapt to vulnerabilities related to climate variables. In concluding, there is need for the agriculture sector to fully appreciate its vulnerability to climate variability and climate change and prepare accordingly. The list below outlines general considerations for improving sector preparedness.

- 1) The case studies highlight that farmers are already perceiving changes in the climate, but do not yet fully understand what is happening or what they should do to adapt to those changes. They will require guidance in this regard.
- 2) The agricultural sector must become more knowledgeable about weather and climate signals and put climate change and climate variability theory into practice.
- 3) Aggressively promote information on preparing for weather events and best practices that build disaster-resilient agricultural communities.
- 4) Mainstream climate change considerations into all agricultural sector and sub-sector policies, strategies and action plans.
- 5) Review the method of reporting on losses from extreme weather events to include the vulnerabilities associated with such losses, along with recommendations for farmers in the different locations.
- 6) To combat drought, consider adoption of farming techniques used in more arid areas of the world, such as conservation agriculture and minimum tillage.
- 7) Consider serious fines for farmers who still engage in the practice of slash and burn, given the strong potential for bush fires during dry conditions.
- 8) Weather insurance should be integrated strongly into all agricultural operations.

1.0 Introduction

The United Nations Framework Convention of Climate Change (UNFCCC, 1992) defines climate change as ‘a change in the state of climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or variability of its properties and that persists for an extended period, typically decades or longer.’ The impacts of the shifts in climate variables and the consequences of severe weather events are particularly threatening to Jamaica as they have strong implications for agriculture, which is a mainstay of the rural economy and makes an important contribution to export earnings and food security through domestic food production.

Declines in agricultural output due to impact of hydro-meteorological events and drought have been a hallmark of the sector over the past thirteen years. According to the Economic and Social Survey of Jamaica (ESSJ 2013), for example, real Gross Domestic Product (GDP) for the agriculture, forestry and fishing industries declined by 0.5 percent during 2013, with contractions in three of the five sub-industries. This decline in output was attributed to the lingering effects of Hurricane Sandy, which occurred in 2012; and drought conditions, particularly during January-April 2013, which reduced productive activities (Table 1).

To assist the development of actions that build resilience in the natural environment, improve climate change adaptation practices, and facilitate development planning in the agricultural sector, this assessment sought to identify climatic factors contributing to the vulnerability of the following targeted sub-sectors:

- (i) Selected traditional export crops (Sugar Cane, Banana, Coffee, Cocoa);
- (ii) Domestic Crops (Roots and Tubers and Vegetables);
- (iii) Protected Agriculture; and,
- (iv) Livestock

1.1 Assessment Methodology

Through document review and consultations with farmers and sector specialists, an evaluation of (i) the sensitivity of the targeted sub-sectors to expected climate signals/stimuli, (ii) potential biophysical and socioeconomic impacts, and (iii) their adaptive capacity was carried out and the vulnerability findings (Appendix 1: Qualitative Vulnerability of Selected Agriculture Sub-sectors in Jamaica) incorporated into the document. Recommendations for potential solutions to mitigate and adapt to these vulnerabilities are also provided.

2.0 Climate in Jamaica

The climate in Jamaica is tropical and humid, with warm to hot temperatures all year round. Soil is fertile and, together with the climate, should provide the perfect recipe for an abundance of healthy crops. The primary rainfall season has normally occurred from June to November, which is also the hurricane season. However, the quantity of rainfall varies geographically, with the northeast receiving more rainfall than the southern coast. Due to the mountainous interior of the island, inland areas also have a more temperate climate than coastal areas¹.

Farmers who depend on rainfall have usually expected a temporary decline in precipitation during July and prepare for this expected mid-summer drought. However, farmers in several parishes have reported that since 2000 the droughts have gotten longer and rainfall patterns are reduced and irregular. They now face difficulty in planning for production as droughts reduce seed germination, cause changes in the growing season, and pest and disease infestations are common after long dry spells. According to farmers in South St. Elizabeth “Planting seasons have changed, and rainfall remains unpredictable.” In addition to the impact of lengthened drought seasons, farmers have also had to deal with the impact of more frequent and stronger hurricanes and storms.

2.1 Past, Current, and Future Climate

The 2012 Report on the State of Jamaica’s Climate² analyses historical data to identify the trend in the country’s climate and also uses global and regional modelling³ to project Jamaica’s future climate. The interpretations of these results have revealed the following:

- Temperature has increased by an average 0.1°C per decade since 1992
- Decreasing number of cool days and nights
- Two percent per decade decrease in annual rainfall since the 1960s (greatest from June to August)
- Sea level rise of 0.9 mm per year from 1955-1971 (measurements in Port Royal)

Projections of future climate include:

- Temperature increases of 2.9°C to 3.4°C by the 2080s
- Median number of hot days and hot nights to increase by 33.9 percent and 28.6 percent, respectively, by 2090
- Decrease in rainfall, particularly in western Jamaica (possibility of greater drought events)
- Increase in very wet days (intense rainfall) island-wide and flooding
- Increase in the number of hurricanes per decade
- Increase in number of high intensity events (flooding, drought, landslide, increase in precipitation and wind speed associated with hurricanes)
- Rise in sea levels

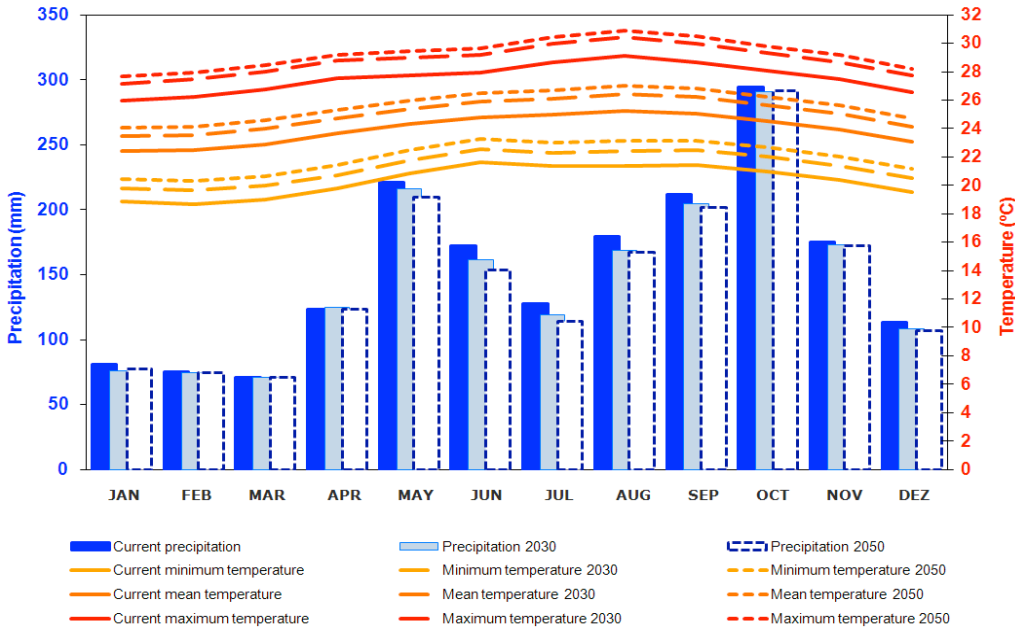
The trend is corroborated by Eitzinger et al. (2011), reporting in a study on the impact of climate change on the Jamaican hotel industry supply chains and on farmers’ livelihoods (Figure 1).

1. Government of Jamaica (2011). The Second National Communication of Jamaica to the United Nations Framework Convention on Climate Change.

2. Climate Studies Group, Mona (CSGM), 2012: State of the Jamaican Climate 2012: Information for Resilience Building (Full Report). Produced for the Planning Institute of Jamaica (PIOJ), Kingston Jamaica.

3. Downscaling methods (dynamical or statistical) have been developed to obtain local-scale surface weather from regional scale atmospheric variables that are provided by Global Climate Models (GCM).

Figure 1: Climate trend summary for Jamaica 2030 and 2050



Source: (Eitzinger et al. 2011)

Jamaica has generally been experiencing warmer temperatures, reduced rainfall and sea level rise, with projections for these climatic changes to continue alongside a greater number of extreme weather events. In 2013, for example, Jamaica’s average annual rainfall was 1470 millimetres (mm), a 97mm decrease relative to the previous year and 303 mm less than the 30 year mean⁴. The decline was consistent with a trend of decreasing annual rainfall, which has been observed since 2000, and with projections for a reduction in precipitation based on climate modelling in Jamaica⁵.

During 2013, several parishes experienced drought conditions (that is, average rainfall ranging between 41 and 60 percent of the 30-year mean) at different times of the year, with some experiencing severe drought conditions. The average annual temperature recorded at Sangster International Airport (SIA) was also the highest on record since 1992. Thus, according to the ESSJ 2013, temperatures rose in keeping with climate change projections for Jamaica and this trend is expected to continue towards the end of the century.

Climate change impacts are already being observed in Jamaica’s agricultural sector, resulting in lower yields, more diseases and economic problems for farmers. Coffee and banana production have faced many extreme weather events during recent years, mainly hurricanes that have destabilized the agricultural industry and caused declining productivity and crop damage. These hurricanes have also caused damage to domestic crops, including the then fledgling protected agricultural sector in 2007, following the passage of Hurricane Dean⁶. Against this background, climate change adaptation and mitigation for food shortages resulting from natural and manmade hazards and emergency situations should become a national priority to ensure food security in Jamaica.

4. The 30-year mean is an average rainfall over the period 1971-2000.

5. Economic and Social Survey of Jamaica (ESSJ) 2013.

6. International Institute for Environment and Development (IIED) in collaboration with Oxfam.

Impact of Climate Change on Jamaican Hotel Industry Supply Chains and on Farmers’ Livelihoods. Final Report 2011. Published by CARIBSAVE 2011.

3.0 Summary of the Agricultural Sector in Jamaica

According to the 2014 Labour Force Survey conducted by the Statistical Institute of Jamaica (STATIN 2014), the agricultural sector absorbs 15.86 percent of the country's labour force (over 207,000 of the 1,305,500 people employed). As such, the sector represents a critical component of Jamaica's national development as an important contributor to food security, GDP, employment, foreign exchange earnings and rural life. The agricultural economy is, however, dualistic, comprising large-scale commercial plantations that produce primarily for the export market under a system of monoculture, and small-scale mixed farms that produce for household subsistence and the domestic market. The dualism extends beyond production orientation but is also reflected in farm size, access to agricultural resources and infrastructure. Small-scale farmers are the most resource deficient, accounting for nearly 80 percent of all farms in Jamaica although having access to less than 15 percent of total arable land.

3.1 Agriculture's Vulnerability to Climate Variability

On an annual basis, growth in the agricultural sector can be impacted by adverse weather conditions and this serves to highlight its significant vulnerability to climate variability. Decline in agricultural output due to impact of a hydro-meteorological event and to drought has been a hallmark of the sector over the past thirteen years (see Table 1). Farmers sustain significant crop loss due to the winds, floods, landslides and prolonged periods of rain that accompany a hurricane. Small farmers, in particular, also suffer significant losses related to lower yield from drought conditions, as their crop production is highly dependent on rainfall (see Table 3).

Table 1: Agricultural Production Index 2013 (2007=100)

YEAR	TRADITIONAL EXPORT CROPS	OTHER AGRICULTURAL CROPS	ANIMAL FARMING	FISHING	POST-HARVEST ACTIVITIES	TOTAL
2007	100	100	100	100	100	100
2008	79.3	94.8	103.2	93.1	111.6	93.7
2009	89.6	112.7	100.5	92.6	101.3	106.2
2010	98.2	113.8	99	101.1	70.2	106.6
2011	99.2	134.4	98.1	98	60.1	117.6
2012	100.9	139.1	102.9	71.4	68.3	119.6
2013	83.4	141.2	101.8	139.9	63.9	
% Change 2013/2012	-17.3	1.5	-1.1	95.6	6.4	
r - revised						

Source - PIOJ

RADA (Table 2) reports that between 1995 and 2010, the total loss in crops, livestock and greenhouses from hurricanes, droughts, floods and fires was close to J\$8 billion, with hurricanes and tropical storms accounting for 84 percent of the total, droughts for 7.7 percent, floods for 6.8 percent, and bush fires for 0.5 percent. Hurricane Ivan in 2004 destroyed a significant portion of the country's domestic and export crop. In the more recent case of Hurricane Sandy (2012), figures produced by the Ministry of Agriculture and Fisheries' (MOAF) show that 40,000 farmers were affected and losses amounted to more than J\$4 Billion. The most severe damage was sustained in the eastern parishes of St. Thomas, Portland and St. Mary, with crops such as coffee, cocoa, and banana affected.

The impacts of hurricanes and storms are significant. Spence (2010), in describing levels of vulnerability, noted that while agriculture contributed J\$13.8 billion to Jamaica's economy in 2004, the cost of the damage caused by Hurricane

Ivan was J\$8.5 billion or 62 percent of total earnings from the sector. In the past decade, the country's agricultural sector has been affected by nine hurricane/storm events, which have occurred in six of the past ten years. The scale of damage caused by these hydro-meteorological events and the frequency of their occurrence has severely challenged the agricultural sector.

Table 2: Losses/Damage caused by Hurricanes/Tropical Storms/Drought/Fire

RURAL AGRICULTURE DEVELOPMENT AUTHORITY (R.A.D.A)								
LOSSES/ DAMAGE DUE TO HURRICANE/ TROPICAL STORM/ DROUGHT/ FIRE								
HURRICANE			FARMERS	CROPS (HA)	CROPS (VALUE \$)	LIVESTOCK VALUE \$	GREEN HOUSE	TOTAL ESTIMATED (VALUE \$)
Charley	August	2004	986	792	88,644,500	1,828,000		90,472,500
Ivan	September	2004	117,698	11,130	2,433,638,540	677,749,950		3,111,388,500
Dennis	July	2005	6,700	610	126,700,000	29,598,000		156,798,000
Wilma	October	2005	19,973	1,572	197,108,000	40,326,000		237,434,000
Emily	August	2007	1,499	656	39,205,000	420,000		39,625,000
Dean	August	2007	63,707	5,473	904,373,000	52,470,000		1,031,343,000
TOTAL			210,563	20,233	3,789,669,040	802,391,950		4,667,061,000
TROPICAL STORM								
Gustav	August	2008	24,255	2,777	520,000,000	26,700,000	19,700,000	565,600,000
Nicole	September	2010	18,601	3,741	531,632,000	32,415,000	12,451,000	1,151,056,000
TOTAL			42,856	6,518	1,051,632,000	59,115,000	32,151,000	1,716,656,000
FLOOD RAIN								
							Others	
1994				2,250	101,459,500			
1998				210	23,030,175			23,030,175
2000				327	46,363,000	2,604,000		48,967,000
2001				13,350	1,911	375,637,708	28,421,400	404,059,108
November, 2006				811	50	20,282,500	2,770,000	15,300,000
TOTAL			14,161	4,748	566,772,883	33,795,400	15,300,000	514,408,783
BUSH FIRE								
March	1996		60	63	2,500,000			2,500,000
April	2000			46	11,300,000			11,300,000
July	2001		38	41	3,800,000			3,800,000
February	2005		100	74	17,450,000	441,000		17,891,000
TOTAL			198	224	35,050,000	441,000		35,491,000
DROUGHT								
1999/2000			8,278	2,779	248,365,600			248,365,600
1995				1,817	149,027,085			
1997				5,907	254,266,420			
March 2005			14,269	2,058	296,048,100			296,048,100
04-March-08			70	79	34,119,000	640,000		34,759,000
Sub-total			22,617	12,640	981,826,205	640,000		579,172,700
Grand total			290,395	44,363	6,424,950,128	896,383,350	47,451,000	7,512,789,483

Source: RADA, 2011 (Values are in J\$)

In addition to the effect of extreme weather events described above, there are other factors⁷ that contribute to the vulnerability of the agriculture sector to climate variability and change, such as:

- (i) Marginal production environments and land use;
- (ii) Rural population's dependence on agriculture; and,
- (iii) Scarce resources and livelihood assets of farm families.

7. Ibid

These factors reinforce each other and intensify farmers' risk to climate change impacts. Crop cultivation on steep slopes and unsustainable farming practices have led to soil erosion, flooding and degradation of watersheds. Furthermore, approximately 60 percent of all farmland is located on the southwestern half (leeward side) of the island, whose climate is semi-arid. Small farmers, with five hectares or less, account for 85 percent of total agricultural holdings. These farmers have limited resources and, as a result, limited capacity to recover from extreme weather events.

3.1.1 Water

Jamaica's agricultural systems are largely rainfed, and the sector's vulnerability to drought coincides with periods of low rainfall⁸. While rainfall is distributed predominantly in the north of the island, the primary centres of population are in the south and, as a result, water resources in the south are over-utilized. As such, wells/aquifers on the south coast are known to be susceptible to saline intrusion, due to slow freshwater replenishment rates during periods of low rainfall.

The Water Resources Authority (WRA) reports that the agricultural sector has the greatest demand for water, accounting for over 75 percent of the water consumed in the country. The sector's heavy reliance on water represents an inherent vulnerability that leads to frequent occurrences of drought and a resulting reduction in output. Intense bush fires during dry periods exacerbate the water shortage problem as the trees lost reduce the catchment capacity of the watershed area.

Periods of drought have been quite common in the last decade. According to Fulton (RADA 2010), drought conditions in 2010 affected several of the productive agricultural zones and severely restricted domestic crop establishment as well as yield in some areas. Of 4564 hectares under production, 1606 hectares were adversely affected resulting in a stark variation in yields from as low as two percent to a high of 70 percent depending on the respective crops' response to the sustained inadequate water supply (see Table 3).

Table 3: Effect of Drought Conditions on Agricultural Production (Fulton, RADA 2010)

Parish	Estimated ha. under production	Estimated ha. affected by drought	Expected yield (tonnes)	Range of reduction in crop yield
St. Thomas	271.2	37.0	652.8	11 – 2%
St. Andrew	246.6	30.1	379.18	2 – 51%
St. Ann	370.4	130.3	1452.0	25 – 50%
St. Catherine	301.3	159.4	1709.0	18 – 50%
Clarendon	607.7	160.4	2656.74	10 – 30%
Manchester	1126.3	282.2	4080.4	25 – 70%
St. Elizabeth	1328.3	789.3	9644.1	29 – 40%
Westmoreland	312.4	17.5	189.2	10 - 30%

The dependence on rainfed agriculture and inefficient irrigation distribution systems present critical limitations to the sector. The proportion of irrigated agriculture is approximately 30 percent in agriculturally important parishes such as St. Thomas, St. Elizabeth, Trelawny and Westmoreland. To compound this situation, some existing irrigation systems are compromised by inefficiencies in water distribution, runoff losses and damage to infrastructure as a result of flooding. An irrigation assessment conducted in 2001 states that conveyance of water from source to farmland is hindered by the poor condition of many existing waterworks. Further losses occur due to the 'continuous flow' method of delivering water to farmland. The irrigation deficiencies will make it difficult for the vulnerable agricultural populations to adapt to climate variability and climate change.

Proper irrigation systems can facilitate year-round intensive production and potentially enable farmers to gain access to competitive commercial markets. As such, through the National Irrigation Development Programme, the National Irrigation Commission has over the past decade made more irrigation available through rehabilitation of old schemes

8. L. Fulton. (Rural Agricultural Development Authority 2010) . Drought Conditions and Management Strategies in Jamaica.

and construction of new ones. Various modes of on farm water conservation and use methods are also being encouraged. However, irrigation remains inadequate as many small farmers lack access to continuous water supply. The projections for future decreases in precipitation suggest conditions that will increase the occurrence of further dry spells and drought events in the future, and thus significantly increase the susceptibility of agriculture to impacts of climate change.

3.1.2 Regional differences in vulnerability

Damage to the agricultural sector in Jamaica from climatic conditions has varied according to geographical location. The areas most affected by the passage of hurricanes have been concentrated in the eastern and southern sections of the island: St. Mary, Portland, St. Thomas, St. Andrew, Clarendon, Manchester, and St. Elizabeth. Hurricanes affecting the island tend to originate from the southeast or south of the island and head northwest or west. Table 4 shows the parishes that have been most affected by hurricanes, storm and flood rain events.

As mountains running along its east-west axis and narrow coastal plains characterize the island, the regional differences in vulnerability are also strongly affected by elevation and physiographic characteristics. For example, the mountainous steep slopes are particularly vulnerable because of the prevalence of unsustainable agriculture practices, such as planting on slopes without use of terracing, barriers, or contouring. As a result, crops are significantly exposed to soil erosion, waterlogging and wind damage during and after hydro-meteorological events with intense rainfall and gusty winds.

The southern belt of the island is found to be susceptible to drought and bush fires. Parishes most affected by bush fires have been St. Thomas, Kingston and St. Andrew, St. Catherine, Clarendon, Manchester, and St. Elizabeth (note incidents of bush fires in Table 2). In 2010, the most severely impacted drought parishes were St. Thomas, St. Andrew, St. Catherine, Clarendon, Manchester, St. Elizabeth, Westmoreland and sections of St. Ann (Table 3). St. Andrew and Kingston were said to be experiencing extreme conditions that were the worst in 25 years. These drought conditions were attributed to the El Niño events.

Table 4: Regional differences in vulnerability – Hurricanes; Storms; Flood Rains

YEAR	EVENT	TOTAL DAMAGE (J\$)	DAMAGE TO AGRICULTURE (J\$)	AREAS MOST AFFECTED
1988	Gilbert		1,660,000,000	
1998	Portland 1998 Floods	339,230,323	201,300,000	
2000	December 2000 - January 2001 Rains	198,256,510.00	48,972,000	Trelawny
2001	October 29 - November 5 Rains	2,229,298,962.26	533,200,108	Portland, St. Andrew, St. Elizabeth
2002	May/June Rains	203,347,750.00	82,813,000	
2002	Tropical Storms Lili and Isidore	840,394,883.00	309,267,150	
2003	May/June Rains	203,347,750.00	59,322,750	
2004	Hurricane Charley	248,912,460.00	90,472,500	St. Elizabeth, Manchester
2004	Hurricane Ivan	35,900,000,000.00	8,550,000,000	Clarendon, St. Catherine,, Manchester, St. James, Hanover and St. Mary
2005	Hurricanes Dennis & Emily	5,976,910,000.00	745,000,000	
2005	Hurricane Wilma	3,419,202,845.40	248,755,000	
2006	Port Maria Rains	48,862,500.00	17,377,500	Portland, St. Mary, St. Ann
2007	Hurricane Dean	23,053,920,000.00	3,715,000,000	St. Elizabeth, Manchester, Clarendon, Portland
2008	Tropical Storm Gustav	15,159,460,000.00	1,678,300,000	St. Thomas, Portland, St. Mary, St. James
2010	Tropical Storm Nicole			St. Elizabeth, Clarendon, St. Mary
2012	Hurricane Sandy			St. Mary, Portland, St. Thomas, St. Catherine,

Extracted from data from RADA (2011) and Planning Institute of Jamaica (2007, 2008, 2010, 2012)

4.0 Vulnerability of Selected Crops and Livestock

The main drivers of agricultural impact from climate change signals are the biophysical effects and socio-economic factors. Crop production is affected biophysically by meteorological variables such as rising temperatures, changing precipitation patterns, increased atmospheric CO₂ levels, the availability of water resources, and the frequent occurrence of extreme weather events. Current research anticipates that biophysical effects of climate change on agricultural production will be positive in some agricultural systems and negative in others. For example, elevated levels of Carbon Dioxide (CO₂) are expected to have a positive impact on plant growth and yields but these effects are likely to be eroded by other effects of climate change, like increasing temperatures⁹.

Socio-economic factors refer to social and economic impacts of climate variability. For example, changes in crop productivity as a result of climate change situations can lead to price changes and shifts in comparative advantage. Extreme weather events also affect agricultural infrastructure and assets and negatively impact households that are highly dependent on agriculture for their livelihoods and their food.

This chapter provides more detailed information on the biophysical vulnerabilities and socio-economic impacts of climate variability on selected agricultural sub-sectors in Jamaica. These vulnerabilities can be addressed by building resilience at various levels, such as: (a) farm level and community management; (b) technology; (c) markets and institutions; and, (d) policy. The chapter will highlight the adaptation measures that can be used by each sub-sector to adapt to climate events, and indicate those measures that can be more easily implemented at the community and farm level.

The selected sub-sectors are:

- Traditional Export Crops (sugar cane, banana, coffee, cocoa)
- Domestic Crops (roots, tubers and vegetables)
- Protected Agriculture
- Livestock

4.1 Traditional Export Crops

The main traditional export crops produced in Jamaica are sugar cane, coffee, citrus fruits, and cocoa, which make a significant contribution to foreign exchange earnings while providing employment in rural areas of the country. Bananas were considered a traditional export crop until 2008, when exports ceased following a series of hurricanes and storms that devastated the sub-sector over a four-year period. However, in June 2014, the Ministry of Agriculture and Fisheries announced the resumption of banana exports. As depicted in Table 5, traditional export crops have experienced mixed fortunes in recent years, some of which are related to the impact of extreme weather events during the period.

Table 5 : Value of Traditional Agricultural Export Crops 2009–2013

VALUE OF SELECTED TRADITIONAL AGRICULTURAL EXPORTS 2009-2013						
US \$'000						% Change
Selected Traditional Export Crops	2009	2010	2011	2012	2013p	2013/2012
Sugar Cane	75.7	45.8	64.3	95.3	71 164	
Bananas (fob) *	6	1	63	120	62	-48.5
Coffee	33 815	19 191	18 326	13 778	16 327	18.4
Cocoa	1 778	1 021	1 108	1 937	504	-74
p - preliminary						

Source: Statistical Institute of Jamaica

* Source: Sugar Industry Authority

9. Economic Commission for Latin America and the Caribbean, 2011. The Economics of Climate Change in the Caribbean.

4.1.1 Sugar Cane

Sugar cane is Jamaican agriculture's largest foreign exchange earner and contributes over one percent of GDP. It is also the second largest employer of labour in the country, with some 38,000 persons directly employed. Sugar cane farming accounts for about 40,000 hectares, or 13 percent, of cultivated farmland, primarily in the parishes of St. Catherine, Clarendon, Westmoreland, Trelawny and St. Thomas. Production peaked at 505,000 tons of sugar in 1965; since then, there has been a steady decline in cane and sugar production¹⁰.

Over the years, the sugar industry has faced a number of challenges, including the high cost of production; inefficient factory operations; low cane production and cane yields; poor cane quality; declining sugar and cane prices; increasing debt burden and high interest rates; weaknesses in the administration and management structure of the industry; low productivity and poor employee morale; and shortage of manual labour, among others. All have contributed to the steady decline in output over the decades. The current European Union (EU) Accompanying Measures Programme is designed to address some of these problems and help enable the sector to compete in a liberalized market from 2015 onwards.

Impact of Extreme Weather Events

As with the case of the general agriculture sector, the sugar industry has been affected by the onslaught of hurricanes and tropical storms over the past decade. The industry suffered extensive damage from Hurricanes Ivan and Dean (2004 and 2007, respectively) and Tropical Storm Gustav in 2008. Gustav caused damage estimated at J\$450 million in St. Thomas, St. Catherine, St. Elizabeth and Westmoreland. The type of damage varied by location: in St. Thomas, stalk breakage caused by gusty winds was very pronounced, while St. Elizabeth (300 hectares) and Westmoreland (500 hectares) suffered more from flooding. In 2010, Tropical Storms Nicole and Richard also caused severe flooding in some cane areas. Hurricane Sandy in 2012 again severely impacted the sector—sugar canes were broken and uprooted in significant extensions, and flooding affected extensive areas—resulting in less sugar cane being replanted in 2013.

Biophysical Vulnerability (Appendix 1)

An assessment of the effects of climate variability on the sugar cane sub-sector has demonstrated that the crop is highly sensitive to strong hurricane winds, flooding and drought. However, the sector is less vulnerable to drought as the large scale of sugar production enables ample irrigation coverage. The following are some of the findings with regards to vulnerability of this sub-sector to weather events:

- Sugar cane yield has proven to be more sensitive to changes in rainfall than temperature.
- High winds uproot sugar cane plants, resulting in reduced sugar content and yield.
- Extensive stalk breaking and lodging (canes blown down) experienced in St Elizabeth, St. Thomas, Westmoreland, and St. Catherine during hurricanes.
- Canes with stalk breakage at the top will be affected by side shooting which impacts on growth and also contribute to poor quality.
- Extended flooding, water scarcity, and drought also affect sugar cane growth, leading to reduced sugar content, lower sugar yield and increased processing costs.
- Extended flooding, water scarcity, and drought cause diseases that result in low land productivity; poor cane quality; reduction in hectares reaped; and deterioration of the conversion ratio (cane to sugar).
- Lodged cane can result in reduced sugar production, through decreased cane yield and sugar content.
- Inadequate drainage after flooding causes crop rotting and, therefore, the potential for canes to be lost is great. Considerable cost is also incurred from pumping.
- Damage to sugar cane varies by location based on the age of the canes (time that has elapsed since previous harvest) and the wind effect on some varieties. It has been observed that:
 - Canes less than three months old suffer minimal damage with some broken tops and leaf shredding;
 - Canes 3–5 months old experience severe stalk breakage but to varying degrees, depending on the cane variety being grown. The continued growth of the cane is usually affected. (In St. Thomas after Tropical Storm Gustav (2008), stalk breakage was very pronounced on canes at the 3-5 month stage of growth and this had a significant impact on production in 2009); and,
 - Canes 5–8 months old will lodge but with little stalk breakage. These will continue to grow but will cause the development of suckers which will affect cane quality at harvest.

10. Ibid

Socio-economic Impact

The vulnerabilities of sugar cane impact the lives of many as the industry plays a central role in rural economies. Social stability and security in several rural areas depend on the existence of a viable sugar cane industry (For example, in Frome and Sav-la-mar in Westmoreland; Lionel Town in Clarendon; Duckensfield in St. Thomas and Clark's Town in Trelawny, sugar cane is the major or only economic activity).

Adaptive Capacity

Based on the known vulnerabilities of the crop and the locations where it is grown, research into more resistant varieties as well as good management are mandatory to improve the sector's resilience to weather-related shocks. While research activities will take some time, the list below outlines other "easy to do" adaptation strategies or practices that can strengthen the sector's resilience to climate variables.

Easy to do:

- (i) Employ good strategies for flood management, irrigation, and for dealing with side shooting after stalk breakage.
- (ii) Improve the application of water in the growing cycle through employment of efficient irrigation systems.
- (iii) Utilise efficient rainwater harvesting, storage and conservation.
- (iv) Use varieties of cane that can better withstand wind. These are now available.
- (v) Employ good strategies for factory management.

4.1.2 Banana

Traditionally, Jamaica has focused on the banana export trade, although the banana is a staple food in the Jamaican diet. Since the 1990s, significant changes have occurred in the banana export market as a result of World Trade Organization (WTO) trading requirements, and increased competition from banana production in the Latin American countries. The preferential treatment once granted by the EU has also been significantly reduced. All this, in addition to adverse weather shocks, especially Tropical Storm Gustav in 2008, has led to a decline in banana production and exports.

Impact of Extreme Weather Events

Large acreages of banana production have been destroyed during each of the hurricanes and storms that have affected the island in recent years. This damage is devastating for a crop that requires a gestation period of 9-12 months. In 2007, Hurricane Dean caused an 85 percent loss of standing crops and 95 percent loss of maiden suckers. The largest number of hectares lost from the non-estate sector was in Portland, St. Mary and St. James. In 2008, intense rainfall and winds associated with Tropical Storm Gustav inflicted heavy damage to the parishes devoted to the production of bananas. This damage came at a time when the industry was just rebounding from losses associated with Hurricane Dean the previous year. The Jamaica Producers (JP) Group reported that a total of 552 hectares of estate bananas were damaged, 57.97 percent of which occurred at the Eastern Banana Estate in St. Thomas. Total damage in the sub-sector was estimated at J\$728.2 million, which comprised J\$505.5 million for estate bananas, and J\$222.7 million for domestic crops. Due to the extensive damage, JP ceased production for export in 2008. As a result, only 1.6 tonnes of the fruit were exported in 2009 compared with 32,428 tonnes in 2006.

The sector was again affected by Tropical Storm Nicole in 2010 and Hurricane Sandy in 2012. Nicole caused damage to 40 percent of banana production, while Sandy destroyed approximately 66 percent of the banana crop. In the case of Hurricane Sandy, the most severe damage was sustained in the eastern parishes of St. Thomas (100 percent loss), Portland (96 percent loss) and St. Mary (93 percent loss).

Biophysical Vulnerability (Appendix 1)

An assessment of the effects of climate variability on the banana sub-sector has demonstrated that the crop is highly sensitive to strong hurricane winds, flooding and drought. In terms of biophysical impacts, the banana is more susceptible to effects of high intensity hurricanes than to absolute changes in temperature or rainfall. In the past five years, four major storms have caused severe damage to the sector. High winds have broken and/or uprooted the plants. Additionally, flooding caused by excessive rain makes the banana susceptible to outbreaks of black sigatoka disease and root rot. The plant does not tolerate poor drainage or flooding. Root rot from cold, wet soil is the biggest killer of banana plants in the tropics. Dry weather is also a constraint to banana production, as bananas are sensitive

to drought through their root system. During drought periods, bananas need frequent irrigation to avoid significant crop losses.

Socio-economic Impact

It was estimated that in 2007 Hurricane Dean was the direct cause of a complete loss of income for up to 3,000 persons who depended solely on banana production for their livelihoods. A further 8,000 individuals (shopkeepers, truck operators, processors, etc.) suffered an indirect loss of income. Additionally, the frequency of such storms places a severe financial burden on the farmers, as the recovery process is very slow and costly. Unemployment resulted in St. Thomas when the major export producer stopped producing for export due to continued extensive damage from hurricanes, and, of course, the country still suffers from the resultant significant loss of foreign exchange earnings.

Adaptive Capacity

A percentage of the potential loss from hurricanes and storms can be salvaged by reaping fruits that are ready for harvest, protecting others that are near to harvest, and cutting back broken plants prior to a storm's arrival. Farmers have reduced their losses by cutting leaves from banana trees to reduce their weight and susceptibility to wind damage, as young fields or sucker plants fair better in high winds. Additionally, resuscitation protocols should be applied immediately (within four weeks after the storm) so that harvest of fruits from damaged fields can be achieved within 5-9 months. The abovementioned practices can be classified as "easy to do" or more readily obtainable adaptation strategies. Other adaptation strategies, which are longer-term and more costly, include use of the triangular bracing mechanism (propping) and the creation of windbreaks. The latter must be installed and managed correctly for the benefits to be realized.

4.1.3 Coffee

Jamaica's Blue Mountain coffee is known for its distinct flavour, body and aroma and is considered one of the best coffees in the world. It is grown at altitudes of between 914 and 1,676 metres (3,000 and 5,500 feet), mostly by small growers. The country also produces two other grades: High Mountain and Lowland coffee (grown at lower altitudes) for export. Coffee growers must meet strict guidelines set by the Coffee Industry Board for export of coffee. The major export market used to be Japan (90 percent of production) but, due to a plunge in export demand, earnings plummeted from US\$33.8 million in 2009 to US\$13.7 million in 2012 and US\$16.3 million in 2013 (see Table 5 above). Due to this significant change, markets are being aggressively sought elsewhere, e.g., in Europe and North America.

Impact of Extreme Weather Events

Losses in the coffee industry have not only been due to the sharp drop in the demand from the Japanese market. The strong winds brought by Hurricane Ivan in 2004 affected the uplands where coffee is grown. This caused a severe setback to the increased coffee production that had been achieved as a result of major resuscitation of coffee trees by farmers. The winds resulted in the loss of berries over nearly 45 percent of the coffee-producing area. Planned production and export volumes could not be met and this translated into a loss of J\$475.7 million in export earnings. The passage of Hurricane Dean in 2007 also resulted in severe damage to 45 percent of the total coffee crop. In addition to crop loss, infrastructure including parochial roads was significantly damaged. Then the following year, Tropical Storm Gustav damaged approximately 5–10 percent of the crop, according to reports from the Coffee Industry Board (CIB).

The effects of these storms would have contributed significantly to the decline in the amount of cherry coffee produced, which fell from 16,459 tonnes in 2004 to 9,035 tonnes in 2008. More recently, Hurricane Sandy, which arrived in October 2012 during the coffee harvesting season, caused damage to 20 percent of unharvested berries. (Approximately 25 percent of projected production had already been harvested). The most severe damage was sustained in the eastern coffee producing parishes of St. Thomas, Portland and St. Mary.

Biophysical Vulnerability (Appendix 1)

Based on the assessment of the effects of climate variability on the coffee sub-sector, the crop is found to be highly sensitive to strong hurricane winds and drought. Strong hurricane winds have resulted in:

- Defoliation of coffee and shade trees
- Severe root damage caused from uprooting and twisting of young 2-3 year old plants
- Scarring of coffee beans which results in a reduction of the production of premium coffee beans
- Mature and ripe berries waiting to be reaped detached by high wind

In the case of drought, researchers link the emergence of the coffee leaf rust (CLR) disease to periods of low precipitation. Areas presently affected by CLR are:

- (i) All lowland areas;
- (ii) Low altitude zone of the Blue Mountains; and,
- (iii) Medium altitude zone recently infected (could be due to subtle changes in weather patterns)¹¹.

The type of coffee grown in Jamaica (Arabica Typica) is particularly susceptible to CLR and this has raised concerns within the industry regarding the disease's impact as a destructive agent and also for quality assurance and safety of Jamaican Coffee. Research has found that healthy Arabica Typica plants can resist the disease and, as a result, emphasis has been placed on healthy genetically controlled Arabica Typica to also maintain the quality of Jamaican Coffee.

Socio-Economic Impact

Coffee production employs approximately 100,000 persons at all levels, and is an important contributor to socio-economic development in rural communities and to foreign exchange earnings for Jamaica. Due to the frequency of extreme weather affecting coffee over the past 10 years, financial resource availability is a challenge for the small farmer.

Adaptive Capacity

Continued research has shown that agronomic measures as well as chemical measures have to be employed to combat CLR, since healthy plants have the capability to resist attack from the CLR pathogen. Agronomic measures include:

- (i) Proper timing and application of fertilizers
- (ii) Pruning of dead and damaged branches after harvesting or wind damage
- (iii) Gormandizing (removal of suckers)
- (iv) Removal of pruned material from root zone
- (v) General cleaning on farm
- (vi) Removal of laterals that lay on soil surface.
- (vii) Adoption of a wider planting distance 10' between rows x 5' along the rows
- (viii) Planting of one seedling per hole
- (ix) Proper shade management
- (x) Maintaining of proper drainage system

Chemical measures that have worked are the application of:

- (i) Copper hydroxide
- (ii) Propiconazole
- (iii) Hexaconazole, or
- (iv) Cupric Sulphate

Farmers can also prepare for extreme weather events by implementing the following "easy to do measures:"

- (i) Prune shade trees to prevent heavy, overhanging branches from breaking or falling on coffee trees;
- (ii) Clear clogged drains
- (iii) Cut trees in wind-swept areas 12-15 inches from the ground;
- (iv) Establish wind breaks;
- (v) Establish grass barriers in areas prone to land slippage to prevent soil erosion; and,
- (vi) Construct drains to take water off farms

¹¹ Coffee Industry Board (CIB).

A longer-term or more costly community adaptation measure would be the construction of dams across gullies to minimize or prevent gully erosion.

4.1.4 Cocoa

Jamaica is one of few countries in the Western Hemisphere that produces and exports a standard of cocoa described by the International Cocoa Organization as “fine and flavour” cocoa, from Trinitario and Criollo cocoa trees. Cocoa has been considered a beneficial crop as it protects against soil erosion, grows well on steep slopes, and prevents weeds from growing under coconut trees. Additionally, its husks are good animal feed and, as a reasonably sturdy tree, it normally weathers strong hurricanes fairly well.

Despite its good attributes, the cocoa industry has suffered many setbacks that have resulted in a dramatic decline in cocoa production over the last 15 years. Production declined from 248,516 boxes in 1993/94 to 40,607 boxes in 2007/2008, due mainly to ageing cocoa trees, pest infestation, poor rehabilitation and husbandry practices, and crop abandonment. In recent years, there has been renewed interest in cocoa farming to take advantage of increasing international prices and demand for the product. Farmers have formed a Jamaica Cocoa Farmers Association, which is addressing use of improved technology, technical assistance, education and training, and collaborating with support entities to rehabilitate cocoa fields.

Impact of Extreme Weather Events

Over the past decade, cocoa production has suffered from both drought and hurricane/storm events. In 2004, the sector experienced a decline in production from both scarcity of rains in the first half of the year and Hurricane Ivan in the second half of the year. The drought resulted in a 47.7 percent decline in production, especially in the main cocoa producing parishes of Clarendon and St. Mary, while Hurricane Ivan caused production losses of J\$27.6 million. The cocoa sub-sector was affected severely again in 2007, particularly in Clarendon, St. Mary, St. Catherine and St. Thomas, due to the passage of Hurricane Dean. According to the Cocoa Industry Board, the hurricane damaged approximately 50 percent of the 9,000 hectares of cocoa under production at the time.

More recently, the cocoa sector reported a decline in production in the 2012/2013 crop year due to the combined effect of Hurricane Sandy in October 2012 and drought conditions in the first four months of 2013. Hurricane Sandy affected an estimated 4,500 acres of cocoa, mainly in the parishes of St. Thomas, Portland, St. Mary, St. Catherine and Clarendon. Consistent with the reduced level of production, the value of exports for the calendar year 2013 was US\$0.5 million compared with US\$1.9 million in 2012 (Table 5).

Biophysical Vulnerability (Appendix 1)

The assessment of the effects of climate variability on the cocoa sub-sector shows that the crop is highly sensitive to strong hurricane winds, drought, high temperatures and precipitation. The cocoa tree grows in a variety of soils provided they are deep and well drained. The mean shade temperature should be about 26°C with an allowance of 7°C above or below. Next to climate and soils, shade is the most important requirement for cocoa. Without shade, cocoa suffers from ‘tieback’ caused by the direct rays of the sun and by thrips, an insect attracted to unshaded cocoa. Hurricanes that destroy cocoa trees also destroy shade trees and this impacts the replanting process in the same area.

Cocoa trees also suffer from the drying effect of continuous winds, which injure the small, tender flowers and dry up young pods. In northern Jamaica, where northeasterly winds are prevalent, plants must be protected either by hills or artificial windbreaks. Drought further stresses crops and delays growth.

Socio-economic Impact

Small farmers are involved in the cocoa industry. Loss of cocoa plants means loss of income to them and their communities. It also means loss of foreign exchange earnings to the country.

Adaptive Capacity

Determination to grow the sub-sector, stimulated by strong demand for Jamaican cocoa, has translated into a resurgence of cocoa farming activity and the formation of a cocoa growers' association that is using various methods to strengthen the sub-sector. It is important that these methods also improve the sub-sector's resilience to climate-related events, to enable the industry to sustain growth over the medium and long term. The list below outlines some "easy to do" adaptation strategies or practices that can strengthen the sector's resilience to climate variables.

Easy to do:

- (i) Practise rainwater harvesting to deal with drought conditions
- (ii) Ensure that cocoa trees have adequate shade
- (iii) Cultivate cocoa in cool locations and where they are also protected from the wind (hills)
- (iv) Plant windbreaks

4.2 Domestic Crops (Roots and Tubers and Vegetables)

Domestic crop production in Jamaica is largely characterized by a multi-crop production system with many farms on small (often hillside) holdings (2–5 acres), utilising low levels of inputs and technology. The main categories of domestic crops in Jamaica include vegetables, legumes, fruits, plantain, yams, other tubers (cassava, coco, and dasheen), potatoes (Irish and sweet), cereals, and condiments.

Impact of Extreme Weather Events

History has shown that the fortunes of the domestic crop sector are closely tied to the presence of favourable or unfavourable weather conditions, as production has declined during periods of hurricanes, storms and droughts. Table 6 outlines the damage to domestic crop production from selected weather events over the past eleven years. In addition to the devastation caused by the passage of several storms in recent years, the domestic crop sector is particularly vulnerable to droughts, given the preponderance of small-scale farmers who do not have irrigation. For example, St. Elizabeth, which in 2009 accounted for 32.4 percent of total hectares of domestic crops harvested, is known to suffer from extreme drought conditions.

Over the past five years, the Ministry of Agriculture and Fisheries (MOAF) has implemented several initiatives to encourage farmers to replant after extreme weather events damaged their crops, and also to expand their acreage. MOAF interventions have also led to an expansion of greenhouse production, to address the vulnerabilities and encourage more efficient and increased use of irrigated land.

Table 6: Impact of Extreme Weather Events on the Domestic Crop Sector

YEAR	EVENT	AFFECTED PARISHES	IMPACT ON DOMESTIC CROP SECTOR
2003	Drought	Central and Western Parishes	6.5% reduction in production
2004	Hurricane Ivan	Manchester (highest losses), Clarendon, St. Elizabeth, Portland	Losses in identified parishes amounting to approximately 50% (\$517.7 million) of total damage
2007	Hurricane Dean		5,354 hectares lost, including 1,514 hectares of roots and tubers. 427,305 tonnes of domestic crop production lost. Ability to produce roots and tubers in the short term adversely affected.
2008	Tropical Storm Gustav	Portland (highest losses), Clarendon, St. Elizabeth, St. James	2,777 hectares of crops affected, Production declined by 400,105 tonnes.
2010	Tropical Storm Nicole	St. Elizabeth	3,740 hectares of crops damaged. 38.7% of total hectares lost were in the parish of St. Elizabeth
2012	Hurricane Sandy	Portland, St. Thomas, St. Mary, St. Andrew	\$1,250 million in damages

Biophysical Vulnerability (Appendix 1)

The domestic crop sub-sector has been found to be sensitive to strong hurricane winds, flooding from excessive rainfall, and drought that severely impacts yields. These impacts comprise:

- Increased pest incidences (broad mite on Irish potatoes, the beet armyworm on escallion¹² (1992, 2009 & 2010);
- Rhizome rot disease in ginger;
- Foliage damage to ginger and turmeric;
- Blight disease outbreak in Irish potatoes;
- High incidence of fungal disease on sweet yam; and,
- Significant foliage damage to ginger and turmeric as a result of waterlogging, excessive run-off, soil erosion and/or leaching.

Meanwhile, high temperatures trigger:

- Bacterial and fungal wilts in Irish potatoes (several outbreaks were recorded in St. Elizabeth, St. Mary, St. Catherine and St. Ann between 1992 and 2010, (RADA)).

Socio-economic Impact

Severe impact on crop yields not only results in loss of livelihood and income in small farming communities but also threatens food security. Prices of domestic food crops normally increase following the passage of a storm/ hurricane.

Adaptive Capacity

The introduction of protected agriculture for selected vegetable crops has proven beneficial in terms of the vulnerabilities to pests and diseases noted above. However, financial outlay and technical knowledge are challenges for many small farmers who are considering this alternative. Recently, the MOAF embarked on a Climate Adaptation Programme for the sub-sector that includes training farmers in best practices and providing rain-harvesting systems to aid their farming activities.

To help the sector cope with the frequent climate events, several adaptation methods are being introduced to farming communities, as listed below:

- Sustainable management of water resources
- Mainstreaming of climate change into related policies
- Utilization of CBOs and NGOs to expand human resources in climate change adaptation

In addition, there are various “easy to do” adaptation strategies that can strengthen climate resilience in the sector. These include:

- (i) Adopting damage-reduction strategies (as used by four farming communities before Hurricane Dean in South St. Elizabeth¹³):
 - Protection of nurseries
 - Transplanting
 - Crop bracing
 - Lowering of yam sticks
 - Cutting of trenches
 - Spraying crops as well as the harvesting and storage of produce
- (ii) Post hurricane measures, including harvesting and plant restoration, relocation of farm plots and scaled-down production
- (iii) “Dry land” farming system – mulching with guinea grass, as used in St. Elizabeth, addresses drought effectively
- (iv) Establish a regular disease control regimen
- (v) Alter crop calendars for short-term crops

12. *Allium fistulosum* L., a species of perennial onion also known as Welsh onion, bunching onion and spring onion.

13. The CARIBSAVE Climate Change Risk Atlas (CCRA): Climate Change Risk Profile for Jamaica (2012).

Mitigation methods include:

- Coupling mulching with drip irrigation to enhance the efficiency of water use and reduce wind erosion, soil temperature and run-off (for use in drought conditions and moisture deficit areas)
- Adopting minimum tillage to reduce fossil fuel usage and soil erosion (for use during drought and for rainfall-related soil erosion)
- Drip irrigation for water conservation
- Creating firebreaks for extra protection against wind damage from storms
- Replanting trees
- Harvesting and storing of rainwater for water conservation and use in drought conditions
 - Aquifer recharge – for drought conditions, flood impact reduction and mitigation of saline intrusion
 - Timing of crop establishment for drought mitigation
 - Raised beds/network drains for reduction in depth and of area extent of floods
 - Planting of drought tolerant crops
 - Contour planning for slope stabilization, and reduction of soil loss

4.3 Protected Agriculture

In recent years, protected agriculture has been promoted in the agriculture sector as a technology that can increase yields, enhance insect and disease control, and improve the quality and consistency of crops and resistance to adverse weather conditions, including hurricanes and the effects of drought. The gains already made in Jamaica are confirmed by statistics that indicate a steady increase of over 100 percent in the annual production of vegetables, such as romaine lettuce, tomatoes, varieties of sweet pepper, and squash, and other herbs under protected agriculture between 2007 and 2011.¹⁴ This, in turn, has helped to boost rural income, knowledge, employment, smallholder and producer group productivity, competitiveness, and food and nutrition security.

Impact of Extreme Weather Events

Despite the greater resilience of protected agriculture production to extreme weather events, recent hurricanes and storms have damaged greenhouse structures and crops. For example, damage caused to greenhouses by Hurricane Dean 2007 was estimated at J\$52.47 million, while damage caused by Tropical Storm Nicole in 2010 was estimated to be J\$12.5 million, accounting for approximately 10 percent of the value of the industry. A total of 26 greenhouses, made primarily of metal, sustained damage during the event. Greenhouses in Manchester and St. Mary suffered the most damage (both structural and crop damage). A significant number of growers were either at the end or the beginning of the crop cycle, and that contributed to the lower level of crop damage.

Biophysical Vulnerability

Greenhouse structures are vulnerable to gusty winds from tropical storms and hurricanes, as such winds can bend and break metal and wood structures and severely tear the greenhouse plastic. Once the greenhouse structure is dismantled, the crops are exposed to the effects of the storm/hurricane. In preparation for storms and hurricanes, greenhouse farmers are encouraged to roll-up the plastic casing to enable the wind to move through the structure, thereby helping to save the structure. However, the removal of the plastic again exposes the crops to the elements.

Socio-economic Impact¹⁵

Protected agriculture can help to reduce losses from heavy rainfall and drought events, as well as the pests and diseases that prevail on open-field production. As a result, the technology has created opportunities for additional investment and employment in the sector for the younger generation, business persons, and people seeking more sophisticated farming methods. Nevertheless, damage to greenhouse structures from hurricanes and storms can potentially result in significant financial losses.

14. <http://www.cardi.org/cfc-pa/country-profiles/jamaica-protected-agriculture-profile/>. Accessed on 18/05/14.

15. Ibid.

Adaptive Capacity

The sub-sector has the distinct advantage of reducing the clearing of land to expand operations and offering a protective barrier against pests; and tends to be linked to water storage for irrigation. While metal- and wood-framed greenhouse structures have been damaged during storms and hurricanes, technical assistance to develop adaptive capacity and mitigate future loss has been constant and has proven effective. Newer structural designs are more resilient to storm-force winds and enable removal of the plastic prior to the storm event. For example, the following factors¹⁶ should be considered when designing the construction of greenhouses in hurricane-prone regions:

- (i) Shade cloth, if used, should be attached so as to be easily removable and secured.
- (ii) The polyethylene glazing and any insect screen should be attached with quick attachment components, such as wiggle wire or rope, which can be rapidly removed. The less costly approach of securing poly with lath nailed to base or shoulder boards will be slow to remove and will likely result in damage to the poly.
- (iii) Allow 15-20 cm (6-8 in) of excess poly or insect screen during initial installation so that there will be sufficient material to hold on to when reapplying these materials to structures.
- (iv) Ideally, indoor storage space for poly and other coverings and seedling trays should be available to minimize debris and wind damage after they have been removed from the structure.
- (v) Design the trellis system so it can be lowered carefully to the ground and covered with a tarp or with the plastic that has just been removed. The edges should be weighed down.
- (vi) Consider whether a fuel pump and/or stand-by generator is necessary to power water pumps or other systems after the hurricane has passed and electricity is not immediately restored.

USAID/JBRP Production Bulletin #14 provides additional recommendations for hurricane preparedness after greenhouses have been constructed. As such, these adaptation measures are more readily obtainable by existing greenhouse operators.

- (i) If the plastic and/or antiviral mesh has not been placed on the structure, wait until the hurricane has passed to do so.
- (ii) Any seedling trays kept in the greenhouse should be taken to a secure location.
- (iii) Clean and deepen the trenches around the greenhouse. All of the soil that is removed must be placed over the bottom of the antiviral mesh to secure it against the heavy winds.
- (iv) Note that is cheaper to replace the plastic than the whole structure. If the plastic is already set up on the greenhouse, be ready to remove it if approaching winds are strong. This will reduce wind pressure under the structure.
- (v) Make sure the water tanks are completely full. This way, they will be heavy enough to withstand strong winds.
- (vi) Before the storm, be sure to apply a fungicide/bactericide to your crop. Use a systemic fungicide. This should be repeated following the storm.

4.4 Livestock

Jamaica has a fairly vibrant livestock sector comprising poultry, beef, dairy, pork and small ruminant production. Over the years, however, the livestock sub-sectors have had mixed fortunes. The country is nearly self-sufficient in poultry products and pork. In fact, the pig industry has suffered from a glut during the past two years due to the expansion in pig rearing over the past decade. On the other hand, there has been a significant reduction in the production of beef and dairy cattle over the past 20 years, following the adoption of trade liberalization policies¹⁷ in the early 1990s. Small ruminant (sheep and goat) production is currently way below demand, with an estimated 69 percent of annual demand being met by imports¹⁸. Table 7 shows the fluctuation in livestock sub-sector production in recent years.

16. USAID Protected Agriculture Manual (2008)

17. Parke, Aaron (2010). Feasibility Study on the Optimal Number, Location and Operation of Abattoirs in Jamaica.

18- FAO, Ministry of Agriculture and Fisheries, (2011). National Consultation on Jamaica's Livestock Sector.

Table 7: Livestock Production

Particulars	Unit of Measurement	2009	2010	2011	2012	2013p	2013/2012
Livestock Slaughter	Heads						
Cattle	"	21 009	20 404	21 218	21 495	20 790	-3.3
Hogs	"	121 954	108 568	108 961	142 716	108 936	-23.7
Goats	"	43 160	49 085	56 498	54 694	52 682	-3.7
Sheep	"	805	400	852	1 296	1 144	-11.7
Meat, Fish & Dairy							
Beef & Veal	000kgs	5 426	5 264	5 621	5 800	6 221	7.3
Pork	"	8 958	7 973	7 110	9 490	8 998	-5.2
Goats Flesh	"	867	937	1 316	1 094	929	-15.1
Mutton	"	17	11	23	32	24	-2.5
Poultry	"	104 502	100 637	101 526	102 167	101 933	-0.2
Aquaculture (Tilapia, Shrimp)	Tonnes	5 141	4 184	1 150	644	836	29.8
Marine (Fish, Conch, lobster, Shrimp)	"	13 205	12 314	14 208	10 494	n/a	n/a
Egg	Million	128.5	109	137.5	170.2	125	-26.6
Milk	Million Litres	14	12.5	12.4	12.9	12.3	-4

n/a - not available, p – preliminary. Discrepancies in table due to rounding.
Source: ESSJ 2013 from MOAF and MOH

Impact of Extreme Weather Events

Damage to the livestock sector from the passage of Hurricane Dean in 2007 was estimated at J\$40 million, which was relatively low in comparison to that for domestic crop production. Losses were greatest in the parishes of Hanover and St. Thomas, which, when combined, accounted for 50 percent of the losses to the sector. The widespread dislocation of electricity and water supplies arising from the passage of the hurricane impacted dairy producers, particularly those in southern parishes. Some producers were directly impacted and others indirectly through the suspension of milk purchases by the distributive trade. As such, the major losses to the sector arose from:

- (i) Deliberate reduction in production by reducing feed to cattle to forestall dumping of milk,
- (ii) Reduction in production by cows due to lack of drinking water supply,
- (iii) Absence of JPS electricity or standby generators; thus, once per day hand milking,
- (iv) Structural damage to milking parlours at WINDALCO, necessitating pooled, once-per-day milking at common site, and
- (v) Dumping of milk due to non-collection.

The passage of the hurricane resulted in moderate damage to the poultry sub-sector. Small poultry farmers, which account for approximately 30-35 percent of national production, experienced the worst damage. It is estimated that prior to the hurricane small farmers had about 2.5 million birds in production and lost approximately 20 percent (500,000 birds) of their birds as a result of the hurricane. On the other hand, large farmers suffered minimal damage as they only lost approximately 150,000 birds. However, other problems related to the health of the birds resulted in further losses.

Tropical Storm Gustav resulted in damages to the livestock sector estimated at J\$29.39 million. Over 1,545 farmers were affected, with Clarendon having the highest number of affected farmers, sustaining damages totalling J\$12.83 million.

Damage to livestock from Tropical Storm Nicole was estimated at J\$32.4 million. The most significant loss was recorded for the parish of St. Catherine (J\$15.79 million, close to 50 percent of overall loss across the country), followed by St. Andrew (J\$3.1million). Some 165,000 birds were lost overall. St. Catherine was the worst hit, accounting for 100,000 birds lost. Following the impact of Hurricane Sandy in 2012, the gross output for the animal farming sub-industry declined by 1.1 percent during 2013.

Biophysical Vulnerability

Results of the assessment of the effects of climate variability on the livestock sub-sector revealed that animals are susceptible to death due to exposure to wind, excessive rainfall and drought. Chickens are particularly susceptible to excessive cold and heat as well as flooding. Drought leads to a low production rate in livestock. The death of cattle translates into a scarcity of milk. As a result of excessive rainfall and flood, small ruminants including goats and sheep are highly susceptible to foot rot disease and this also contributes to the livestock mortality rate.

Socio-economic Impact

These losses in the livestock sub-sector, though less than that of domestic crops, are significant and should not be underestimated, as this industry contributes significantly to the livelihoods of many small farmers and householders. Many small-scale poultry farmers and cattle farmers also suffer from the secondary effects of storms, such as the loss of electricity and water in the aftermath of a storm.

Adaptive Capacity

The Ministry of Agriculture has introduced new and more resistant varieties of goat and sheep to strengthen livestock production. In the case of chickens (which are raised by many small farmers), adaptation to projected rising temperatures is of great concern. Generally, farmers should seek to establish farm buildings away from flood prone areas as well as join their local farmers' group and establish a revolving credit fund to assist with hurricane damage recovery. The list below outlines some "easy to do" adaptation strategies or practices that can strengthen the sector's resilience to climate variables.

Easy to do:

- (i) Adjust ventilation systems for bird coops using drapes, or compartmentalise coops,
- (ii) Adjust wattage of bulbs (40w vs. 100w) - difference in heat,
- (iii) Extend coops to provide more ventilation per bird,
- (iv) Develop a rearing calendar that includes timing of hurricane preparedness tasks to be completed by the end of May,
- (v) Regularly prune shade trees to prevent heavy overhanging branches from breaking and falling on livestock,
- (vi) Always ensure that you have more than one week's supply of feed, water, medication, pesticides, fertilizer and other supplies in storage, and
- (vii) Practice rainwater harvesting to ensure livestock have an adequate supply of water during periods of drought.

4.5 Summary of Vulnerabilities

The information presented in this chapter shows that all the agricultural sub-sectors are susceptible to the negative effects of storms and hurricanes, although the level of damage ranges from severe to moderate (Table 8). The eastern and southern parishes have notably suffered the bulk of losses from these events. Eastern parishes (St. Mary, St. Thomas and Portland) are particularly susceptible to hurricanes and storms. Southern parishes have also been affected by such hydro-meteorological events, but are also vulnerable to drought conditions.

Banana production is severely affected by storm events, given the ease of trees bending and breaking during gusty winds, and the situation of large banana acreages in eastern parishes, which have generally felt the brunt of these storms. Coffee production is also situated largely in the same geographic belt, and while loss of berries from storms has been significant, the damage is not as catastrophic as for banana, as the trees are not lost.

Cocoa production has suffered from both storms and drought. The sub-sector is weak in comparison to other export crops, and these events will have a debilitating impact, setting back efforts to resuscitate the industry. In the

case of sugar cane, storm events are likely to result in reduced productivity and thus lower sugar output, which is a problem for an industry that already has challenges with low productivity.

The domestic crop sector is severely impacted by storm and drought events. Much of the sub-sector is located in southern parishes, which lie in the traditional hurricane path and which also receive the least rainfall. As the sub-sector is dominated by small farmers, vulnerabilities are further exacerbated since these farmers have limited resources to prepare for, and recover from, such occurrences. Damage to the domestic crop sector will also result in food shortages and higher prices for local consumers.

These weather events have not impacted the protected agriculture and livestock sub-sectors to the same extent as the other sub-sectors mentioned. Preparatory measures may be more advanced in the former but they remain vulnerable, as individual losses in those sectors can easily exceed that for the other sub-sectors, given the higher investment costs inherent in greenhouse and livestock production.

Table 8: Vulnerability of selected crops and livestock based on two hurricane events

Agriculture sub-sector	Hurricane Ivan (2004)	Hurricane Dean (2007)
Banana	Entire crop (both for export and domestic consumption) damaged. Major exporter ceased exporting. 8,000 people out of work for 6-9 months until crop production resumed.	95% of suckers damaged 85% of standing crop down Losses of J\$525million
Coffee	Loss of berries in 45% of coffee producing areas and destruction of 5% of coffee trees. Some farmers ceased production due to expense of insurance coupled with low world prices.	Severe damage to Blue Mountain and other varieties J\$855million in losses
Sugar Cane	Broken and uprooted canes as well as flooding in large areas. This led to reduced sugar content, decreased sugar yield and increased processing costs.	2007-2008 crop reduced by 21% J\$802million in losses
Cocoa		2007-2008 crop severely damaged. J\$-100million in losses
Livestock	Poultry, goats and pigs were most affected by Ivan and milk production decreased due to the death of dairy cattle. J\$30M loss in dairy sub-sector	20% loss by small farmers; J\$13.07million in losses by dairy sub-sector
Protected Agriculture	Greenhouses and crops destroyed.	J\$52.47million in losses

4.6 Projections

Various studies and models have predicted changing climate parameters for areas in which the selected agricultural sub-sectors are located. These changes will not only result in frequent extreme weather events as described in this and previous chapters, but will also result in adjusted or new growing climates. According to the CARIBSAVE Climate Change Risk Atlas Study (2012), while damage from hurricanes is a threat, the comparative effect of 'shifting climate zones' on production has been forecasted as significantly more dangerous for high value crops like banana, coffee, and sugar cane. Furthermore, the ecocrop¹⁹ model and the 2012 State of the Jamaican climate²⁰ predict that the local geographic suitability for certain agricultural sub-sectors in the future (2030, 2050, and 2080) will be different from the current situations. Crop suitability and yields in present locations will be impacted by forecasted decreases in precipitation and increases in temperature.

19. Parke, Aaron (2010). Feasibility Study on the Optimal Number, Location and Operation of Abattoirs in Jamaica.

20. FAO, Ministry of Agriculture and Fisheries, (2011). National Consultation on Jamaica's Livestock Sector.

5.0 Case Studies

5.1 Vulnerability Case Study: Comma Pen Farmers, St. Elizabeth

The information presented in this case study is an extract from a sociological report and feasibility study (Bedasse, 2012), which looked at the feasibility of irrigation in Essex Valley, St. Elizabeth. The study reported on a December 2011 survey of 294 farmers in Comma Pen St Elizabeth, to establish baseline data for an Irrigation Feasibility Study²¹.

Demographic information

The Comma Pen community consists of mostly male farmers (69.53%), who are between the ages of 31 and 60 years. The majority of farmers (87.9%) earn less than J\$50,000 per month from farming activities. Farm sizes are skewed to the smaller end, with approximately 25 percent being less than half an acre and between half an acre and one acre, respectively. With the exception of one farmer, the farmland is used mainly to plant crops. Farm produce is used primarily for sale (90.77%) and is the farmers' main source of income. A small proportion of farmers cited consumption of farm produce as the main purpose for production (7.69%). Animal consumption was also mentioned as a reason for production.

Main problems faced by farmers in Comma Pen

The lack of irrigation water (98.28%) was identified as the overwhelming problem being faced by farmers in the Comma Pen community. Currently, rainwater (54.94% of the total) is the main source of irrigation for most farmers. Tank water also plays a significant role, and was identified by 17.6 percent of farmers as their current source of irrigation water. Approximately 18 percent of farmers have to purchase water from trucks to irrigate their farms. The bulk of farmers (96.43%) would expand their farms if adequate irrigation systems were put in place. Most would add between one (24.3%), two (22%) and three (17.3%) additional acres. Such an improvement would call for additional equipment, with most farmers requiring irrigation pipes (67.12%) and sprinklers (29.68%).

Coping Strategies – example of the Powell Farm

After the land is weeded, guinea grass is spread over it for moisture retention. As this farmer germinates his tomato seeds (bought at the farm store) in trays, his planting regimen varies according to the season. During the summer, he “drills” the soil with a hoe to be able to retain water better but during the rainy season the soil is “punched” with a machete. The fertilizer is put into the hole and left to dissolve properly before the sucker is put in if the “drill” method is used. If the “punch” method is used, the fertilizer is applied after the plant grows to a particular size and water is available. When the suckers are placed in the ground, they are watered individually with a pan if it is not raining. After the tomato plant gets to a particular size, there is no watering by hand as this action can damage the fruits. The farmer is now dependent on rainfall.

Tomatoes are left to grow for three months and then the harvesting of the fruit begins. One crop usually produces two “pickings” and in good weather conditions the crop lasts some two months. The farmer advises against using seeds from the tomatoes, as the yield will not be good. Hybrid seeds are used and only weather (heavy rainfall) affects the yield. During the summer months (June, July and August of 2010 and 2011) of the period studied, the weather was very favourable for tomato production (right amount of rainfall) and the farmers were hopeful that this trend would continue, while accepting that it could no longer be predicted with any degree of accuracy. Farming, the farmer concluded, had become a very risky business.

Despite the fact that the farmer has a big tank, experience has taught him to practice water conservation. When there is no rain, water is pumped from the main tank to a smaller one in the field and water is applied to the crops from a “dipping pan.” In some cases, a 55-gallon drum is also used for rainwater catchment. See pictures below (Figures 3, 4, 5).

21. Adapted from OAS/ODPEM, 2010. Economic and Community Vulnerability Assessment of Climate Change in Jamaica.



Figure 2: Rainwater Harvesting Tank - Comma Pen, St. Elizabeth



Figure 3: Field Water Tank in Comma Pen, St. Elizabeth



Figure 4: Field Water Drum and mulching with guinea grass

Production of escallion and other crops in Comma Pen

Escallion farmers in the Baseda area of Comma Pen report that during the 1980s and 1990s when they had access to National Water Commission's (NWC) domestic water supply, the areas now in ruinate were farmed. They also attribute their devotion to escallion farming to the fact that it is the most drought-resistant of crops (especially the new white variety). Large amounts of cauliflower and broccoli were once planted by these same farmers when they had access to water.

If the farmer cannot afford to purchase water, he plants and "prays" for rain. If water is available, 200lbs of escallion planted is expected to yield 500lbs. However, if water is insufficient, 200lbs escallion planted will yield 200-300lbs. If the drought is extreme, and there is no water in his tank built to harvest rainwater, the farmer will try to buy a small truck of water to prevent the escallion from dying. At the time of this survey (January 2012), farmers paid J\$2,500 for 100 gallons of water, while scallion was costing higglers J\$25-\$30/lb. The price at the time was much higher than in 2011, (when escallion cost J\$10/lb), due to the Christmas holiday season coinciding with elections and a four-month drought that had caused shortages.

The desk review revealed evidence of a decline in the production of cucumbers in the area, and reasons for this were sought. Farmers explained that cucumber had been one of their main crops for many years. However, for over five years farmers in Comma Pen have stopped planting this crop due to extensive losses through "burning of leaves," which is still unexplained. The farmers are unsure whether the brand of seeds or weather elements are to blame.

Climate Change

The threat of natural disaster was widespread, with farmers highlighting hurricanes (69.63%) as the most significant natural disaster threat, followed by flooding (15.42%) and droughts. Farmers say far less rain than usual fell during the years 2000-2009. Although the last two years (2010 and 2011) had reasonable rainfall, they recognize that they can no longer depend on the traditional rainy seasons for planting. The traditional seasons were May to June and September to October.

Most farmers also specified the rainy season as the best time for planting crops. Farmers are of the view that the most favourable times for planting crops have changed over the years (91.8%), with over 50 percent citing the 'shift to the start of the rainy season' and the 'increase in the number of hurricanes' as the two main contributors. Farmers also highlighted the shift in the start of the dry season as another possible reason for this change in the most favourable times for planting.

Farmers claim that there have been no deliberate changes to planting seasons to accommodate these changes but at the same time they speak of planting "right through" the year, especially if the rains come, regardless of the month and hoping for the best. Although rainwater is the preferred mode of watering, the experience during 2000-2009 was that excessive rain also damaged the crops (especially tomatoes and traditional escallion) and caused extensive losses. For the previous two years, the weather variability had been bad but there was surprisingly

moderate weather in July and August during both 2010 and 2011. Tomato is usually planted three times during the year (in June, July and September) but was planted during July and August in those two years with a most satisfactory yield.

The traditionally planted red and white escallions were well known for their strong flavour and were always sought after, thus creating fluctuating price trends depending on the demand/supply ratio. Over the previous twelve years, farmers had begun to notice a downward trend in the yield of this crop and attributed it to climate change. The crop could not withstand the heavy rainfall recorded between 2000 and 2009, and farmers suffered serious losses. A new variety of white escallion from Costa Rica was introduced in 2005 through the Agricultural Support Services Project (ASSP), and although the flavour cannot be compared to that of the traditional red and white varieties, it has proven resistant to bad weather and also produces a better yield. Additionally, it can be harvested in six weeks while traditional escallion required three months.

Consequently, fluctuations in escallion prices are not as erratic as they used to be. Farmers also prefer this variety because they feel that the crop will not be easily lost. Although the flavour of the new variety is not as strong as traditional ones, the sale of the commodity is still guaranteed.

Interestingly, this new variety of escallion cannot be planted in the same field as traditional ones, as it will overwhelm them. This new escallion was introduced to farmers in seed form, which they had never seen before, as some of the escallion crop being harvested had always been used for planting. Farmers were instructed to “pull” all of the crop and purchase seeds to replant. However, this mode of planting escallion never materialized as the farmers applied their traditional technique, which has worked well. The traditional escallion is still planted but on a small scale and especially for home use. Farmers are not sure if the “army worm” pest that attacks the new variety of escallion is a result of climate change but have not ruled this possibility out.

Disease and Pests

Farmers have a regular regimen for disease control. This entails use of a basic spray every seven days to keep away regular pests, as well as application of aggressive treatment if an unusual pest is noticed during their inspections. Pesticides utilized include Lan 8 (active ingredient: Methomyl) and Pegasus (active ingredient: Diafenthiuron). There has been an “army worm” pest associated with the white escallion currently being planted. This pest is difficult to control and wipes out an entire crop. The susceptibility of the escallion (which has been the main crop of Comma Pen farmers for many years) to the armyworm pest has contributed to farmers inclusion of other cash crops for diversification.

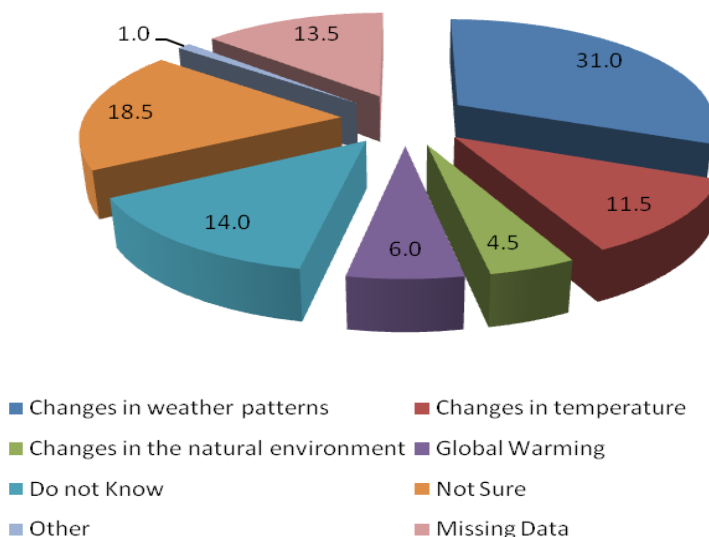
5.2 Case Study – St. Elizabeth (Flagaman) and Westmoreland (Darliston) Farmers

This case study is adapted from the OAS/ODPEM 2010 Community Vulnerability Assessment,²² which aimed to raise awareness of policy makers to the importance of considering precautionary mechanisms to cope with abrupt climatic events and to support adaptation strategies at the local level for long-term climate change impacts. Long-term effects of climate change such as droughts, rising atmospheric and water temperatures, unpredictable rainfall patterns, and increasing pests represent a considerable challenge for Jamaica. Through focus groups and surveys, people from two farming communities in Jamaica (Flagaman in St. Elizabeth and Darliston in Westmoreland) identified a number of these events as currently taking place and were able to relate these events to their changing livelihoods and incomes. The findings of the focus groups and surveys highlighted that between 2000 and 2010, 72 percent of farmers had noticed that the crop season was changing, and 61 percent had felt changes in crop yield.

Farmers’ Perception of Climate Change

Many respondents in the survey (32.5%) either were not sure or did not know what climate change was. Together they made up the largest group of responses. The majority of those who gave their perception of climate change defined it as changes in weather patterns (31%), while approximately one tenth perceived climate change as changes in temperature. Other definitions included changes in the natural environment and global warming. Figure 6 summarizes these findings.

22. Adapted from OAS/ODPEM, 2010. Economic and Community Vulnerability Assessment of Climate Change in Jamaica).

Figure 5: Perception of Climate Change**Identified Impacts of Climate Change**

Farmer participants were asked to identify the three major impacts of climate change affecting their respective farming communities. In order of priority, the participants listed the following:

- Drought** – Droughts are now longer and unexpected. Droughts now occur at any time in the year and are no longer restricted to a particular period. This results in lower yields and higher production costs. This affects diet, as foods are now consumed on the basis of availability.
- Rainfall Pattern** – Rainfall is now unpredictable, and hurricanes more intense; this leads to destruction of crops, which further creates crop shortages.
- Rapid Changes in Temperature** – This particularly affects poultry farmers, as it results in the death of birds and low egg production. There are also human health implications from sudden and rapid temperature changes.
- Crime** - Due to the impact of low agricultural production on livelihoods, there has been a shift from vegetable production to cash crops, such as marijuana. Droughts are not likely to affect marijuana farmers because they have devised ways of harvesting within six weeks with high technology farming practices. Similar technology cannot be employed in vegetable cultivation due to cost of the technology and relatively low returns.
- Pollution from Chemicals** – Some chemicals lead to soil erosion, completely killing the root of plants and triggering erosion on denuded slopes when it rains.

From the discussion among participants, it was evident that definitions of climate change were linked to areas of economic activity. Farmers also readily linked climate change with temperature and rainfall.

Recommended Strategies

To better cope with these impacts, the group recommended the following strategies:

- Increased Public Awareness and Education** – Less educated persons are entering farming and literacy levels are generally low. Participants felt that without the appropriate education, they will not understand the issues and the implications of their actions.

- b) Drought Management
 - Replant trees
 - Install drip irrigation
 - Improve water storage via black tanks
 - Improve agricultural practices (e.g., mulching)
 - Intercropping - vegetative barrier
- c) Rainfall Pattern
 - Contouring hillsides including tree planting
 - Re-afforestation
 - Proper disposal of garbage vs. drain clearing, will positively impact marine environment
 - More attention to preparedness and information from ODPEM at individual and community level
- d) Rapid Changes in Temperature
 - Adjust ventilation systems for bird coops using drapes, or compartmentalize coops
 - Adjust wattage of bulbs 40w vs. 100w - difference in heat
 - Extend coops to provide more ventilation per bird
 - Preserve marine life

Coping strategies followed by farmers

Farmers were given the opportunity to highlight the coping strategies that they have implemented to deal with the changes they have noticed between 2000 and 2010. Some of the highlighted strategies were generic while others were specific to the area of livelihood activity – farming. For instance, water storage was the general strategy employed to deal with less rainfall and drought. Other farming-specific coping strategies relating to changes in crop season and crop yield included planting of more crops, and the use of more fertilizers to boost output. Beyond irrigation, farmers felt that there was a need to address indirect issues that may be linked to the unpredictability of the weather. These included expanding the market for agricultural produce, especially during periods of glut. An improved market, they said, can help reduce waste, which currently stands at about 30 percent of their output.

The farmers generally recognized the need for more coping strategies to minimize the impact of changing climate conditions on their livelihoods. For example, maintaining similar crops year by year is a livelihood decision for the farmers in St Elizabeth. They strongly contend that escallion is important to the farmers and homemakers in Flagaman. In Darliston, a number of coping strategies, such as crop diversification and changes in crop season, were articulated during the focus group sessions, given the recognition that there were sustained weather and environmental changes that forced farmers to respond to these changes. Despite similarities in the impact of climate change on both farming communities, adaptation strategies differed slightly, as residents of Flagaman did not readily seek to diversify crops. The two most popular coping strategies were trucking in additional water and using guinea grass as a mulch to minimize loss of soil moisture.

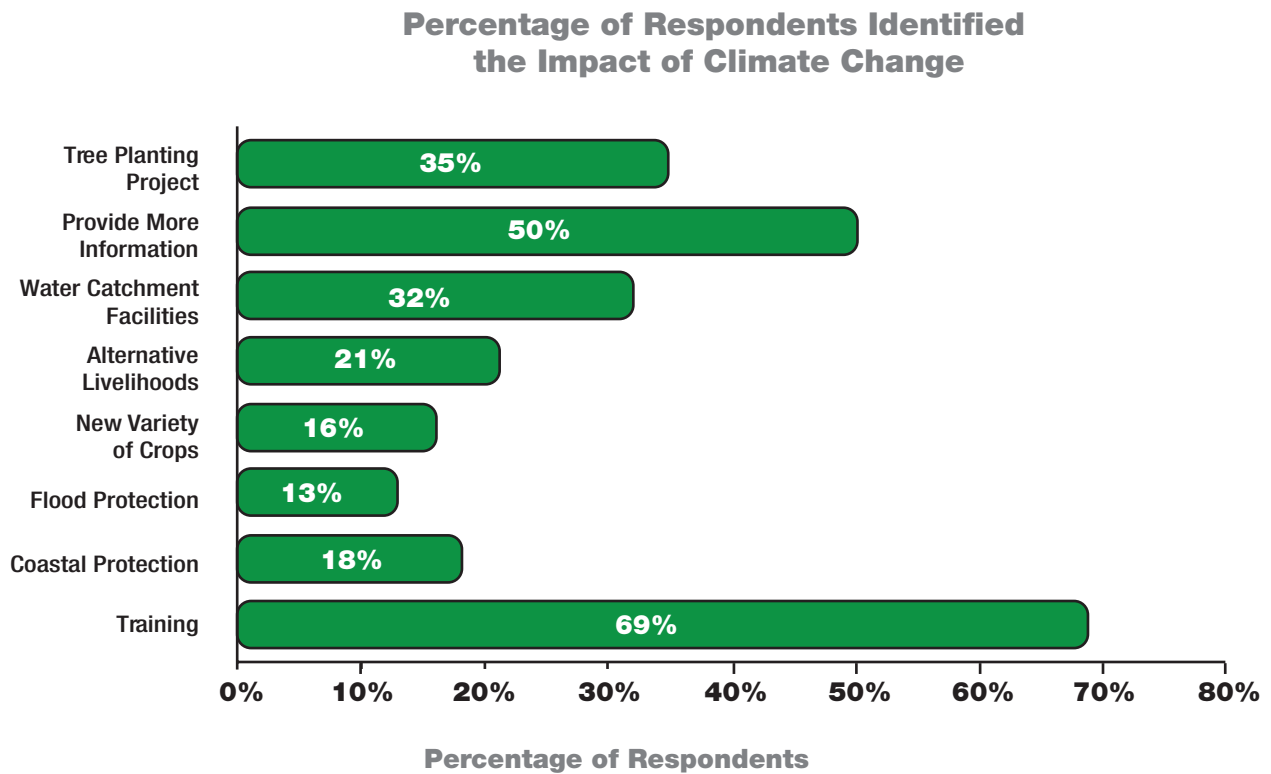
The issue of pesticides sparked a debate amongst the farmers, and at the end there seemed to be an acknowledgement that the situation is one where there is no safe outcome. The farmers felt that long dry spells lead to worm and pest infestation, which usually means that pesticides have to be applied. Additionally, without pesticides crop yields decrease, thereby affecting local livelihoods.

In other sessions the mood was more resigned and there was a general feeling that there is hardly much that anyone can do to cope with, or adapt to, climate change. While there seemed to be a high level of success from employing these strategies, participants felt they were merely superficial and “just for survival”.

Projects to reduce the impact of climate change proposed by communities

Survey questionnaires were used to ask the respondents about the kinds of projects that would be most useful to reduce the impact of climate change on their respective communities. Sixty-nine percent of respondents felt that training in climate change issues would help to reduce anticipated impacts, while 50 percent thought that the provision of more information is required. The dissemination of information is important for raising awareness to increase the knowledge base of farmers and fisher folk. Additionally, a strong consensus exists between respondents who identified tree-planting projects (35%) and their belief that deforestation is a significant cause of climate change in Jamaica.

Figure 6: Projects that respondents identified to reduce the impact of climate change



6.0 Potential Solutions to Adapt to Vulnerabilities

These recommendations were compiled from various studies:

General (Impact of Climate Change on Agriculture – ECLAC, 2009)

- 1) Educate farming community about the global, regional and national trends in climate change, weather, and climate variability, using information prepared by the met services in formats that are easily understood by the farming community
- 2) Public and private extension services need to develop education programmes
- 3) Conduct livelihood assessments in communities – Adaptation to climate change will bring opportunities for new livelihoods
- 4) Employ more and improved practices for irrigation to better manage the provision of water to crops - export agriculture vs. domestic rainfed agriculture (energy cost/water cost/agricultural cost)
- 5) Enforce proper zoning of land for agriculture to avoid hillside slopes
- 6) Protect agriculture by using trees and shrubs as windbreaks
- 7) Locate greenhouses in protected areas with disaster preparedness plans that allow for quick disassembly to minimize wind damage
- 8) Improve ventilation of chicken houses
- 9) Ventilate all animal houses – barns for cows and horses
- 10) Develop and expand the range of crops to meet the needs of the domestic food supply, given the projection for warmer climates in tropical areas that could compromise productivity and lead to higher prices and increased importation of food.

Sugar Cane (Impact of Climate Change on Agriculture – ECLAC, 2009)

- 1) The principal adaptation to climate change for sugar cane will be improved management of the application of water in the growing cycle and research into varieties that are more suitable to high temperatures. In the case of water, the modelling results suggest the increased imperative for the employment of efficient irrigation systems.
- 2) Efficient rainwater harvesting, storage and conservation
- 3) Renewable energy resources
- 4) Research into more heat resistant plants

Coffee (Coffee Leaf Rust Workshop – Louis Campbell, CIBOJ)

- 1) Implement a national CLR control programme
- 2) Breed a rust-resistant variety with desirable (Blue Mountain) taste profile
- 3) Intensify research work on the identification, epidemiology and control of local races of the pathogen
- 4) Increase collaboration with regional universities and the Coffee Research Institute
- 5) Step up collaboration with chemical companies
- 6) Conduct research aimed at improving Arabica Typica's resistance without reducing its quality traits

Domestic Crops (The Economics of Climate Change in the Caribbean – ECLAC 2011)

- 1) Use water-saving irrigation systems and water management systems (e.g., drip irrigation) to offset the loss due to the shift in the precipitation pattern (tubers – drip irrigation systems – 1000-gallon tanks designed for 0.1-hectare farms)
- 2) Mainstream climate change issues into agricultural management
- 3) Repair/maintain existing dams
- 4) Alter crop calendars for short term crops
- 5) Adopt improved technologies for soil conservation
- 6) Establish systems of food storage
- 7) Promote water conservation – install on-farm water harvesting off roof tops

- 8) Design and implement holistic water management plans for all competing uses
- 9) Build on-farm storage (ponds, tanks, etc.)
- 10) Improve agricultural drainage
- 11) Research and development
- 12) Mainstream climate change issues into planning
- 13) Adopt climate-sensitive farming systems
- 14) Raise awareness and increase communication

Domestic Crops (Roots and Tubers and Vegetables) (OAS/ODPEM 2010)

- 1) Changes in farming practices:
 - a. Introduction of higher yielding varieties
 - b. Studies of crops resistant to floods, higher temperatures and drought, and the dissemination of such crops
 - c. New irrigation schemes for cultivation of arid lands
 - d. Appropriate use of fertilizers
 - e. Implementation of pest and disease control systems
 - f. Reduction of soils and surface water contamination effects caused by indiscriminate use of pesticides and herbicides
 - g. Move climate-sensitive agriculture to highland regions with more water
- 2) Disseminate weather index-based insurance for crops. Insurance of this kind allows farmers to better manage risks, and encourages investment in agricultural activities that require higher initial investment
- 3) Through government agencies, provide appropriate information on climate change
- 4) Implementation of international standards governing the use of agrochemicals
- 5) Promotion of agro-forestry, perennial crops, and conservation tillage
- 6) Water management:
 - a. Improve water management
 - b. Control demand for water through more efficient use
 - c. Construction of infrastructure to improve water management
 - d. Water conservation education campaigns

Recommendations from farmer parish workshops

(Economic and Community Vulnerability Assessment of Climate Change in Jamaica - OAS/ODPEM, 2010)

- 1) Increase public awareness of, and education about, climate change
- 2) Drought Management:
 - a. Replant trees
 - b. Install drip irrigation
 - c. Improve water storage via black tanks
 - d. Improve agricultural practices (e.g., mulching)
 - e. Use intercropping methods – vegetative barrier
- 3) Rainfall Pattern
 - a. Contour hillsides, including tree planting
 - b. Re-afforestation
 - c. Proper disposal of garbage vs. drain clearing will positively impact marine environment
 - d. More attention to preparedness and information from ODPEM at community and individual level
- 4) Rapid Changes in Temperature
 - a. Adjust ventilation systems for bird coops using drapes, or compartmentalize coops
 - b. Adjust wattage of bulbs, 40w vs. 100w – difference in heat
 - c. Extend coops to provide more ventilation per bird

7.0 Conclusions

Climate variability has resulted in increased vulnerabilities for Jamaica's agricultural sector, given increased occurrence of storm/hurricane events, shifting rainfall patterns and inherent weaknesses in the sector. In the past decade, the agricultural sector has been negatively impacted by nine hurricane/storm events. In view of the fact that these events have occurred in six of the past ten years alongside situations of medium-to-severe drought conditions in some years, the agriculture sector can expect to face some type of weather limitation at least every three years.

These weather events have resulted in significant losses in monetary terms, including lost production, income, infrastructure, and foreign exchange earnings, as well as the additional cost of the recovery process. They have also led to temporary food shortages and higher prices for the local consumer.

Current climate modelling is predicting warmer temperatures, reduced rainfall, longer drought periods, increased number of wet days (intense rainfall), increased number of hurricanes, and sea level rise. Hence, the indications are that the experience of the past ten years will continue and perhaps even worsen. Moreover, the local climates we are accustomed to may change over time and have a more serious impact on the agricultural sector than extreme weather events.

As highlighted by the case studies, farmers already are perceiving changes in the climate, although they may not fully understand what is occurring or what they should do to manage those changes. Some farmers have been adapting to the new circumstances, with mixed results. In general, farmers will need much guidance to implement practices that protect their livelihoods from extreme weather events and the effects of climate variability.

Against this background, the agricultural sector must become more knowledgeable about weather and climate signals and put climate change and climate variability theory into practice. This means analysing the potential impact of climate forecasts such as El Niño and La Niña, and preparing farmers for the potential impacts of adjusted climate conditions and extreme weather events. In addition, public and private sector entities should try to mainstream climate change considerations into all agricultural sector and sub-sector policies, strategies and action plans.

Information on preparatory measures and best practices in relation to managing the effects of weather events exist, as stated on the Rural Agricultural Development Authority (RADA) website and in the Agricultural Disaster Risk Management (ADRM) Plan. However, there is a need to more aggressively promote, communicate, and thus implement these measures. Preparedness of the agricultural sector for such events should become the norm in the same way that householders have become proficient in preparing for hurricanes. Additionally, communicating for disaster preparedness through community communication plans, as advocated by the ADRM plan, should facilitate not only an early warning system but spread information on best practices long before the disaster event.

The sector should also review the method of reporting on losses from extreme weather events and look at the vulnerabilities associated with the losses, in addition to the monetary value of those losses. Such reports could also provide recommendations for the affected areas to mitigate the scale of loss from future events. The process would then become more proactive in strengthening the sector's ability to deal with these recurring situations.

There is a need to look at possible scenarios of higher temperatures and determine ways to treat various crop and livestock sub-sectors that may be affected by such changes. The sector should consider farming techniques used in more arid areas of the world, such as conservation agriculture (e.g., minimum tillage) and new approaches to water management. The island's climate may become dryer and, if so, the sector may need to adopt different practices for a new climate. For example, the widespread practice of slash and burn for clearing agricultural land should be strongly discouraged, possibly through the use of fines, given the potential for bush fires during dry conditions.

Finally, the entire value-chain will need to more seriously consider incorporating insurance into the modus operandi. The possibilities include building insurance into marketing contracts and loans, to help protect the various parties from the known losses that can result from extreme weather events.

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Appendix 1: Qualitative Vulnerability of Selected Agriculture Sub-sectors in Jamaica

Evaluation of exposure to climate signals/stimuli: Which climate stimuli do we expect in Jamaica?

Overall climate becomes more seasonal in terms of variability through the year in temperature, and more seasonal in precipitation²³.

Climate change signals/stimuli	
Temperature Changes	Temperature increases by 1.1°C by 2030 and 1.7°C by 2050 ²⁴
Increased intensity of rainfall	Rainfall decreases over the years ²⁵ . Rainfall decreases from 1846 millimetres (mm) to 1787 mm in 2030, and then to 1746 mm in 2050.
Extended drought periods	The number of cumulative dry months remains constant at three months ²⁶ . The driest month gets drier, with 58 mm of rain instead of 62 mm, while the driest quarter gets drier, with 9 mm of rain in 2050.
Changes in frequency of tropical storms	High risk of extreme weather events

Climate change signals/stimuli					
General climatic characteristic	Temperature changes	Increased seasonal intensity of rainfall	Extended drought periods	Changes in frequency of tropical storms	Sea level rise
Domestic Crops (Roots and tubers) (Vegetables)	<p>For 2030, the predictions show suitability as still very good, and excellent for sweet potatoes (low elevation)</p> <p>For 2050, an ongoing decline for Irish potatoes is predicted. Yellow sweet potatoes (high elevation) remain suitable. Ginger ends up in marginal conditions for crop development and would not have sufficient productivity. The crops most affected will be ginger and sweet potatoes (high elevation), with 25% - 47% declining suitability.</p> <p>Highly sensitive to changes in temperature and precipitation</p> <p>Pests multiply and diseases increase</p> <p>Decrease in precipitation and rise in temperature by 2080s will put crops under stress</p> <p>High temperatures trigger bacterial and fungal wilts in Irish potatoes</p> <p>Food security threatened</p>	<p>Increased precipitation and flooding lead to more favourable conditions for crop disease.</p> <p>Irish Potatoes: Blight disease; Sweet Yam: Fungal Disease; Ginger Rot Disease Foliage damage to ginger and turmeric as a result of water-logging, excessive run-off, soil erosion and/or leaching</p> <p>Unreliable/unpredictable rainfall patterns will affect product distribution, quantity and quality.</p>	<p>Increased pressure on water supplies for irrigation. (Irrigated agriculture depends on 75% of local water supply)</p> <p>High water and production costs for local food production</p> <p>Abandonment of wells due to increased salinity and unsuitable water for agricultural use</p> <p>Insect pest outbreaks: broad mite on Irish potatoes; beet army worm on escallion</p>	<p>Sensitive to strong winds</p> <p>Crop loss and flooding</p> <p>Inundation of production fields</p> <p>Food and insurance more expensive, and higher rates of interest for capital cost loans</p> <p>Threat to livelihood (agriculture employs 25% of population)</p>	<p>Saline water intrusion</p> <p>Coastal erosion</p> <p>Inundation in coastal rural farming communities</p>

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25. Ibid., p. 8.

26. Ibid., p. 8.

Climate change signals/stimuli					
General climatic characteristic	Temperature changes	Increased seasonal intensity of rainfall	Extended drought periods	Changes in frequency of tropical storms	Sea level rise
Protected Agriculture	Improved resistance to adverse conditions Rise in temperature will put crop under stress Threat to food security Threat to export earnings	Improved resistance to adverse weather conditions	Improved resistance to adverse weather conditions High water and production costs for local food production Abandonment of wells due to increased salinity and unsuitable water for agricultural use.	Metal and wood infrastructures sensitive to strong winds; Threat to livelihood	
Sugar Cane	Rise in temperature will put crop under stress Threat to export earnings	Increased precipitation and flooding lead to more favourable conditions for crop disease Low land productivity Reduced sugar content Decreased sugar yield Increasing processing cost Inadequate drainage after flood cause rotting Loss of canes Unreliable/unpredictable rainfall patterns will affect product distribution, quantity and quality	Scarcity of water for irrigation High water and production costs for local food production Disease Low land productivity Reduced sugar content Decreased sugar yield Increasing processing cost Loss in export earnings Abandonment of wells due to increased salinity and unsuitable water for agricultural use	Sensitive to strong winds High winds uproot sugar cane plants resulting in reduced yield and content Stalk breakage causing side shooting which impacts growth and contributes to poor quality canes Lodging (canes blown down); Canes 3-5 months old most vulnerable to stalk breakage (depending on variety)	Inundation in coastal farming communities
Banana	Good growing conditions in the more mountainous regions	Increased precipitation and flooding lead to more favourable conditions for crop disease Unreliable /unpredictable rainfall patterns will affect product distribution, quantity and quality	Scarcity of water for irrigation High water and production costs for local food production Abandonment of wells due to increased salinity and unsuitable water for agricultural use Decline in production output Loss of export earnings	Sensitive to high wind which breaks or uproots plants Crop loss and flooding Inundation of production fields Food and insurance more expensive and higher rates of interest for capital cost loans Threat to livelihoods	Inundation in coastal farming communities
Coffee	Rise in temperature will put crop under stress Heat brings insect infestation – thrips	Increased precipitation and flooding lead to more favourable conditions for crop disease Unreliable /unpredictable rainfall patterns will affect product distribution, quantity and quality	Scarcity of water for irrigation High water and production costs for local food production Decline in production output Loss in export earnings Disease: coffee leaf rust	Sensitive to strong winds Loss of berries Defoliation of coffee and shade trees Breaking up or uprooting of trees Severe root damage caused from uprooting and twisting of young 2-3 year old plants Scarring of coffee beans	

Climate change signals/stimuli					
General climatic characteristic	Temperature changes	Increased seasonal intensity of rainfall	Extended drought periods	Changes in frequency of tropical storms	Sea level rise
Cocoa	Rise in temperature will put crop under stress Heat brings insect infestation – thrips	Increased precipitation and flooding lead to more favourable conditions for disease Unreliable /unpredictable rainfall patterns will affect product distribution, quantity and quality	Scarcity of water for irrigation High water and production costs for local food production Decline in production output Loss in export earnings Stress to crop causing delay in growth High water and food production costs for local food consumption	Scarcity of water for irrigation High water and production costs for local food production Decline in production output Loss in export earnings Stress to crop causing delay in growth High water and food production costs for local food consumption	
Livestock	Animals under stress Mortality threatened Chickens susceptible to excessive cold or heat Inconsistent productivity of livestock due to variability in pastoral and water resources Food security threatened	Increased precipitation and flooding lead to more favourable conditions for disease Unreliable/unpredictable rainfall patterns will affect product distribution, quantity and quality Chickens susceptible to flooding Death of cattle and subsequent scarcity of milk Death of goats and pigs Foot rot disease for small ruminants including goats and sheep	High water and food production costs for local food consumption Abandonment of wells due to increased salinity and unsuitable water for agricultural use Animal death and low production rates	Damage to infrastructure Inundation of pastureland	Inundation in coastal farming communities

Evaluation of potential biophysical and socio-economic impacts: What does the combination of exposure and sensitivity tell us?

Bio-Physical					
General climatic characteristic	Temperature changes	Increased seasonal intensity of rainfall	Extended drought periods	Changes in frequency of tropical storms	Sea level rise
Domestic Crops (Roots and tubers) (Vegetables)	High temperatures trigger bacterial and fungal wilts in Irish potatoes Heat stress on crops Increased occurrence of pests New pests and spatial redistribution of pests	Inconsistent crop quality Significant yield loss New pests and spatial redistribution of pests	Crop planting delays Drought triggers diseases Increased insect and disease control Crop failure and significant yield loss	Hurricane and excessive rains trigger diseases Ginger susceptible to rhizome rot disease Foliage damage experienced by ginger and turmeric	Increased occurrence of pests New pests

Bio-Physical					
General climatic characteristic	Temperature changes	Increased seasonal intensity of rainfall	Extended drought periods	Changes in frequency of tropical storms	Sea level rise
Protected Agriculture	Reduction in land clearing to expand operations	Reduction in land clearing to expand operations	Reduction in land clearing to expand operations	Reduction in land clearing to expand operations Metal and wooden frames of greenhouse structure susceptible to wind damage	
Sugar Cane	Crop failure and yield loss, although more sensitive to changes in rainfall than temperature	Significant yield loss from extensive flooding – reduction in hectares harvested and deterioration in the conversion rate of cane to sugar	Drought stresses plant leading to reduced sugar content, and decreased sugar yield	High winds uproot sugar cane plants Wind effect impacts worse on some varieties Age of cane related to type of damage sustained	Significant yield loss on coastal plains
Banana	Increased occurrence of pests New pests BUT also creation of better conditions in the mountainous regions - Land availability may be an issue for relocation	Susceptible to black sigatoga disease	Crop stress affects and delays yield	Highly sensitive to effects of high-intensity hurricanes as high winds break or uproot plants. Most of the eastern coastal locations where bananas are grown at present are very vulnerable to the effects of hurricanes as well.	Biodiversity loss
Coffee	Increased occurrence of pests New pests		Coffee leaf rust (CLR) linked to periods of low precipitation Type of coffee grown extremely susceptible to CLR	Coffee and shade trees sensitive to high winds Mature and ripe berries affected by high wind	
Cocoa	Sensitive to high temperatures Mean shade temperature should be about 26°C with an allowance of 7°C above or below Without shade, cocoa suffers from 'tieback' caused by the sun's rays. An insect called thrips is attracted to unshaded cocoa			Sensitive to wind	
Livestock	Large-scale losses of cattle and chickens Lower reproduction rates of livestock	Foot rot disease (small ruminants including goat and sheep)	Lower reproduction rates of livestock Low milk production	Animal death due to exposure to wind and rainfall Large-scale losses of cattle and chickens Low milk production	

Socioeconomic					
General climatic characteristic	Temperature changes	Increased seasonal intensity of rainfall	Extended drought periods	Changes in frequency of tropical storms	Sea level rise
Domestic Crops (Roots and tubers) (Vegetables)	Loss of livelihood and income	Loss of livelihood and income	Loss of livelihood and income	Loss of livelihood and income	Loss of livelihood and income
Protected Agriculture	Protected agriculture ensures far less loss to farmers and presents an opportunity for mitigation of hurricane and drought. Increased opportunities for employment Increased opportunities for small enterprise development Attractive to youths	Protected agriculture ensures far less loss to farmers and presents an opportunity for mitigation of hurricane and drought. Increased opportunities for employment Increased opportunities for small enterprise development Attractive to youths	Protected agriculture ensures far less loss to farmers and presents an opportunity for mitigation of hurricane and drought. Increased opportunities for employment Increased opportunities for small enterprise development Attractive to youths	Protected agriculture ensures far less loss to farmers and presents an opportunity for mitigation of hurricane and drought. Increased opportunities for employment Increased opportunities for small enterprise development Attractive to youths	
Sugar Cane	Crop failure and significant yield loss Social stability and security in sugar-dependent areas threatened	Crop failure and significant yield loss Social stability and security in sugar-dependent areas threatened	Crop failure and significant yield loss Social stability and security in sugar-dependent areas threatened	Crop failure and significant yield loss Social stability and security in sugar-dependent areas threatened	Significant yield loss Social stability and security in sugar-dependent areas threatened
Banana		Difficult to get crop insurance because of high vulnerability Loss of livelihoods Loss of foreign exchange earnings		Difficult to get crop insurance because of high vulnerability Loss of livelihoods Loss of foreign exchange earnings	Loss of livelihoods Loss of foreign exchange earnings
Coffee	Loss of livelihoods Loss of foreign exchange earnings	Loss of livelihoods Loss of foreign exchange earnings	Loss of livelihoods Loss of foreign exchange earnings	Loss of livelihoods Loss of foreign exchange earnings	
Cocoa	Small farmers involved in cocoa production Loss of livelihoods Loss of foreign exchange earnings	Loss of livelihoods Loss of foreign exchange earnings	Loss of livelihoods Loss of foreign exchange earnings	Loss of livelihoods Loss of foreign exchange earnings	
Livestock	Loss of livelihoods and income	Loss of livelihoods and income	Loss of livelihoods and income	Loss of livelihoods and income	Loss of livelihoods and income

Adaptive Capacity: Which resources are available at the small- and medium/large-scale agriculture level?

Agriculture subsectors (Systems of interest)	Small-scale agriculture	Medium-large scale agriculture
Sector cross-cutting resources	Traditional knowledge National extension service No savings No access to risk insurance	
Domestic Crops (Roots & Tubers & Vegetables)	Forecasts are that overall root crop production is expected to be better for all decades up to 2050. Increased yield in escalation forecast despite projected changes in temperature and precipitation Use of weather data in crop planning Sustainable management of water resources Rainwater harvesting Drip irrigation systems Timing of crop establishment for drought mitigation Adopt damage-reduction strategies Adopt minimum tillage to reduce soil erosion Research climate-resistant varieties and produce seeds for production	
Protected agriculture	i) Establishment of Greenhouse Growers Association ii) Launch of project "Increased production of vegetables and herbs through the use of protected agriculture in the Caribbean." Achievements include: (a) assistance with construction of and support for greenhouses, water storage reservoirs, and needed instruments for selected beneficiaries to serve as demonstration sites; (b) an increase in trained extension officers, research technicians, and greenhouse farmers in best practices in greenhouse production; and, (c) development of manuals, videos and technical publications addressing greenhouse production-related subject areas. iii) Addressing of issues related to low production and productivity; high prices; inconsistent supply and variable quality. iv) Caribbean Agricultural Research and Development Institute (CARDI), MOAF, Jamaica Greenhouse Growers Association (JGGA), and the Rural Agricultural Development Authority (RADA) have intervened to provide a centralized marketing and distribution system, consumer and retailer differentiation of vegetables grown under protected agriculture, and protection of the industry from the competition from imported produce.	i) Establishment of Greenhouse Growers Association. ii) Launch of project "Increased production of vegetables and herbs through the use of protected agriculture in the Caribbean. Achievements include: (a) assistance with construction of and support for greenhouses, water storage reservoirs, and needed instruments for selected beneficiaries to serve as demonstration sites; (b) an increase in trained extension officers, research technicians, and greenhouse farmers in best practices in greenhouse production; and, (c) development of manuals, videos and technical publications addressing greenhouse production-related subject areas. iii) Addressing of issues related to low production and productivity; high prices; inconsistent supply and variable quality. iv) Caribbean Agricultural Research and Development Institute (CARDI), MOAF, Jamaica Greenhouse Growers Association (JGGA), and the Rural Agricultural Development Authority (RADA) have intervened to provide a centralized marketing and distribution system, consumer and retailer differentiation of vegetables grown under protected agriculture, and protection of the industry from the competition from imported produce.
Banana		Forecasts are that better conditions will prevail in the mountainous regions Farm locations can be changed depending on land availability Potential losses from hurricanes can be salvaged through resuscitation protocols, which must be applied within a particular timeframe
Sugar cane		Research on varieties that better withstand high winds and use the ones identified Ensure drainage systems are adequate Forecasts are that based on projected weather patterns, sugar cane yield will decline during the decade of the 2020s then increase steadily through to 2050

Agriculture subsectors (Systems of interest)	Small-scale agriculture	Medium-large scale agriculture
Coffee		Financial resource availability is a challenge for the small farmer to combat the various effects of climate change Proper agronomic measures are to be applied as research has found that healthy plants have the capability to resist attack from the CLR pathogen. Chemical measures can be applied as well Genetic control of the Arabica Typica, the predominant type of coffee grown, is important so propagation of hybrids discouraged
Cocoa		Cocoa Grower's Association formed, among other things to ensure the conditions are right for increased cocoa production and productivity.
Livestock	Introduction of new and more resistant varieties of goat and sheep to strengthen livestock production has begun. Adjust ventilation systems for chickens (birds), using drapes, or compartmentalize coops Extend coops to provide more ventilation/bird Adjust bulb wattage to cooler temperature	Introduction of new and more resistant varieties of goat and sheep to strengthen livestock production has begun. Adjust ventilation systems for chickens (birds), using drapes, or compartmentalize coops Extend coops to provide more ventilation/bird Adjust bulb wattage to cooler temperature



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