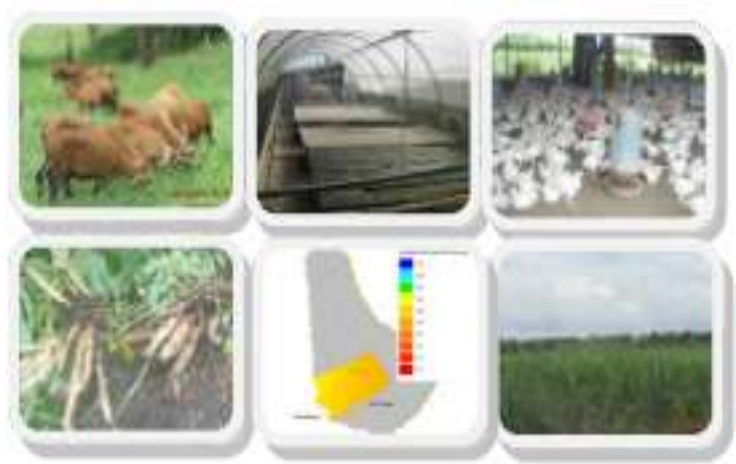
A VULNERABILITY AND CAPACITY ASSESSMENT OF THE FOOD ZONE OF BARBADOS



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and

Ministry of Agriculture, Food, Fisheries and Water Resource Management

Bridgetown, Barbados

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A Vulnerability and Capacity Assessment (VCA) of the Agriculture sector of the Food Zone of Barbados

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The report was prepared by Climate Change Solutions International (CCSI), Lead Consultant – Professor Bhawan Singh. CCCCC Technical supervision: Mr. Joseph McGann, Programme Manager, EU-GCCA Project.

We would at first like to express our gratitude to the European Union Global Climate Change Alliance (EU GCCA), the Funding Agency and the Caribbean Community Climate Change Centre (CCCCC), the Executing Agency for having awarded this Contract on the Vulnerability and Capacity Assessment (VCA) of the agriculture sector of the Food Zone of Barbados to Climate Change Solutions International (CCSI).

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For more information visit:

- The Global Climate Change Alliance website: http://www.gcca.eu/
- The African, Caribbean and Pacific Secretariat website: http://www.acp.int/
- The Caribbean Community Climate Change Centre website: http://www.caribbeanclimate.bz
- The National Climate Change Office - Ministry of Environment and Drainage: Email: ricardo.ward@barbados.gov.bb
- Ministry of Agriculture, Food, Fisheries and water Resources Management website: http://www.agriculture.gov.bb

Foreword

The Agricultural Sector continues to play a critical and multi-functional role in contributing to the social, economic and environmental well being of Barbados. The sector is also central in the transition to a green economy.

I acknowledge that the new challenge of climate change in addition to the existing ones of environmental degradation and natural disasters will certainly affect this country's capacity to have a vibrant and productive sector.

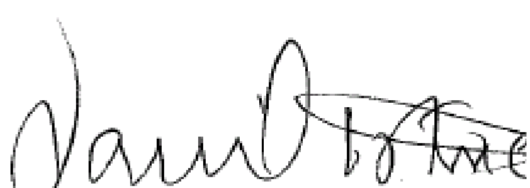
This Vulnerability and Capacity Assessment Study of the agricultural sector is therefore both timely and appropriate since it allows us to identify the risks to the sector, the measures needed to minimize them and the accompanying resource requirement.

The Ministry has recently prepared two new policy documents for the sector; 'National Agricultural Policy -A Vision for the Future of Agriculture in Barbados' and 'Food and Nutritional Security Policy and Action Plan'. These documents outline the intervention strategies to be pursued in order to increase production and productivity to ensure the availability of nutritious food for all.

I am sure that the recommendations resulting from this European Union funded study executed by the Caribbean Community Climate Change Centre will benefit our farmers and improve the sector's contribution to the economy.

This Ministry will continue to put in place the requisite policy measures to advance the integration of adaptation measures to reduce the sector's vulnerability to adverse impacts of climate change. These measures will ultimately enhance the resilience of the sector and sustain the livelihoods of the many persons employed in agricultural production.

I wish therefore to take this opportunity to thank the European Union, the Caribbean Community Climate Change Centre, the consultants and all those involved in this study.



Dr. the Hon. David C. Estwick, M.P.
Minister of Agriculture, Food, Fisheries
and Water Resource Management

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Abbreviations and Acronyms

A1B	Median Emissions Scenario
AF5	IPCC Fifth Assessment Report
A-OGCM	Atmosphere-Ocean General Circulation Model
AHP	Analytic Hierarchy Process
BADMC	Barbados Agricultural Development and Marketing Cooperation
BAMC	Barbados Agricultural Marketing Company
BAS	Barbados Agricultural Society
BSS	Barbados Statistical Service
BWA	Barbados Water Authority
CCSI	Climate Change Solutions International
CCCCC (5Cs)	Caribbean Community Climate Change Centre
CIMH	Caribbean Institute for Meteorology and Hydrology
CNCD	Chronic Non-communicable Diseases
CMIP3	Coupled Model Intercomparison Project phase 3
CPACC	Caribbean Planning for Adaptation to Climate Change
DSSAT	Decision Support System for Agrotechnology Transfer
FAO	Food and Agriculture Organization
ECHAM5	European/German General Circulation Model (version 5)
ENSO	El Nino Southern Oscillation
EU GCCA	European Union Global Climate Change Alliance
GDP	Gross Domestic Product
GNI	Gross National Income
GoB	Government of Barbados
HadCM3	Hadley Centre General Circulation Model (version 3)
HadCM3/AEXSM:	Version of Hadley Centre General Circulation Model
HadCM3Q11	Hadley Centre General Circulation Model (QUMP)
HACCP	Hazard Analysis Critical Control Points

HDI	Human Development Index
INSMET	Instituto de Meteorologia de Cuba
IICA	Inter American Institute for Cooperation in Agriculture
IPCC	Intergovernmental Panel on Climate Change
INC	Initial National Communication
ITCZ	Inter Tropical Convergence Zone
MACC	Mainstreaming Adaptation to Climate Change
MARD	Ministry of Agriculture and Rural Development
MDRs	Minimum Daily Requirements
MPI-M	Max-Planck-Institute for Meteorology
NGOs	Non-Governmental Organisations
NFIDC	Net-food Importing Developing Country
OECD	Organisation for Economic Cooperation and Development
PCMDI	Program for Climate Model Diagnosis and Inter-comparison
PRECIS	Providing REgional Climates for Impacts Studies
QUMP	Quantifying Uncertainties in Model Projections
RCP	Representative Concentration Pathway
SIDS	Small Island Developing States
SRES	Special Report Emissions Scenarios
SST	Sea Surface Temperature
SWOT	Strength Weakness, Opportunity and Threat
THI	Temperature-Humidity Index
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VCA	Vulnerability Capacity Assessment
WB	World Bank

Executive Summary

This VCA project on the agriculture sector of the Food Zone of Barbados is funded by the European Union Global Climate Change Alliance (EU GCCA) and executed by the Caribbean Community Climate Change Centre (CCCCC). Furthermore, this Caribbean Forum (CARIFORUM) regional project designed to assist participating countries like Barbados to develop capacity to formulate and implement climate change adaptation policies and measures.

The VCA undertaken by Climate Change Solutions International (CCSI) closely abided with the methodologies suggested by the Caribbean Community Climate Change Centre (CCCCC). Furthermore, the VCA study focussed on the vulnerability and adaptive capacity of the farming community of the Food Zone located in the Parishes of Saint Michael and Saint George, Barbados.

The VCA study essentially consisted of two components: the biophysical impacts of climate change on agriculture and the adaptive capacity of the farmers in the Food Zone to cope with future climate changes and socio-economic stressors. Two future time horizons, namely the near-term decade 2030-2040 and the far-term decade 2060-2070 were selected to look at future climate change and variability and socio-economic conditions.

Downscaled climate scenarios from the Providing REgional Climates for Impact Studies (PRECIS) nested by two global climate models, namely HadCM3/AEXSM and ECHAM5 were used as the basis for assessing changes in climate. These high-resolution climate scenarios were integrated into the Decision Support System for Agrotechnology Transfer (DSSAT), a mechanistic crop model, in order to anticipate the potential impacts of climate change on productivity of some selected crops, namely sugarcane, cassava and tomatoes. On the other hand, using the Analytic Hierarchy Process (AHP), the information collected during the interviews with the farmers and other key stakeholders was used to assess the adaptive capacity of the agriculture sector in the Food Zone.

The most salient results of the VCA study, based on the PRECIS-downscaled climate scenarios, namely HadCM3/AEXSM and ECHAM5, are that temperatures would increase by ~ 1 ^{0} C by (2030s) to ~ 2 ^{0} C (2060s) and that rainfall would decrease slightly, with changes in seasonality, and become more variable and that droughtiness would become more persistent.

In terms of climate change impacts on crop productivity and livestock, without appropriate adaptation measures, the poultry and cattle industries as well as sugarcane and tomatoes are likely to be negatively affected. However, cassava could continue to perform fairly well under the anticipated climate conditions if diseases, pest and weed are controlled.

As for the assessment of adaptive capacity our survey results indicate that financial resources, market conditions, government policies and programs and human capital and technology would be the most important determinants of adaptive capacity of farmers and stakeholders of the Food Zone of Barbados.

In order to address these threats posed by climate change, a number of recommendations are proposed. Broadly speaking, these recommendations relate to actions and strategies that need to be implemented in order to increase the capacity and consequently to reduce the vulnerability of the agriculture sector in the Food Zone to climate change combined with other socio-economic stressors. The final choice of these recommended actions and strategies must be the result of a participatory and inclusive process likely to facilitate their implementation and their appropriation by the main stakeholders of the sector.

1 Introduction

The European Union Global Climate Change Alliance (EU GCCA) project is a Caribbean Forum (CARIFORUM) regional project designed to assist participating countries to develop capacity to formulate and implement climate change adaptation policies and measures. The EU GCCA project is executed by the Caribbean Community Climate Change Centre (CCCCC). The aims of the EU GCCA are to strengthen dialogue and cooperation on climate change with developing countries most vulnerable to climate change and to support their efforts to develop and implement adaptation and mitigation responses. It focuses on the Least Developed Countries (LDCs) and the Small Island Developing States (SIDS), countries that have contributed the least to greenhouse gas emissions, but are often the most affected by climate change and that have limited resources to address the related challenges.

It is common knowledge that Barbados is a SIDS which is very vulnerable to climate change for many reasons, notably its limited size, and the fact that its strategic sectors, notably tourism and agriculture, depend greatly on climate conditions, especially water supply in terms of quantity and temporal distribution. Climate change combined with other stressors such as global trade restrictions is likely to jeopardize the development process of this island. In order to sustainably maintain the fundamental functions of strategic socio-ecological systems for the economy of Barbados, adjustments to the actual and anticipated climate conditions are inevitable. For a better definition of these adjustments or adaptations activities and strategies, it is necessary to have a good understanding of both biophysical and socio-economic factors that determine the level of vulnerability of these strategic socio-ecological systems to climate variability and change in the context of multiple stressors. This logical sequence in mainstreaming climate change action plans and elaborating upon adaptation strategies aimed at increasing resilience to climate variability and change, particularly in regards to the agriculture sector of Barbados will be the focus of this Vulnerability and Capacity Assessment (VCA).

The VCA methodology was developed to provide useable decision support information and tools to assist civic and business leaders in making critical decisions to mitigate climate hazards, including climate change, in regions and sectors of high consequence.

The most important component of the VCA is the social aspect and how people cope with events at present: included in this is an assessment of their awareness and perception of risk; if they do not perceive themselves to be vulnerable then they are unlikely to implement adaptation options.

In order to ensure that investments in adaptation measures achieve desired outcomes it is first necessary to determine the degree to which a community (Parishes of Saint Michael and Saint George, Barbados – focus on Agriculture sector) is vulnerable and the extent of their capacity to adapt and/or cope with climate related events.

However, key adaptation uncertainties arise from a limited understanding of:

- Physical/material vulnerability and capacity: the most visible area of vulnerability is physical/material capacity and limitations. It includes land, climate, environment, health, skills and labour, infrastructure, water supply, housing, finance and technologies;
- Social/organisational vulnerability and capacity: this aspect includes formal political structures and the informal systems through which the nation of Barbados and its communities achieve planned goals;
- Motivational/attitudinal vulnerability and capacity: how individuals and communities in Barbadian society view their ability to affect their environment, manage their risks and take charge of their future direction; experience shows that groups that share strong ideologies or belief systems, or have experience of successful co-operation are usually the most resilient.

It is further necessary to conduct practical and usable vulnerability and capacity assessments to guide the decision making process in prioritizing appropriate steps that should be taken to adapt to climate change. Furthermore, in order to effectively adapt to climate change impacts in vulnerable communities (Parishes of Saint Michael and Saint George, Barbados – focus on Agriculture sector), requires financial, technical or human resource capacity to implement and sustain adaptation practices.

While its contribution to the national GDP (actually estimated at 3.1%) has decreased over the last years, the agriculture sector is still perceived as one of great economic and social importance to Barbados. Indeed, this sector represents the main economic activities for 10% of the Barbadian labor force. The agricultural production systems are mainly made of sugarcane, cotton and a large variety of vegetables (tomatoes, cabbage, radish, cucumber, hot and sweet peppers…and root crops (cassava, yam, sweet potatoes eddoes…).

The Island of Barbados is highly dependent on a wide range of imported foods. Due to this fact, it is considered as a 'Net-food Importing Developing Country (NFIDC)'. This sector is facing various types of issues both biophysical and socio-economic, including the Praedial Larceny that jeopardizes its potentialities. In order to ensure that an acceptable balance is achieved in terms of food imports, domestic food production, and enhancing foreign exchange earnings, the Government of Barbados (GOB) has developed a global strategy for the agriculture sector consisting of the following seven Medium Term Growth and Development Objectives:

- To alleviate the impact of Praedial Larceny on agricultural production;
- To promote Food and Nutrition Security through improved production and productivity;
- New Product Development and Agro-processing;
- Enhance Marketing and Post-Harvest Handling of agricultural produce;
- Enhance Research and Development in agriculture;
- Implement measures to facilitate the Export and Development of agricultural products;
- Building Human Resource Capacity to manage the agriculture sector.

For the GOB, the main objectives of these policies are to promote Food and Nutrition Security through improved production and productivity of the agriculture sector and to alleviate the impact of praedial larceny. The GOB has set major policy goals on these initiatives to enhance the country's food security which are:

- To put in place a comprehensive food and nutrition security policy and plan, which seeks to ensure that the country is capable of feeding itself at all times, including under disaster situations, both through domestic production and goods sourced from their CARICOM neighbours;
- To put in place a trade policy for food commodities/products that has as its focus the sustainability of the local agricultural sector.

Praedial larceny is one of the greatest limiting factors to the implementation of this food policy and plan. To this end the GOB plans to introduce and enforce modern praedial larceny legislation to help farmers protect their production. It will also partner with the insurance industry to develop a crop insurance scheme to protect farmer's investment in agricultural production.

Anthropogenic climate variability and change represents an additional stressor for the agriculture sector of Barbados. This unprecedented phenomenon is likely to negatively impact most key components of this sector. Due to the socio-economic importance of this sector, it is appropriate to have a better understanding of the vulnerabilities and capacities of this sector that can inform the elaboration process of sustainable adaptation strategies likely to increase its resilience to changing climate conditions in the context of other types of stressor.

The overall objective of this Consultancy then is to conduct a Vulnerability and Capacity Assessment (VCA) of Barbados' agriculture sector to climate variability and change in the context of other socio-economic stressors. The VCA when completed is expected to provide baseline information and data on the projected impacts of climate change and climate variability on the agriculture sector in terms of potential impacts on crop yields and agricultural production, stakeholders' capacities to face the risk posed by this unprecedented phenomenon, and formulate recommendations and options based on the assessment that will assist the GOB to further develop and implement agricultural measures to enable the community to cope with the expected impacts.

Furthermore, the purposes of this Consultancy are as follows:

- Conduct a VCA for Barbados with the focus on the agriculture sector;
- Build and strengthen the national capacity of technical experts to conduct future vulnerability assessments in the agriculture and other sectors.

The VCA methodology and stages that are that are followed in this Draft Report, though not sequentially, are those recommended by the CCCCC (Pulwarty and Hutchinson, 2008).

The following diagram summarizes our methodological approach in undertaking the VCA of the agriculture sector of Barbados (Figure 1).

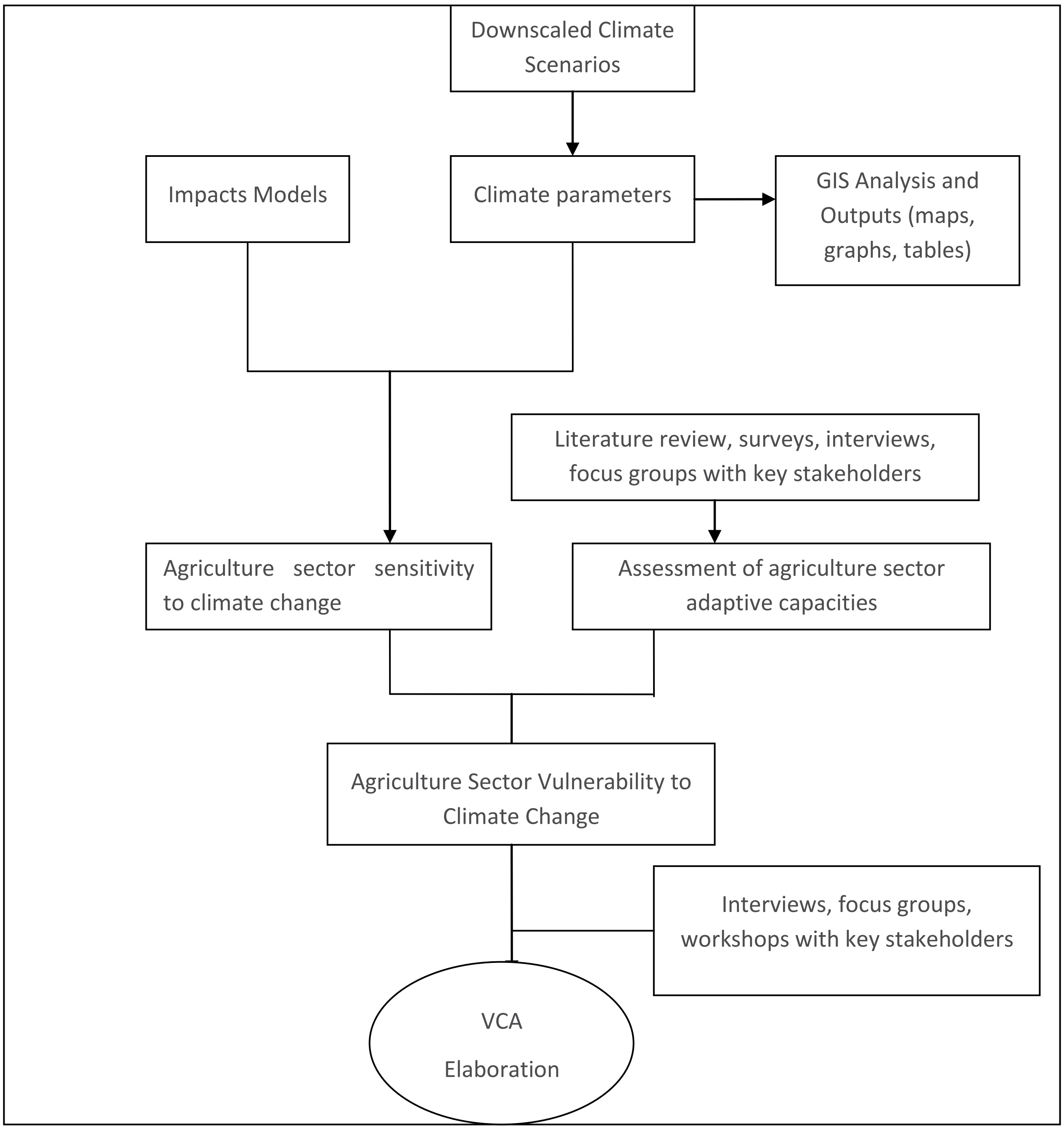


Figure 1: Structure of the Methodological Steps of the VCA Project

2 VCA-Stage 1: Define and Scope the VCA

The Terms of Reference for this VCA study called for an assessment of the vulnerability and the adaptive capacity of the agriculture sector located within the Parishes of Saint Michael and Saint George. However, during the Inception Workshop (August 24-30, 2014) held at the Ministry of Agriculture, Barbados, it was decided by the National Advisory Group that the focus of the study should be on the Food Zone located within the Parishes of Saint Michael and Saint George.

Barbados has the ability to purchase and produce sufficient food to meet the nutritional needs of its population but there are a number of concerns. Firstly, most of its food is imported, requiring ever increasing amounts of foreign exchange earnings. The value of which places it among the top Net Food Importing Developing Countries (NFIDC) in the world. Secondly, the reliance on imported food has resulted in a shift to consumption more highly processed refined foods, which tend to promote obesity and cardiovascular diseases. Thirdly, there are some persons among the poor and vulnerable who find it difficult to meet their minimum daily requirements (MDRs) RDAs (FAO Concept Note, 2013; Government of Barbados, 2013).

High food prices in Barbados is are also a major challenge, especially for approximately 19% of the population who live below the poverty line, and are unable to purchase adequate quantities of food. The high price of food also encourages unhealthy eating habits especially among the poor and disadvantaged sector of the population. Vulnerability analysis shows that many of these persons are either unemployed or engaged in menial, temporary, insecure labour, or they are dependent on pensions and other benefits. The global financial crisis has further exacerbated the impact on these vulnerable groups (FAO, Concept Note, 2013; Government of Barbados, 2013).

In order to address these problems, there is need for a multi-sectoral approach which (FAO, Concept Note, 2013; Government of Barbados, 2013):

- promotes sustainable and efficient domestic production, processing preparation, commercialization, including reduced food losses and wastage;
- encourages improved food choices and nutrition decisions for consumption of safe, affordable, and nutritious high quality food commodities/products;
- ensures stable access of national households, especially the poor and vulnerable, to sufficient quantities of safe, affordable quality food at all times, particularly in response to diverse socio-economic and natural shocks;
- improves the nutritional status of the national population with specific attention to the consequences of poor nutrition and the resulting high prevalence of overweight and high incidence of Chronic Non-communicable Diseases (CNCDs) such as diabetes and hypertension;
- improves the resilience of the Barbadian communities and households to natural and socio-economic crises, thus ensuring that all persons in Barbados will have access to adequate, safe and nutritious food at all times.

To increase domestic agricultural production in Barbados requires an increase in the area currently under production, as well as an increase in productivity of existing production systems. However, competing demands for land for housing and tourism have resulted in high prices for land as well as conflicts in land zoning, with prime agricultural land being converted to non-agricultural uses. In some instances, many of the agricultural lands remain idle or underutilized because of an aging agricultural population, high cost of labour and general disinterest of the youth in agriculture. In other cases, lands were purchased by absentee Barbadian nationals with the intention of either returning when they retire to cultivate the land or for speculation. Those lands now remain idle or underutilized. More recently, the private sector has seen the potential for agricultural investment and one company has purchased 400 acres of prime agricultural land for future agricultural development. To date, that land also remains idle. Furthermore, tenure is another impediment to the development of agricultural lands, as persons farming on family lands or lands with insecure tenure may not be able to use the land as collateral for investment (FAO, Concept Note, 2013; Government of Barbados, 2013).

In an effort to address the aforementioned challenges, the Government has been promoting strategies to enhance domestic production. One such strategy is to develop food zones, which are areas of land which have been designated for use exclusively in agriculture. This strategy is also aimed at stemming the trend of converting prime agricultural land for non-agricultural uses and ensuring that a critical mass of land is available for food production. These zones have the potential to be used, not only be centres of domestic production, but also enclaves for rural development. In this regard, the Government also intends to strengthen the linkages between the producers and key institutions such as schools, marketing and credit agencies which operate in the communities adjacent to the food zones (FAO, Concept Note, 2013; Government of Barbados, 2013).

The key issues that are to be addressed by the intervention are:

- land capability – which crops/livestock are best suited to the soil and climatic conditions of the food zones;
- terms of occupancy – what type of lease arrangements will be offered, (options for private land owners);
- food production systems – what size holdings, what combination of crop and livestock enterprises and inputs are required;
- marketing of produce – school feeding programme, local supermarkets, health institutions, local farmers' markets;
- value addition – agro processing and linkages with tourism;
- support systems – extension, credit, and even crop insurance;
- nutrition – promoting healthy options – less processed foods, low inputs of inorganic fertilizers and pesticides;
- education – to ensure sustainability, promote by-in and build capacity within the communities.

2.1 Formation of the National Advisory Group (Council or Advisory Panel)

During the Inception Workshop (August 24-30, 2014) held at the Ministry of Agriculture, Barbados, a National Advisory Group (Council or Advisory Panel) comprising of representatives from relevant government ministries/departments, private sectors, NGOs and trade associations, and including the GCCA Focal Point Dr. Lorna Innis (represented by Ms. Sadie-Anne Jones). This council will be central in increasing the likelihood of mainstreaming the results of this VCA assessment into practice and will hopefully be capable of supporting the adaptation process and prioritizing subsequent adaptation needs after the initial VCA lifetime.

At the end of the Inception Workshop it was decided that the following Potential members of Advisory Council:

- Professor Bhawan Singh (Lead Consultant)
- Dr. Kénel Délusca (Consultant: Agriculture)
- Mr. Charleston Lucas (Ministry of Agriculture)
- Mr. Colin Wiltshire (Ministry of Agriculture)
- Mr. Kenny Ward (Ministry of Agriculture)
- Ms. Sadie-Anne Jones (Coastal Zone Management Unit: Representing Dr. Lorna Inniss – EU GCCA Focal Point)
- Others to be added: Rickardo Ward (Ministry of the Environment). Mr. Adrian Trotman (CIMH), NGOs, Local Sector…

2.2 Selection of the Exposure Unit and the Time Horizon

In selecting the food zone which will be used for this project, it was decided to use an area where there are poor and vulnerable communities, where the pilot demonstration is easily accessible by the members of the community, where there is already some agricultural production and an area in which farmers have access to services by agencies such as the Barbados Agricultural Development and Marketing Cooperation (BADMC), the Barbados Agricultural Marketing Company (BAMC), the Soil Conservation Unit and the Ministry of Agriculture. To this end, based on discussions with the National Advisory Council, the project area (Exposure Unit) finally selected was the Food Zone located in the Parishes of Saint Michael and Saint James.

Furthermore, based on data availability the baseline for the assessment was chosen to be the period 1961-2013. Data on daily maximum and daily minimum air temperature, rainfall, evaporation and solar radiation was obtained from the Caribbean Meteorological and Hydrological Institute (CIMH) for both their station at Husbands and the station located at the Grantley Adams International Airport for this time period.

As for the future climate scenarios, climate data on daily maximum and daily minimum air temperature, rainfall, evaporation and solar radiation was obtained from the Cuban Institute of

Meteorology for the period 1961-2100. These future climate scenarios were generated by the British Meteorological Institute regional climate model PRECIS (Providing REgional Climates for Impact Studies). The global climate data was provided for two Atmosphere-Ocean General Circulation Models (A-OGCMs), namely the ECHAM5 and the HadCM3 (AEXSM) models. The global data sets were then downscaled on a 25 x 25 km using PRECIS by the Instituto de Meteorologia (INSMET) of Cuba for the Caribbean Community Climate Change Centre (5Cs) and provided to us.

ECHAM5 is the 5th generation of the ECHAM general circulation model of the Max-Planck-Institute for Meteorology (MPI-M), initially developed by Roeckner et al., 2003.HadCM3 is the model of the British Met Office Hadley Centre provides boundary data from a 17-member perturbed-physics ensemble (PPE) (HadCM3Q0-Q16, known as 'QUMP': Quantifying Uncertainties in Model Projections) for use with PRECIS in order to allow users to generate an ensemble of high-resolution regional simulations (McSweeney and Jones, 2010).

The Hadley Centre's PPE includes 17 members which are formulated to systematically sample parameter uncertainties under the A1B emissions scenario. Based on data availability and fit with observed data (1961-1990), we selected the HadCM3Q11, a moderately high sensitivity model from the QUMP ensemble data outputs

Data representing future sea level changes for the 2046-2065 and the 2081-2100 decadal periods are derived from the latest IPCC (2013) Climate Change Report. However, sea level rise values of the IPCC (2013) are rather conservative when compared to other recent studies that integrate the land ice contribution to sea level rise (Rahmstorf, 2007, 2010; Horton et al., 2008; Vermeer and Rahmstorf, 2009; Grinsted et al., 2009). In view of this conservativeness, we selected the extreme values of the IPCC (2013) based on the Representative Concentration Pathway (RCP) forcing scenarios: 0.38 m for the 2046-2065 period (RCP 8.5) and 0.82 for the 2081-2100 period (RCP 8.5) (See Table 1).

Table 1: Global mean sea level rise for the 2046-2065 and 2081-2100 time periods (Source: IPCC Climate Report, 2013)

Variable	Scenario	2046–2065		2081–2100	
		mean	*likely* range [c]	mean	*likely* range [c]
Global Mean Surface Temperature Change (°C) [a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
		mean	*likely* range [d]	mean	*likely* range [d]
Global Mean Sea Level Rise (m) [b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Future Socio-economic scenarios, namely non-climate drivers on population, economy…for the future periods (2030s and 2060s) will be extracted from the literature (ex.: Government of Barbados (2003: Physical Development Plan (amended).

2.3 Construction of Risk maps - physical infrastructure and administrative units

Barbados, the most easterly of the islands of the Lesser Antilles of the Caribbean, is a small island developing state of area 431 km2, located in the Caribbean at 13^{o} 4' North latitude and 59^{o} 37' West longitude. The island is non-volcanic, consisting of underlying sedimentary deposits, all capped by a layer of coral up to 300 feet (90m) thick. In the more elevated north-eastern part of the island, erosion has removed the coral cover across an area comprising about 15% of the island's total surface. This unique section of the island is known as the Scotland District, and has within it the island's highest promontory, Mount Hillaby, which stands only 340m above sea level. The topography of Barbados is also marked by giant cracks in the limestone cap of the island, which form a complex series of gullies running mainly from this higher, eastern portion of the island to the west coast. These gullies, act as a major conduit of recharge of rainfall to the limestone aquifers, transporting water via underground streams to discharge into the sea at the west coast (Barbados' First National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), 2001).

Land Use/Farming use issues

In view of the fact that disaggregated land use and farming data is unavailable at the Parish, namely Saint Michael and Saint George, within which the food zone is located, this section addresses the issues of land use and faming issues at the national level for Barbados. It is believed that these national level issues are especially relevant to the Food Zone located in the Parishes of Saint Michael and Saint George (Figure 2 and Table 2).

Agricultural land (% of land area) in Barbados was last estimated at 190.0 sq. km (44.2 % of land area) in 2010, according to the World Bank (2011) (Table 3). Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Arable land includes land defined by the FAO (Food and Agriculture Organization) as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded. Land under permanent crops is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber. This category includes land under flowering shrubs, fruit trees, nut trees, and vines, but excludes land under trees grown for wood or timber. Permanent pasture is land used for five or more years for forage, including natural and cultivated crops (Table 2).

Table 2: Agricultural Holdings in Barbados Distributed by Parish and Principal Agricultural Category (Source: Homer, 1989).

Parish	No. of Holdings	Size of Holdings (ha)	Principal category (ha)						
			Sugar	Vege-tables	Root crops	Fruits	Livestock/ poultry	Mixed	Other
St Michael	2950	837	116	33	2	93	183	401	2
Christ Church	2753	2536	815	47	7	154	46	1262	204
St George	1764	2295	350	27	2	59	39	1814	2
St Phillip	2091	3711	810	82	4	79	125	2498	113
St John	1277	2516	320	144	2	42	45	1963	0
St James	1315	1008	90	6	1	81	56	772	2
St Thomas	1122	2664	174	9	0	34	29	2411	6
St Joseph	928	1129	238	15	-	117	191	564	3
St Andrew	876	744	149	6	1	23	73	489	1
St Peter	991	2612	496	3	1	17	34	2059	1
St Lucy	1075	1507	362	48	3	221	113	760	0
TOTAL	17178	21560	3920	419	23	921	933	14996	334

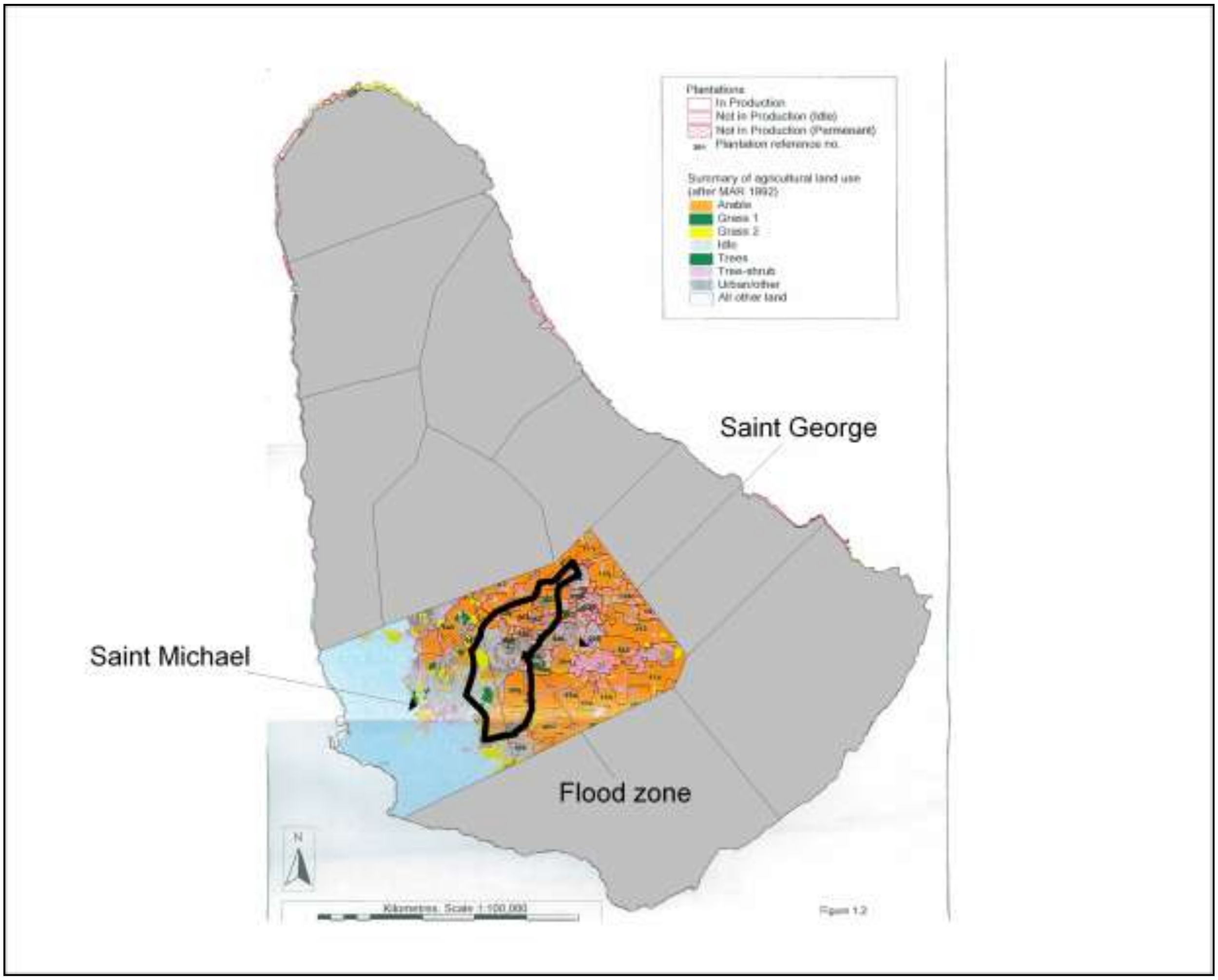


Figure 2: Summary of Agricultural Land Use in the Food Zone of Barbados (Source: MARD, 1992)

Given the relatively small land area of Barbados, with a total land area of 43,176 ha, land is a very limited resource with an obvious impact on agricultural activities (Table 3). In addition, Barbados is considered one of the most densely populated countries in the world. The last four decades were characterized by a decrease in agricultural land resources. Estimates from the last census recorded the total agricultural land (Table 3) at 190 km^2 (NAS, 2007). This limited land resource has decreased over time (see Table 4). Agricultural land is also experiencing competing uses such as housing, social and recreational facilities (schools and playing fields), and alternative economics uses such as golf courses and tourism-related projects. Land continues to be alienated from agriculture at the rate of approximately 1,000 acres annually (Chelston and IICA, 2013). Were these trends to continue, the survival of agriculture in Barbados will be severely compromised.

Table 3: World Bank indicators for Barbados: Land Use (2011)

	1990	**2000**	**2010**
Agricultural land (sq. km) in Barbados	190.0	190.0	
Agricultural land (% of land area) in Barbados	44.2	44.2	
Arable land (hectares) in Barbados	16000.0	16000.0	
Arable land (hectares per person) in Barbados	0.1	0.1	
Arable land (% of land area) in Barbados	37.2	37.2	
Permanent cropland (% of land area) in Barbados	2.3	2.3	
Forest area (sq. km) in Barbados	17.0	80.0	80.0
Forest area (% of land area) in Barbados	4.0	18.6	18.6
Average precipitation in depth (mm per year) in Barbados			
Land area (sq. km) in Barbados	430.0	430.0	430.0

In addition, these stressors have led to an increase in the price of agricultural land in Barbados which is now so prohibitive to the extent that it is not profitable for small farmers to engage in farming. This may limit further agricultural development. Two major land tenure systems exist in Barbados; the plantation system and the small holder system in which 1% of the farming unit controls 86% of the land and the other 99% of farming units are left with 14% of the land. Thus, the land tenure is dominated by smallholdings which accounted for about 90% of the total number of agricultural holdings (Gregg and Rawlins, 2003). In addition, the increasing demand for land for competing uses has resulted in agricultural lands being held for speculative purposes, and consequently not being actively cultivated. In addition, even where land is available, it is priced so high that, if purchased for agricultural use, the impact on the overall cost of agricultural production would be significant with serious consequences for international competitiveness.

Available information suggests that landless farmers who are classified as those with holdings of less than 0.025 hectare, accounted for approximately 36% of the total number of holdings (Table 5), and that a significant proportion of farmers in Barbados continue to operate holdings of 0.5

hectare or less. This has serious implications for the adaptive capacity of these farmers to withstand uncertainty as these farmers lack the technical and financial resources as well as requisite infrastructures to withstand stresses such as the adverse effects of climate change and variability for example, relative to the cost of production.

On another level, studies (Chelston and IICA, 2013; Rawlins, 2003) show that there has been an upsurge in the acreage of idle land in the country due to one or the combination of the following factors:

- Smallholders becoming unable or unwilling to work and the fact that sugar-cane production was gradually becoming unprofitable on such units;
- Run-down plantations;
- Unavailability of labour to work for both small farmers and plantations;
- The sale of two or four acre lots to ‘White collar workers’.

This issue of land tenure is of high and strategic importance and needs to be addressed as it is incumbent on the government to bring idle land into production as efficient use of arable land is a major concern in a country where land availability is a major constraint to socio- economic activities such as agriculture.

Table 4: Evolution of land use for Barbados.

Evolution of land use							
	Area [Millions of ha]				**Annual growth rate [%]**		
	1997	**2002**	**2007**	**2012**	**1997-2002**	**2002-2007**	**2007-2012**
Total area	0.04	0.04	0.04	0.04	0	0	0
Arable land	0.02	0.01	0.01	0.01	-12.94	0	0
Permanent crops	0.00	0.00	0.00	0.00	n.a.	n.a.	n.a.
Forest cover	0.01	0.01	0.01	0.01	0	0	0
Source: FAOSTAT, FAO of the UN, Accessed on September 18, 2014. http://faostat.fao.org/site/377/default.aspx#ancor							

Table 5: Total number and total area of agricultural holdings reported by size of holding

Size of Holding	HOLDINGS	AREA
Landless(<0.125 acres)	4,920.00	-
0.125 < 0.25 acres	3,024.00	438.00
0.25 < 0.5 acres	2,332.00	623.00
0.5 < 0.75 acres	1,095.00	562.00
0.75 < 1 acres	246.00	188.00
1 < 5 acres	1,530.00	2,853.00
5 < 10 acres	158.00	979.00
10 < 25 acres	128.00	1,660.00
25 < 50 acres	28.00	921.00
50 < 100 acres	12.00	850.00
100 < 200 acres	11.00	1,542.00
200 < 400 acres	30.00	7,778.00
400 < 800 acres	11.00	5,928.00
> 800 acres	12.00	13,628.00
Total	**13,537.00**	**37,950.00**

Source: National Agricultural Survey (NAS) 2007

Main factors (social, economic, political of biophysical) that inhibit the adaptation process

During discussions held a group of stakeholders (See Appendix -1) on August 25th, 2014, regarding the main factors that inhibit the adaptation of the agriculture sector of Barbados to climate and socio-economic factors, the following list of factors were advanced:

- Age of farmer;
- Full-time or part-time farmer;
- Access to technical information;
- Perception of the importance of the agriculture sector;
- Perception/Acceptance of climate change;
- Government support – somewhat inadequate;
- Agricultural policy – appropriateness from farmer's perspective;
- Administrative process – to access and receive rebates;
- Cost of inputs – production costs (irrigation water use, fertilizers…);
- Profitability of farming operations;
- Economies of scale – small population – lack of research by seed companies;
- Lack of biophysical and economic research locally;
- Regionalization (CARICOM) and competition from other regional producers;

- Lack of research and knowledge concerning appropriate cultivars;
- Resistance to the use of biotechnology;

However, the stakeholders did allude to certain positive factors that characterize the agriculture sector of Barbados, and amongst these were:

- Growth of partnerships – sharing tractors, farming cooperatives…;
- Fairly educated population – more open to take risks - new technologies;
- A fair level of market certainty – produce consumed, transformed, exported…;
- Ease of mechanization - relatively flat terrain;
- Good soils – natural capital
- Some level of insurance provided by Government

2.4 Review of Available Data and Data Quality and Datasets Development

This section reviews data available for the current (1981- 2010) period for two meteorological stations in Barbados, namely the Grantley Adams International Airport station located in Christchurch Parrish to the south of the island and the CIMH (Caribbean Institute for Hydrology and Meteorology) station located at Husbands in Saint James Parrish to the west of the island. However, we have chosen to closely examine trends at the Husbands (CIMH) station, that has a more complete data set and that is located in Saint James Parrish and closer to the Food Zone

2.4.1 Background

Barbados, like most small islands developing states in the Caribbean region, is attempting to address different issues posed by climate variability and change. Indeed, it is trying to reduce their vulnerability to the adverse conditions triggered by climate change. One common aspect of the framework used in seeking potential solutions to face this phenomenon is an ex-post or current vulnerability assessment of one or several sectors to recent past climate risks. In doing this type of assessment, three main components, namely exposure, sensitivity, and adaptive capacity, are always taken directly or indirectly into consideration. For the description of a system's or sector exposure to climate risks, several methods or approaches can be used. Among these, trend analyses have been very useful in characterizing the climatic context of these vulnerability assessment studies. From this perspective, it seems appropriate to identify and to present any potential signals or findings that can provide insights on the general climatic trends that has prevailed over the period covered by this present VCA assessment of the Barbadian agriculture sector with a focus on the Food Zone.

2.4.2 Data and Methodology

Daily climate data, namely rainfall, minimum and maximum temperatures, solar radiation, and evaporation were obtained from the Caribbean Institute for Meteorology and Hydrology (CIMH) and the Barbados Meteorology Office (BMO) for the 1981-2010 period and for 2 climate stations: HUSBANDS and GRANTLEY ADAMS located at 13.2° latitude north, 59.6° longitude west, and 13.1° latitude north, 59.6° longitude west, respectively. However, for purposes of brevity and relevance, we only present the trend analyses for the Husbands (CIMH) station.

A quality control of the time series consisting of checking for inconsistent values, particularly days with maximum temperature greater than the minimum and for negative rainfall values has been carried out. After this quality control, the data have been averaged annually and seasonally in order to detect potential change or trend in these series. As solar radiation and evaporation are not commonly measured and used by the main stakeholders of the agriculture sector, the analyses have focused only on the most currently used climate variables, notably minimum and maximum temperatures, and rainfall. The trend analyses of these variables have been performed using the non-parametric Mann-Kendall test (Kendall and Gibbons, 1990) along with the non-parametric Theil-Sen slope approach (Hirsch et al. 1982). To account for potential serial auto-correlation in the annual and seasonal time series of minimum and maximum temperatures, and rainfall, the above-mentioned test and approach have been applied according to the methods introduced by Yue et al. (2002) and Zhang et al. (2000). The trend analyses were carried out in the RStudio programming environment (v0.98.1049; RStudio, Inc.) using a script that integrates the "zyp" package (v0.10-1; Bronaugh, 2013). The results presented below are specific to each climate station with two different levels: annual and seasonal. For both levels, detected trends along with their statistical significance p values are showed for alpha=0.05 using both the Yue Pilon and Zhang methods.

2.4.3 Results for Husbands Climate Station

The analysis of the annual mean minimum temperature over the 30-years period at Husbands climate station showed an increase of 0.53 °C (with the Yuepilon Method) and 0.54 °C (with the Zhang Method). However, these warming trends were not statistically significant, with p values for the Mann-Kendall test greater than 0.05 for both methods. The figure and the table below show the non-statistically significant warming trends for the annual mean minimum temperature at Husbands station (Figure 3 and Table 6).

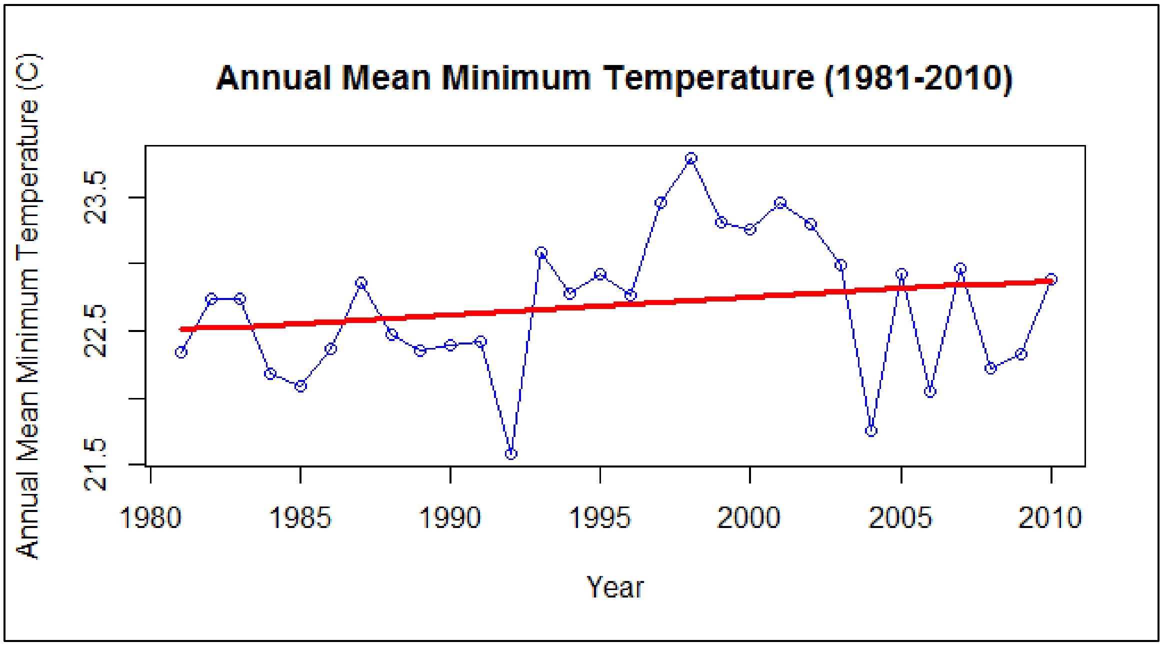


Figure 3: Trend in annual Mean temperature (0C) at the Husbands station, Saint James Parish

Table 6: Total number and total area of agricultural holdings reported by size of holding

Method	Global Trend (°C)	p-value	Yearly Trend (°C)
Yuepilon	0.53	0.110838532	0.017
Zhang method	0.54	0.110838532	0.018

Seasonal Mean Minimum Temperature for Husbands station (1981-2010)

On a seasonal basis, unlike the other 3 seasons (see results presented in Figure 4 and Table 7 below), a highly statistically significant warming trend has been detected for the spring season (March, April, and May). As shown in the Table 7, over the 30-years period, this warming trend is estimated at 1.004 °C (with the Yuepilon method) and 1.093 °C (with the Yang method). For this season and on a yearly basis, these warming trends correspond to an increase of 0.033°C and 0.036 °C using the Yuepilon and Yang methods, respectively. With this increase, spring nights around Husbands climate station is becoming warmer than usual with potential implications for some crops.

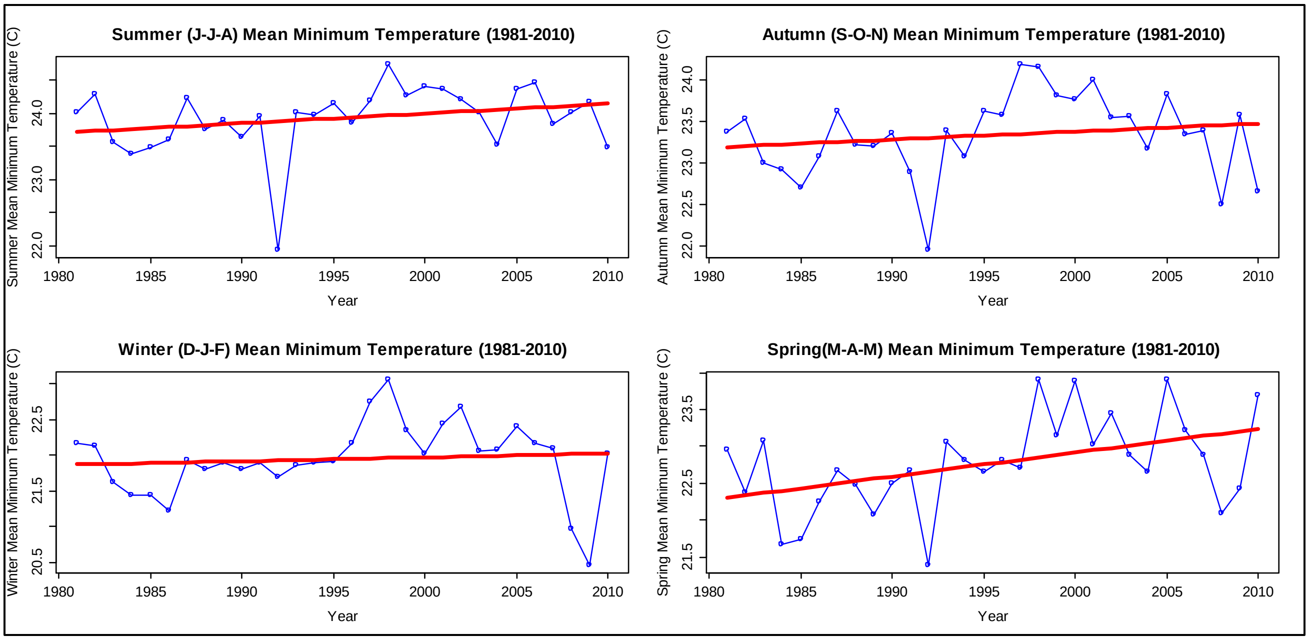


Figure 4: Trend in annual seasonal mean temperature (0C) at the Husbands station, Saint James Parish

Table 7: Results of the trend analysis for the seasonal mean minimum temperature (Climate station: Husbands, 1981-2010)

Season	Seasonal Mean Minimum Temperature (Yuepilon Method)			Seasonal Mean Minimum Temperature (Zhang Method)		
	Global Trend (°C)	**p-value**	**Yearly Trend (°C)**	**Global Trend (°C)**	**p-value**	**Yearly Trend (°C)**
Summer	0.511	0.063	0.017	0.549	0.110	0.018
Autumn	0.401	0.377	0.013	0.435	0.377	0.014
Winter	0.511	0.063	0.017	0.683	0.063	0.022
Spring	**1.004**	**0.010**	**0.033**	**1.093**	**0.010**	**0.036**

Annual mean maximum temperature Trend Analysis (Husbands, 1981-2010)

Over the 1981-2010 period, Mean Maximum Temperature has increased annually by 0.006 °C and 0.009 °C with the Yuepilon and the Zhang methods, respectively. Over the 30-years period, a total increase of 0.190°C (with the Yuepilon method) and 0.292°C (with the Zhang method) has been detected. However, according to the p value for the Mann-Kendall test, these increases are not statistically significant (p value greater than alpha=0.05) (Figure 5 and Table 8).

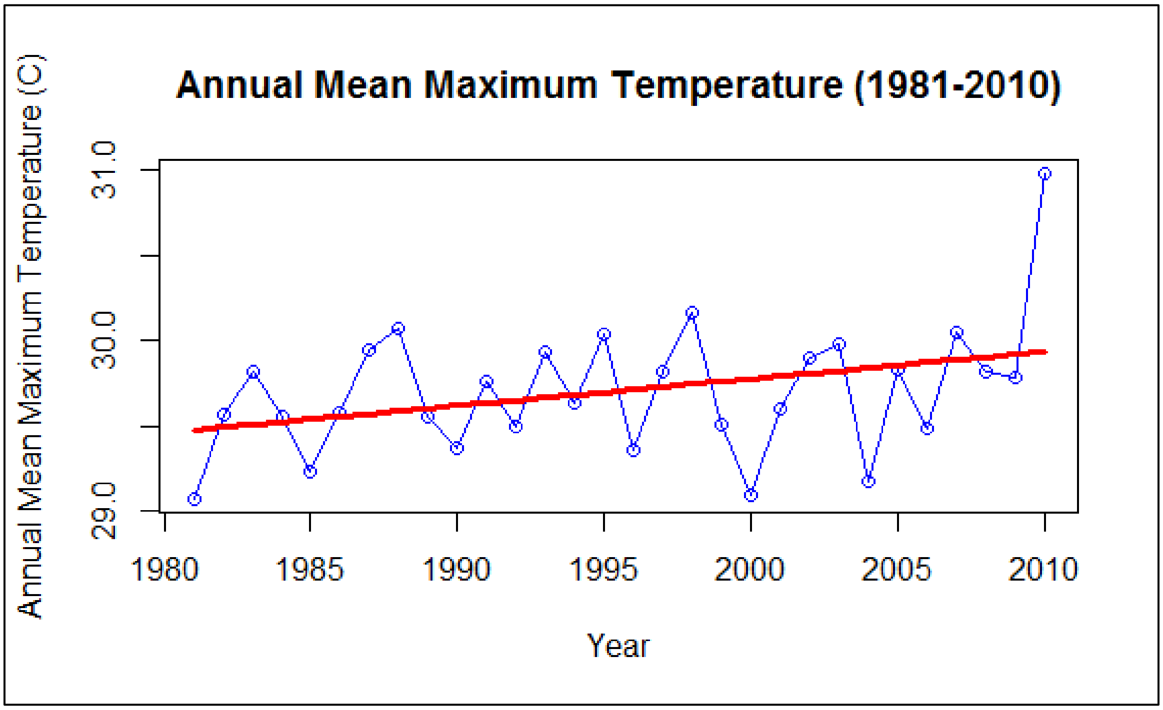


Figure 5: Annual mean maximum temperature Trend Analysis (Husbands, 1981-2010)

Table 8: Results of the trend analysis for Annual mean maximum temperature (Climate station: Husbands, 1981-2010)

Method	Global Trend (°C)	p-value	Yearly Trend (°C)
Yuepilon	0.190	0.159	0.006
Zhang method	0.292	0.159	0.009

Seasonal Mean Maximum Temperature at Husbands climate station

The trend analysis of the seasonal mean maximum temperature at the Husbands climate station showed a statistically significant warming trend only during autumn over the 30-years period. This increase in the mean maximum temperature during this season is estimated at 0.568 °C (with the Yuepilon method), and 0.921 °C (with the Zhang method). Even though it is not statistically significant, the mean maximum temperature during the spring season showed a slight cooling trend estimated at 0.261 °C over the 30-years period (Figure 6 and Table 9)

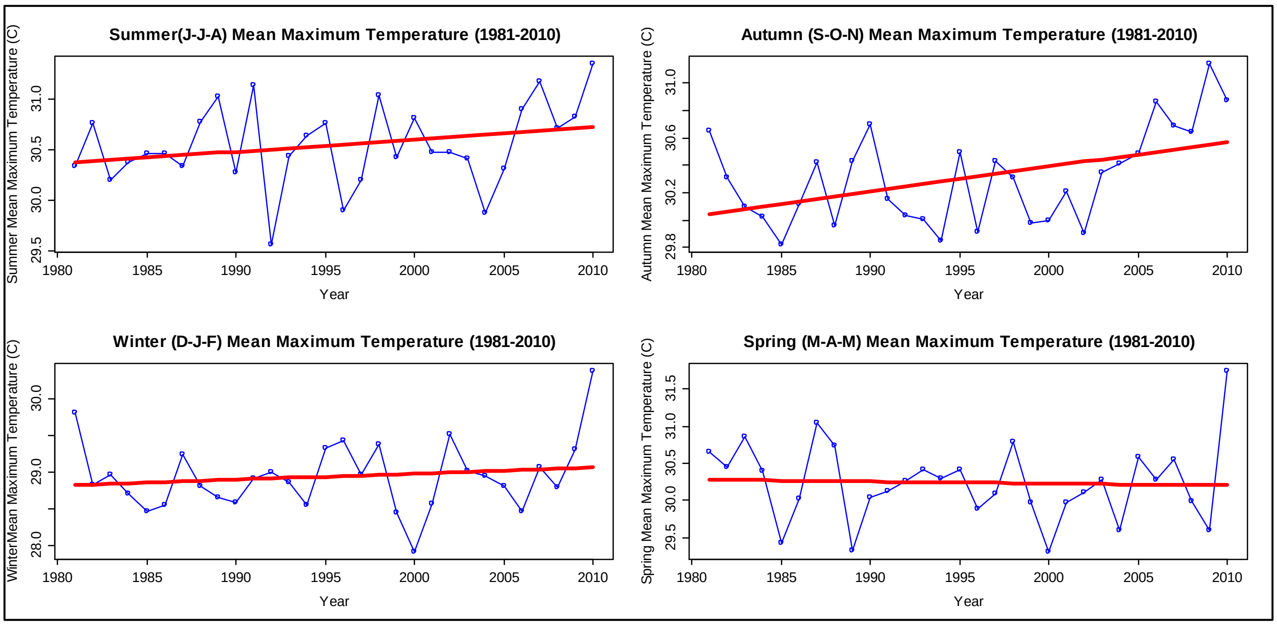


Figure 6: Seasonal Mean Maximum Temperature at Husbands climate station (1981-2010)

Table 9: Results of the trend analysis for the seasonal mean maximum temperature (Climate station: Husbands, 1981-2010)

Season	Seasonal Mean Maximum Temperature (Yuepilon Method)			Seasonal Mean Maximum Temperature (Zhang Method)		
	Global Trend (°C)	**p-value**	**Yearly Trend (°C)**	**Global Trend (°C)**	**p-value**	**Yearly Trend (°C)**
Summer	0.377	0.119	0.012	0.377	0.100	0.012
Autumn	**0.568**	**0.015**	**0.018**	**0.921**	**0.015**	**0.030**
Winter	0.258	0.138	0.008	0.427	0.138	0.014
Spring	-0.261	0.612	-0.008	-0.261	0.372	-0.008

The trend analyses of annual mean minimum and maximum temperature over the 30-years period at the Husbands climate station revealed only weak and non-statistically significant.

However, on a seasonal basis, a highly and statistically significant warming trend of 1.004°C with the Yuepilon method or 1.093°C with the Zhang method, and 0.568 °C with the Yuepilon method or 0.921 °C with the Zhang method has been detected for spring minimum temperature and autumn mean maximum temperature, respectively. The warming trend detected is stronger for the seasonal spring mean minimum than the one for seasonal autumn mean maximum temperature (Figure 6 and Table 9).

Annual Mean Rainfall Trend Analysis at Husbands climate station

Over the 30-years period, Annual mean rainfall at Husbands climate station varies between 855.8 mm and 1791 mm with an average value of 1282 mm. In terms of trends, Annual mean rainfall time series at this station showed a non-statistically significant trend. As it can be observed in the figure below and as indicated in the following table, a non-statistically increase in annual mean rainfall of 158 mm (with both Yuepilon and Zhang methods) has been determined for the 30-years period (Figure 7 and Table 10).

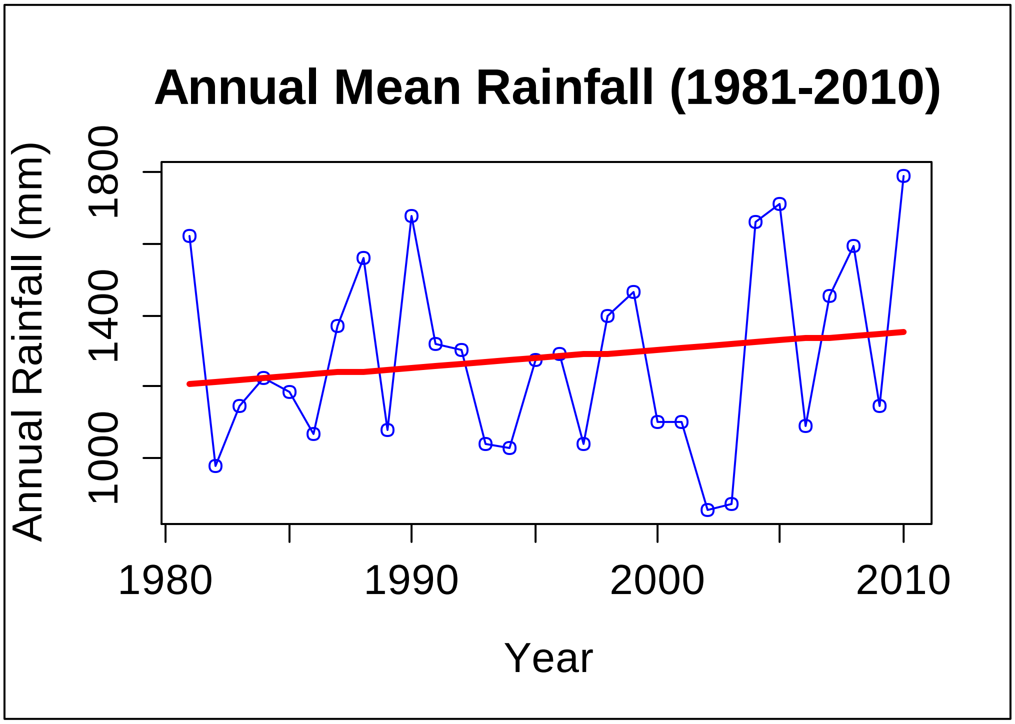


Figure 7: Trend in mean annual Rainfall at Husbands climate station (1981-2010)

Table 10: Results of the trend analysis for annual mean rainfall (Climate station: Husbands, 1981-2010)

Method	Global Trend (mm)	p-value	Yearly Trend (mm)
Yuepilon	158	0.195	5.266
Zhang method	158	0.411	5.266

Seasonal Mean Rainfall Trend Analysis at Husbands climate station

On a seasonal basis, the mean rainfall data at Husbands climate station showed mixed and non-statistically significant trends. Unlike the other seasons, a low decreasing and non-statistically significant trend estimated at 4.00 mm has been detected over the 30-years period. The figure and the table below present the results of the trend analyses for the seasonal mean rainfall (Figure 8 and Table 11).

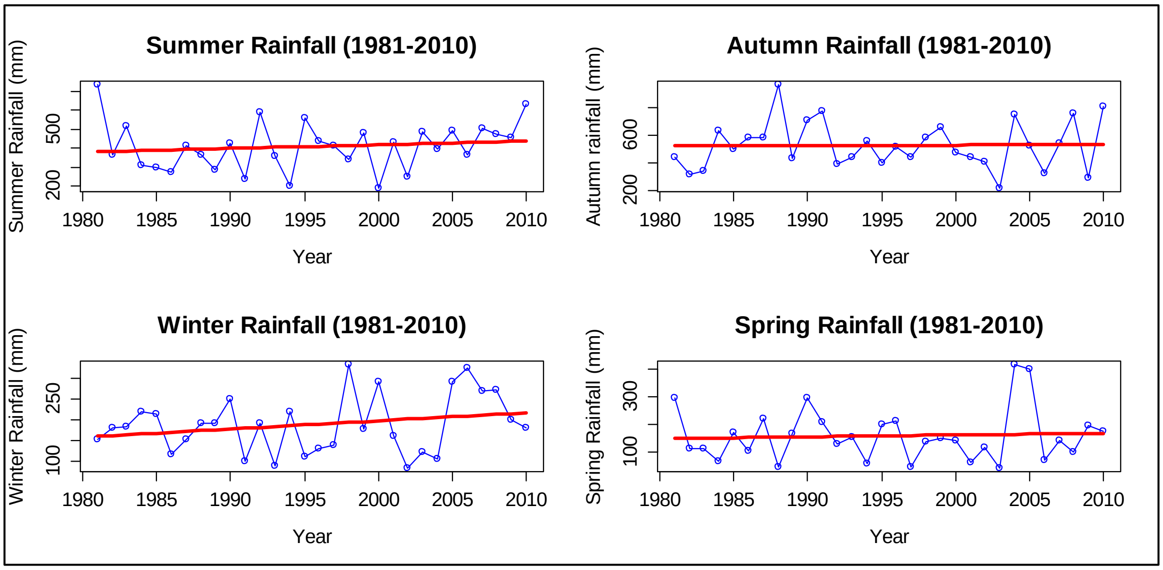


Figure 8: Trend in mean annual Rainfall at Husbands climate station (1981-2010)

Table 11: Trend in mean seasonal Rainfall at Husbands climate station (1981-2010)

Season	Seasonal Mean Rainfall (Yuepilon Method)			Seasonal Mean Rainfall (Zhang Method)		
	Global Trend (mm)	**p-value**	**Yearly Trend (mm)**	**Global Trend (mm)**	**p-value**	**Yearly Trend (mm)**
Summer	111	0.06	3.7	111	0.28	3.7
Autumn	31.5	0.955	1.05	31.5	0.721	1.05
Winter	43.09	0.560	1.436	59.08	0.560	1.969
Spring	*-4.00*	*0.749*	*-0.133*	*-4.00*	*0.943*	*-0.133*

Unlike temperature time series at Husbands climate station, no statistically increasing or decreasing trend has been found for the rainfall data on both annual and seasonal bases.

2.4.5 Main Conclusions

The analysis of time series of temperature and rainfall carried out for the Husbands station over the 1981-2010 period showed different trends depending on the climate variables and the spatio-temporal scales considered. Regarding temperatures, broadly speaking, the Grantley Adams climate station showed more significant warming trends for both annual and seasonal horizons than the Husbands climate station. These significant warming trends were generally higher for the average minimum temperatures. With respect to rainfall, mixed trends have been found at both climate stations. In general, these results are similar to those obtained by Stephenson et al. (2014), and Singh (1997). Finally, the analyses revealed significant results in terms of rainfall for areas around the Grantley Adams climate station. An increasing trend was observed for winter rainfall, while a decreasing trend (not statistically significant) was found for the other seasons, especially the summer and fall seasons that correspond to the main agricultural season in the island. These trends along with some other climatic indices need to be analyzed more deeply in order to better assess the potential implications for the agricultural sector.

2.5 Brief Descriptions of Present Vulnerabilities

This section examines the present vulnerabilities of the agriculture sector of the Food Zone to current and past climate conditions with the focus on the major crops, namely sugarcane, cassava and tomatoes, livestock and fisheries.

2.5.1 Agriculture: the impacts of climate change and variability

There is a widespread agreement about the impacts of climate change and variability on economic sectors such as agriculture. This evidence is even stronger for a small island country such as Barbados whose economy is limited by low land resources and an increased dependence on tourism as a major economic activity.

Climate modelling projections for Barbados predict (Caribsave, 2012):

- An increase in average temperatures between 2.4˚-3.2˚C in mean annual temperatures by 2080s in higher emissions scenarios;
- Reduced average annual rainfall;
- Increased Sea Surface Temperatures (SST);
- The potential for an increase in the intensity of tropical storms.

The impacts of such a phenomenon is likely to affect the socioeconomic sectors such as tourism, agriculture and food security, as well as water resources, health and biodiversity.

As for agriculture, the main factor contributing to the decline of the sector is the change in land use, characterised by the removal of productive agricultural land for high economic return activities such as residential use, commercial buildings, hotels and golf courses. This change in land use has increased the coverage of hard surfaces, resulting in an increase in surface run-off and flash flooding. The situation is exacerbated by inappropriate agricultural practices that use herbicides that kill ground cover and promote soil runoff; and planting systems that encourage runoff instead of water retention in the topsoil and aquifer. In addition, this transformation of agricultural lands adversely affects environmental stewardship, rural development and entrepreneurship particularly in younger persons, thereby increasing the social vulnerability of the island (Braithwaite and IICA, 2013: Singh et al., 2005).

Also, in terms of agricultural production, this phenomenon characterised by periods of severe drought and flooding, and the frequent occurrence of extreme events such as tropical storms, poses serious challenges for the local agriculture industry. For example, the passing of tropical storm Tomas in October 2010 affected more than 230 farmers who suffered huge financial losses on account of the heavy rains which led to flooding. Thousands of dollars in crops and young seedlings were destroyed and harvesting for others was made difficult due to the saturated fields (Braithwaite and IICA, 2013: Singh et al., 2005).

The damage assessment in the aftermath of tropical storm Tomas indicated losses in crops, livestock as well as structural damage. It is reported that local farmers also observed a marked increase in the incidence of the bacterial disease affecting some crops. Even the livestock, poultry and birds have shown the greatest vulnerability to increasing temperatures and local farmers have sustained considerable losses as a result of heat related illnesses. Heat stresses have also reduced both meat and milk production in ruminants. As a result, production of meat and milk has dropped so much that the country has to import these products massively (Braithwaite and IICA, 2013: Singh et al., 2005).

However, farmers are undertaken effort to address these issues. For instance, farmers in Barbados have started soil testing to address the issue of land degradation caused by traditional agricultural practices and natural climatic stresses in order to strategically and systematically replace the nutrients that are removed with each harvest in an effort to keep production levels high and costs low. Additionally, the Government of Barbados has made provisions for stimulating growth in the agricultural sector since agriculture has had to compete for scarce resources such as land, labour and capital. A report commissioned by UNDP shows that on *Best Practices for Youth in Agriculture*, Barbados has failed to identify and promote model farmers with best practices for youth in agriculture. However, there are some areas that are attractive prospects to young people, like greenhouse technology, organic farming and farming of certain crops, particularly vegetables because of the quick turnover cycle. In terms of livestock; pig, chicken and rabbit rearing have also captured interest amongst youth because of their profitability and guaranteed local market (Mangal, 2009).

The Government of Barbados (GoB) has already included in its policy choices some measure that inherently respond to the effects of climate change. However in order to increase the adaptive capacity, there is a need for policy choices and initiatives to explicitly seek to reduce adverse impacts on local farmers and assist them in exploiting opportunities. Such initiatives would include crop research, particularly for cultivars suitable for a changing climate; and extension programmes consisting of capacity building geared towards adaptation and mitigation to climate change using suitable local technologies.

The Barbados Ministry of Agriculture can already capitalize on its extensive experience with crop research. Therefore, it has to acknowledge the need for investment in laboratory infrastructure in order to produce useful results for farmers.

We focus on the three chosen crops that are selected for study, namely, sugarcane, cassava and tomatoes.

2.5.2 Sugarcane

Sugarcane, the main export crop, has also been subject to declining production and yields and its contribution to GDP in 2012 was only for 1% (Bank of Barbados 2013).

Sugarcane production is mainly controlled by large plantations. There are currently ten (10) large farms (600 to 1,000 acres each) distributed across the island: 3 large farms are located in

Constant (St. Michael), Bell (St. George). Furthermore, sugarcane farmers are now paid based on sugar/sucrose content of cane rather than based on weight as before. (Dr. Orville Wickam, BAMC: Barbados Agricultural Management Co. Ltd – Personal Communication, August, 2014; Dr. Sandra R. Bellamy, Barbados Agricultural Management Co. Lt– Personal Communication, August, 2014).

Climate fluctuations, especially prolonged drought, are one of the main factors leading to reduced sugarcane production and yields. All commercial sugarcane production is rain fed – irrigation is used only for breeding/seedling plots. The other yield reducing factors are diseases, such Smut disease (negligible), Rust disease (negligible) and Ratoon stunting disease (bacterial). But all diseases combined: cause at most a 5 % reduction in yields. Another major factor contributing factor to lower yields is the greater use of mechanization: in order to practice mechanized production, the land has to be flat / and sugarcane has to be planted linear rows upslope, as opposed to contoured planting with drain holes for retaining moisture, and this causes the water to run off fields, thereby leading to lower soil moisture retention. Furthermore, water holding capacity of the soil is critical for sugarcane growth and production. Surface soil depth in Barbados: on average about 2 feet, underlain by coral formations. The Food Zone (Saint Michael and Saint George) lies in a zone of intermediate rainfall (Dr. Sandra R. Bellamy, Barbados Agricultural Management Co. Lt– Personal Communication, August, 2014). The choice of cultivar: a compromise between quality also affects sugarcane yield (sucrose/sugar content) and potential yield (Dr. Orville Wickam, BAMC: Barbados Agricultural Management Co. Ltd – Personal Communication, August, 2014); Dr. Anthony Kennedy (West Indian Central Breeding Station) Ltd – Personal Communication, August, 2014).

Sugarcane yields in earlier times, (50s to 70s) when sugarcane production was mainly manual yields averaged ~ 60 tonnes/acre; but in recent years yields have decreased to ~ 45 tons/acre. In earlier years (50 s and 60s (for upright-standing sugarcane), yields were ~ 30 to 35 tons/acre. But with the introduction of mechanization (beginning in the late 80s-early 90s) today yields are down to ~ 18 to 25 tons/acre. Mechanized harvesting has affected and lowered soil fertility, and consequently yields, since machines compact the soil and remove invaluable organic matter (Dr. Orville Wickam, BAMC: Barbados Agricultural Management Co. Ltd – Personal Communication, August, 2014; Dr. Anthony Kennedy (West Indian Central Breeding Station) Ltd – Personal Communication, August, 2014; Dr. Sandra R. Bellamy, Barbados Agricultural Management Co. Lt– Personal Communication, August, 2014. On the other hand, FAO statistics show that total sugarcane production was ~ 1.6×10^6 tonnes in 1961 and decreased to < 2×10^5 tonnes in 2013 (Figure 9), whereas as sugarcane yields decreased from ~ 72,000 Kg/Ha in 1961 to < 50,000 Kg/Ha in 2013 (Figure 10) (FAO, 2014).

Another reason for decreasing sugarcane yields is the choice of cultivar. In the past, the major variety used was B62163 and this was not suited for mechanized production (shallow roots), but this variety has now been replaced by other higher-yielding varieties. The B82238 variety is the most suitable and versatile variety since it can even withstand drought and certain diseases;

Figure 9: Sugarcane Production (tonnes) for Barbados: 1961-2013 (Source: FAO Statistics)

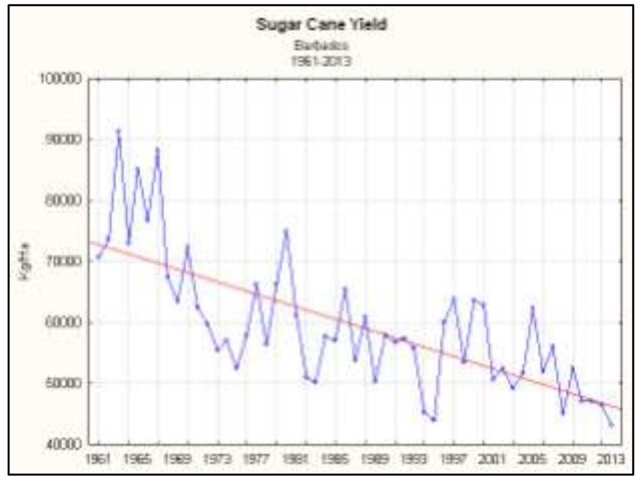
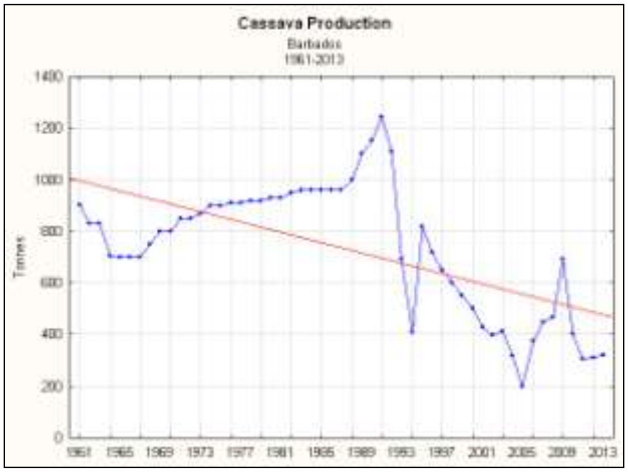


Figure 10: Sugarcane Yield (Kg/Ha) for Barbados: 1961-2013 (Source: FAO Statistics)

2.5.3 Cassava

In general, both cassava production and yields are decreasing over the period 1961-2013 in Barbados: from 1,000 tons in 1961 to ~ 430 tonnes in 2013, and this trend also applies to the Food Zone. This is very likely due to lowering of the acreage under production, decreasing soil fertility due to the lack of application of fertilizers (organic manure and mineral), since cassava is highly efficient in nutrient absorption and therefore requires frequent fertilizer applications (Brereton and Devonish, 2014). Peaks in cassava production (1991, 1994 and 2009) were the results of government programs and incentives to increase cassava production (bitter variety) for producing flour and more local food (Figure 11).

Similarly, cassava yields have been generally decreasing over the period 1961-2013 in Barbados: from ~ 30,000 Kg/Ha) in 1961 to ~ 16,200 Kg/Ha) in 2013, and this trend also applies to the Food Zone. This again is very likely due decreasing soil fertility due to the lack of application of fertilizers (organic manure and mineral), since cassava is highly efficient in nutrient absorption and therefore requires frequent fertilizer applications (Brereton and Devonish, 2014). Peaks in cassava yields (1992, 2004 and 2009) were likely the result of good weather conditions (no water-logging in the root zone), increases fertilizer applications and the introduction and use of high-yielding varieties (including hybrids) such as M Mex 59 and COL 1468 and COL 22 from Mexico and Columbia (Brereton and Devonish, 2014) (Figure 12).



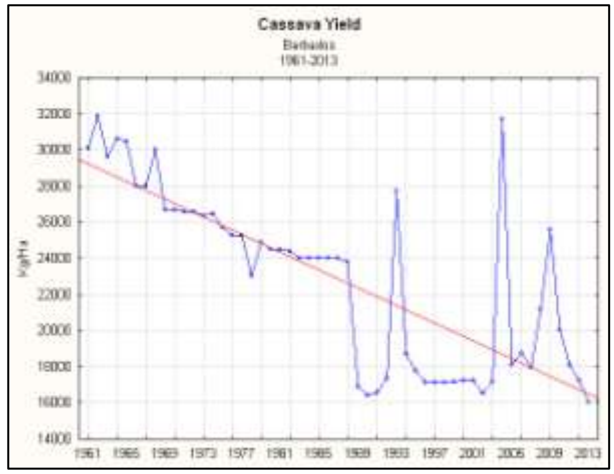


Figure 11: Cassava Production (Tonnes) for Barbados: 1961-2013

Figure 12: Cassava Yield (Kg/HA) for Barbados: 1961-2013

2.5.4 Tomatoes

Unlike sugarcane and cassava, both production and yield of tomatoes have been increasing in Barbados, and in the Food Zone, during the recent past (1961-2013). Tomatoes production has increased from ~ 300 tonnes on average in 1961 to ~ 1,000 tonnes on average in 2013, with spikes in the years some years such as 1980 when production increase to ~ 1,600 tonnes (Figure 13).

Several varieties of plum and cherry tomatoes are grown year-round in Barbados: Calypso (dry season), RomaVF (dry and wet season), HA3019 (wet season) FA-38 (wet season), Florida 47R (dry season), Heatmaster (dry and wet season), Heatwave (dry season), Summer star (dry season), Small fry (dry and wet season), Capaya (wet season) and Paramus (dry season) (Sheete et al., 2012).

Tomato yields, on the other hand were more or less steady between 1961 and the late1980s. But beginning in the early 1990s and up to 2013 yields increase rapidly and stabilized at ~ 18,000 Kg/Ha) (Figure 14) . These lower yields from 1961 to the late 1980s was due mainly to inadequate control of pests (Aphids, Leaf miners, White flies, Flea beetles, Cut worms and Mole crickets) and diseases (Bacterial Spot, Buckeye Rot, Grey Leaf Spot, Blossom End Rot, sunscald), and Early and Late Blight (Sheete et al., 2001).

Weather conditions and soil fertility were other contributing factors to relatively low yields from 1961 to the late 1980s.

But the rapid increase in yields beginning in the early 1990s were due mainly to greater use of pesticides, based on recommendations by the Ministry of Agriculture, the increasing use of shade houses (ventilated greenhouses) and to changes in variety (HA3019-from Israel) (Mr. Colin Wiltshire, Ministry of Agriculture: Personal communication, October, 2014).

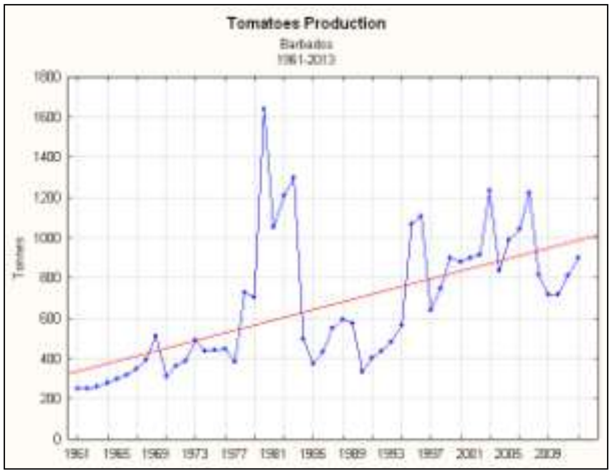


Figure 13: Tomatoes Production (Tonnes) for Barbados: 1961-2013

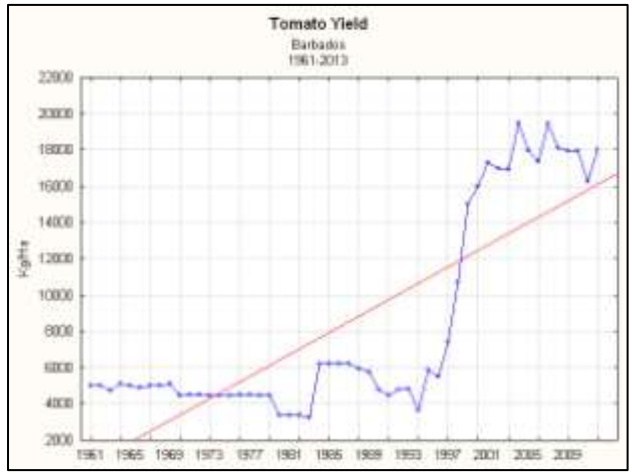


Figure 14: Tomatoes Production (Kg/HA) for Barbados: 1961-2013

2.5.5 Fisheries

The fisheries industry is extremely important in Barbados. In 1998 it was estimated that the fishing industry contributed 0.6 % of the GDP Over, 6000 fishers are employed in the industry of which 80% are full time. Target fisheries are largely pelagic, as near shore coastal reef fishery landings have declined significantly over the last two decades. There are twenty-six coastal landing sites and nine fish processing plants, one of which is an aquaculture fish processing plant. Freshwater fisheries are limited (Mr. Steve Willoughby Chief of Fisheries, Ministry of Agriculture: Personal Communication, December, 2014).

Climate change may lead to a number of physical stressors to the marine environment, which in turn may result in a range of biological/ecological responses affecting coastal fisheries. The main potential physical stressors are: sea surface temperature, currents, stratification and upwelling; ocean acidification; sea level rise; ultra violet radiation; rainfall patterns. On the other hand the main biological/ecological are: phytoplankton and primary production; zooplankton and larval supply; changes in species ranges and abundances; changes to habitats that support fisheries production; calcification rates of reef organisms; physiological responses of organisms to climate change; timing of life history events (MRAG. 2010), Climate change factors, including increasing water temperatures and ocean acidification mainly, represents a threat to the sustainability of capture fisheries development. The consequences, namely fish populations and catch, of gradual warming on a global scale and the associated physical changes in oceanic water conditions will become increasingly evident, as will the impact of more frequent extreme weather events, such as increased storminess. Climate change will mainly have a negative impact on fisheries both directly and indirectly. Fisheries will be impacted directly by changing water levels and flooding events; temperature changes will cause a shift in the range of fish species and a disruption to the reproductive patterns of fish. Rising sea levels could also affect important fishery nursery areas such as along the coast of Oistins Town in Christ Church, Skeete's Bay in St. Philip and Speightstown and Six Men's in St. Peter. Warming can increase disease transmission and have an influence on increasing numbers of marine pathogens. Because of their comparatively small economies, countries like Barbados that are highly dependent on fish for food and tourism have low capacity to adapt to climate change (Calvosa, 2010).

There is as yet an incomplete understanding of the link between climate change and fisheries.
However, alongside the growing acceptance that global average sea surface temperature has increased by at least 0.60C during the last 100 years and, that this trend is expected to continue through the 21st Century, has been the understanding that fishery systems, fisherfolk and other economic and food systems are vulnerable to climate change and variability. In the surface layer of the ocean, several components of climate, including solar radiation, wind and temperature may impact, negatively, the distribution and abundance of fish. Stock production, and to a lesser extent, catchability are known to be closely tied to climatological factors. Despite the resilience of many species of fishery resources, their ability to overcome changes in weather patterns, including increased frequency and severity of extreme events, such as hurricanes, are at best uncertain (Gillett and Myvette, 2008).

Many fisheries however, have throughout history, shown an ability to adopt migration and livelihood diversification strategies in an effort to adapt to climate change and variability. However, the ability to adapt may be lessened in the realm of present day experience given the multiple stress associated with coastal urbanization, changes in frequency and intensity of extreme weather events and the impacts of climate change on sensitive coastal ecosystems such as corals and mangroves. The coral reef ecosystem of Barbados is particularly sensitive to climate change. This makes climate variability extremely important to Barbados's fisheries resources given the nature and extent of the fisheries dependent ecosystems. The primary concern is therefore with the impacts of climate change on marine habitats with the subsequent impacts on fisheries (Gillett and Myvette, 2008).

Coral reefs provide the habitat for a wide variety of reef fishes that are exploited in Barbados.
Over the past two-three decades, there has been widespread deterioration of corals reef worldwide .Much of the deterioration has been attributed to exploitation, pollution, disease,

coastal development and more lately coral or thermal bleaching caused by increasing SSTs (Sea Surface Temperature)

Corals may also be affected by increasing levels of ocean acidification. Elevated levels of dissolved CO_2 reduce the ability of corals to deposit their limestone skeletons, affecting coral growth and the ability of these forms to remain in the photic zone of the water column. Predictions are that ocean acidification will have more negative impacts on corals and coral reefs (Gillett and Myvette, 2008).

Increase in sea temperatures may also affect seagrass beds. Additionally, any increase in rainfall caused by climate change may result in increases in freshwater runoff, which could also negatively impact seagrass beds. Seagrass beds are important to fish. They serve as nursery areas for many species of fish. The predicted rise in sea temperature should not adversely affect the physiological functioning seagrasses, an important habitat for fisheries (Gillett and Myvette, 2008).

Reef fish kills have been observed from time to time in Barbados waters. During the period August to November 1999 there was a major fish kill. This fish kill was attributed to the influx of water with higher than normal temperatures and chlorophyll concentrations and low nocturnal oxygen levels. This appeared to be associated with an unusual trajectory in the sea, of waters from the Orinoco River. This fish kill was devastating to the local fishing community, and is an example of the type of problems, which could occur in Barbados under a changing climate (Parker, 1998).

The records show that during the 1999 fish kill episode in Barbados the fish died from *septicaemia* and *epicarditis* caused by pathogenic bacterium *Streptococcus iniae.* The proliferation and transmission of *S. iniae* among the fish appears to be the result of unfavorable environmental conditions caused by an influx of warm, nutrient-rich and plankton laden water and low nocturnal oxygen levels which placed the fish under stress to create conditions needed to trigger the proliferation of the *S. iniae* that eventually killed the fish (Mr. Steve Willoughby Chief of Fisheries, Ministry of Agriculture: Personal Communication, December, 2014).

The Fisheries Division of the Ministry of Agriculture has set up a Strategic Plan for the Fisheries sector. The draft Strategic Action Plan is a fisheries sector plan which focuses on protecting and strengthening the assets of fishers, creating an enabling environment to pursue sustainable livelihood and mitigating the impact of vulnerabilities as a holistic approach to managing and developing the fisheries sector and empowering the fishers.) (Mr. Stephen Willoughby Chief Fisheries Officer, Fisheries Division). The approach is based on the fact that fisheries in Barbados have five (5) major assets, namely (Mr. Steve Willoughby Chief of Fisheries, Ministry of Agriculture: Personal Communication, December, 2014

1. Physical assets – boat, equipment, gear, infrastructure…;
2. Natural assets – fishery resources, land, waters, bio-diversity…;
3. Financial assets – savings, credit, debt income, pensions, insurance…;
4. Social assets – formal or informal support groups and relationships, networks…;
5. Human assets – skills, knowledge, ability to work, health, nutrition, education.

It is very likely that that climate change and variability and climate-driven sea level rise and storm surges will directly impact on Physical and Natural assets and indirectly, due to spill-over effects, on Financial, Social and Human assets and these will very likely lead to secondary impacts related to livelihood issues.

2.5.6 Livestock

The possible effects of climate change on food production are not limited to crops and agricultural production. Climate change will have far-reaching consequences for dairy and meat production, mainly arising from its impact on grassland and rangeland productivity. Heat distress suffered by animals will reduce the rate of animal feed intake and result in poor growth performance. Lack of water and increased frequency of drought in certain countries will lead to a loss of resources. Consequently, existing food insecurity and conflict over scarce resources will be exacerbated (Calvosa, 2010).

The temperature predictions for the mid (2030-2040) and latter part (2060-2070) of this century are expected to severely affect the local livestock industry of Barbados. At present, poultry birds have shown the greatest vulnerability to increasing temperatures, as tens of thousands of these animals die each year as a result of heat related illnesses (Barbados' First National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), October 2001). However cooling fans are now being used in several chicken farms/pens to counter this heat stress (Mr. R. Young, Poultry Framer: Personal Communication, October, 2014)

Consequently, both egg and meat production is expected to decline; negatively impacting on food and nutrition in Barbados. Larger animals such as cows, black belly sheep and pigs tend to be a more resistant to heat stresses; yet in recent times, high daily temperatures have been responsible for the death of several mature pigs and young piglets (Barbados' First National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), October 2001).

Heat stresses also reduces both meat and milk production in ruminants, and the fact that most of these animals, cows in particular, graze in the sun for much of the day, local meat and milk production are expected to decrease as daily temperatures increase. Reduced availability of local meat and meat-products will impact negatively on food quality, quantity, and ultimately, on human nutrition. There will also be associated economic problems, since local meat producers would have to either alter existing farm buildings, or construct new ones to provide adequate shelter for animals, in order to obtain maximum production from their farm animals. This obviously increases the overall production cost and could possibly wipe out traditional small farmers, and entire farming communities. In addition, meat and other livestock products would have to be imported to supplement expected shortfalls, impacting negatively on foreign reserves (Barbados' First National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), October 2001).

Furthermore, low rainfall and increasing drought impact negatively on biomass growth in most, if not all, plants and that includes grasslands upon which animals and ruminants feed. Certainly, the quality and quantity of grasses, including those that are regularly consumed by large ruminants would be significantly reduced if precipitation predictions for the future (2030-2040 and 2060-2070) were to come to pass. To ensure that farm animals receive an adequate amount of food and nutrition, farmers may either have to increase the sizes of their grasslands or consider other food supplements, both of which will require additional funds. There are already problems with respect to very high operational costs, which is certainly expected to increase in the very near future and could see several livestock farmers going out of production either temporary or permanently (Barbados' First National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), October 2001).

3 Assessment of current and projected climate conditions

Current Climate

Barbados enjoys a tropical, oceanic climate with an average temperature of 26.8^{o}C, with no drastic changes in either seasonal or daily temperatures. Weather seasons can be classified as either wet or dry, with the wet season coinciding with the Atlantic hurricane season, which runs from June to November. Monthly average rainfall ranges from a peak of approximately of 168.4mm (6.63in) during the wet season, to a low of approximately 39mm (1.53in), during the dry season. The island is affected by a number of weather systems during the year. During the wet months, most of the rainfall is derived from tropical waves moving across the Atlantic Ocean, along with the Inter-Tropical Convergence Zone (I.T.C.Z.), which shifts northwards on occasions, especially during the passage of tropical waves. Although during the dry season, upper level troughs and lows and, to a much lesser extent, the tail end of cold fronts which survive after moving off the eastern seaboard of the United States of America, can contribute to the rainfall totals (Barbados' First National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), 2001).

In Barbados fifty-eight over 58 severe rainfall (flood) and wind events of a significant nature have been documented in past years. Hurricanes and tropical storms in 1955, 1970, 1980, 1980, 1994, 1995(2), 1997 and tropical waves in 1998 caused flooding, damaged houses and buildings, and displacement of people. Hurricane Janet in hit Barbados in1955 and thirty-five (35) persons were known to have died, and eight thousand, one hundred, (8,100) small dwelling houses were damaged, leaving twenty thousand (20,000) people displaced. Barbados has also sustained significant losses from passing systems, and flooding from rainfall events. Hurricane Allen in 1980 passed to the north of Barbados causing over BDS $7 million dollars in damage; whilst a tropical wave in combination with an upper level trough in August 1995, produced up to 225mm of rain in certain areas of the island, causing severe flooding and over BDS $ 4 million dollars in damage. (US $1.00 = BDS $2.00) (Barbados' First National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), 2001).

However, the infrequent occurrence of major storms has led to some complacency within the general population and Tropical Storm Tomas in October 2010 was a "wake-up call" and a painful reminder of the importance of disaster preparedness. Public utilities were interrupted in some parts of the island for several days and large areas of vegetation as well as many homes were severely damaged (CARIBSAVE, 2012).

- As a matter of fact, Barbados is already experiencing some of the effects of climate variability and change through damages from severe weather systems and other extreme events, as well as more subtle changes in temperatures and rainfall patterns. Detailed climate modelling projections for Barbados predict (CARIBSAVE, 2012):
    - an increase in average atmospheric temperature;
    - reduced average annual rainfall;
    - increased Sea Surface Temperatures (SST);
    - the potential for an increase in the intensity of tropical storms.

- Furthermore, North Atlantic hurricanes and tropical storms appear to have increased in intensity over the last 30 years. Observed and projected increases in SSTs indicate potential for continuing increases in hurricane activity and model projections indicate that this may occur through increases in intensity of events but not necessarily through increases in frequency of storms (CARIBSAVE, 2012).

3.1 Development of a Climate Risk Inventory: past, recent (and projected) events

The climate risk inventory aims to characterise the current state of relevant knowledge of climate variability on relevant time-scales for social and environmental impacts. Most importantly, these would highlight the characteristics of recent important/focussing events for use in stakeholder surveys and interviews for the determination of adaptive capacity.

3.2 Characterisation of Future Climate and Sea Level Projections

In order to characterize future climate and sea level conditions we will use stations (CIMH and Grantley Adams) (1981-2010) data to prepare maps or trends of current temperature (T^0C) rainfall (P: mm/season), evaporation (E: mm season) and water excess/deficits (P-E: mm/season) for the entire island but focussed on the Food Zone in the Parishes of Saint Michael and Saint George.

For future conditions, we will use PRECIS-downscaled (25 x 25 km) data (A1B forcing) of HadCM3 and ECHAM5 to prepare maps of the future climate (2030s and 2060s) focussed on the Food Zone in the Parishes of Saint Michael and Saint George. This will allow us to prepare seasonal maps of temperature (T^0C) rainfall (P: mm/season), evaporation (E: mm season) and water excess/deficits (P-E: mm/season) for the entire island but focussed on the Food Zone in the Parishes of Saint Michael and Saint George.

We will also map sea level rise and storm surges (2046-2065 and 2081-2100 future periods) and inundation of coastal land use classes in the Parishes of Saint Michael and Saint George.

In this section, we focus on the future (2030-2040 and 2060-2070) temperature and rainfall changes that are projected, compared to current (1961-2013 climate conditions for the Parishes of Saint Michael and Saint George within which the Food Zone is located. The future temperature and rainfall are derived from the two PRECIS-downscaled global climate models, namely HadCM3/AEXSM and ECHAM5.

3.2.1: HadCM3/AEXSM: Mean Temperature - 2030-2040 versus 1961-2013

At first, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the March-April-May season, we see that, on average, modelled temperature for the current period (1961-2013) is 26.96 ^0C, whereas modelled temperature for the future period (2030-2040) is 28.12 ^0C, thereby indicating a seasonal temperature increase of 1.16 ^0C (Figure 15a and Table 12).

Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the June-July-August season, we now see that, on average, modelled temperature for the current period (1961-2013) is 27.75 ^0C, whereas modelled temperature for the future period (2030-2040) is 29.09 ^{0}C, thereby indicating a seasonal temperature increase of 1.34 ^{0}C (Figure 15b and Table 12).

When however using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the September-October-November season, we now see that, on average, modelled temperature for the current period (1961-2013) is 28.04 ^{0}C, whereas modelled temperature for the future period (2030-2040) is 29.34 ^{0}C, thereby indicating a seasonal temperature increase of 1.30 ^{0}C (Figure 15c and Table 12).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the December-January-February season, we now see that, on average, modelled temperature for the current period (1961-2013) is 26.87 ^{0}C, whereas modelled temperature for the future period (2030-2040) is 28.07 ^{0}C, thereby indicating a seasonal temperature increase of 1.20 ^{0}C (Figure 15d and Table 12).

It is evident then that average seasonal temperature increases for the near-term future (2030-2060) period, when compared to the current period (1961-2013) would be higher by > 1.0 ^{0}C, with the highest temperature increase (1.34) ^{0}C occurring in the June-July-August rainy season (Table 12).

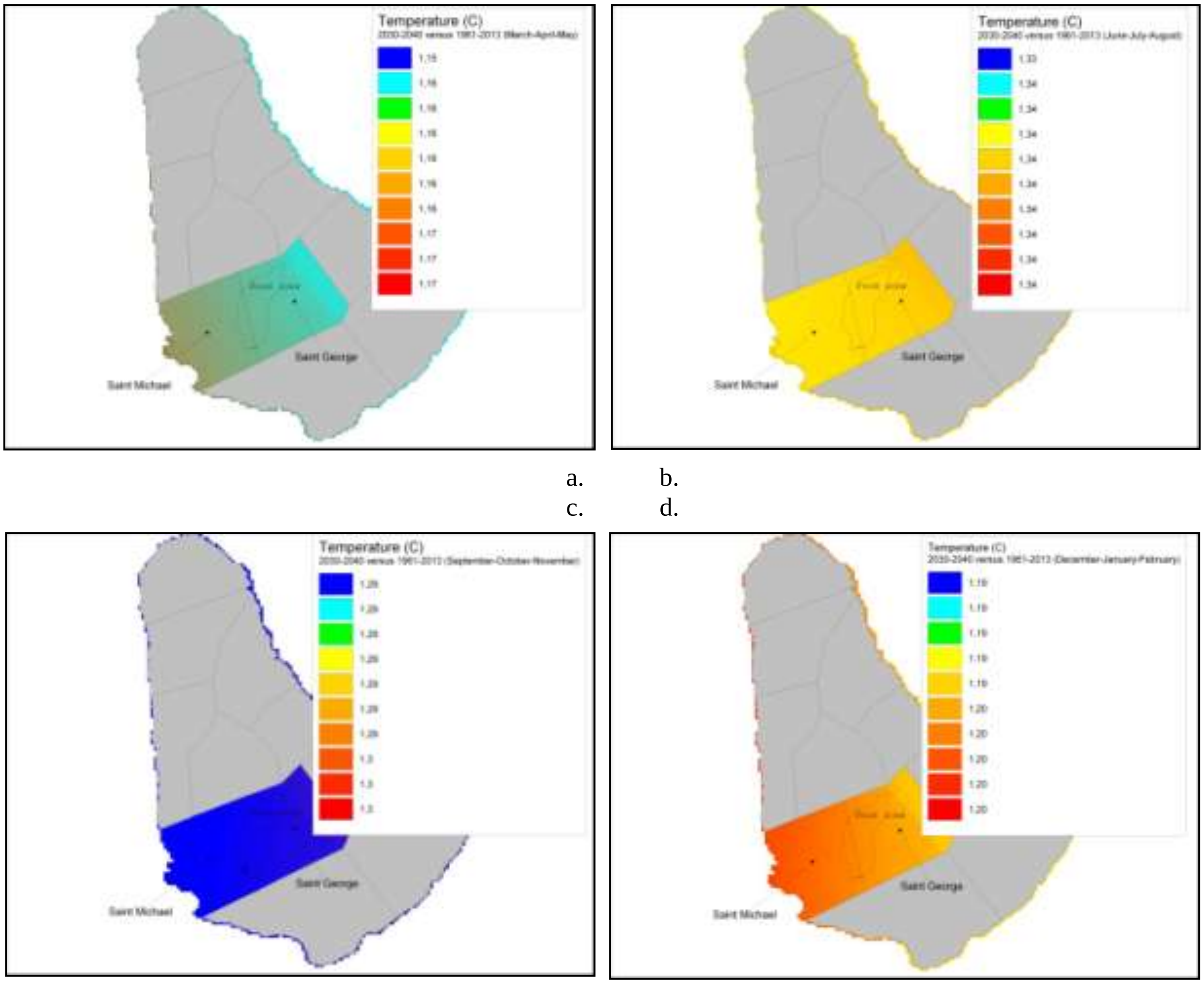


Figure 15: Mean seasonal temperature anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.2: HadCM3/AEXSM: Mean Temperature - 2060-2070 versus 1961-2013

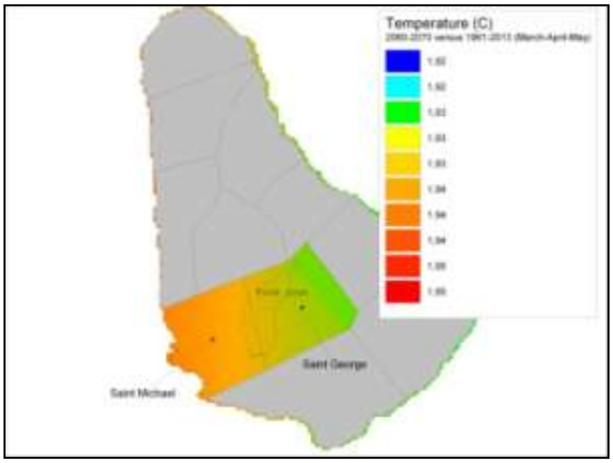
Now, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the March-April-May season, we see that, on average, modelled temperature for the current period (1961-2013) is again 26.96 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 28.89 ^{0}C, thereby indicating a seasonal temperature increase of 1.93 ^{0}C (Figure 16a and Table 12).

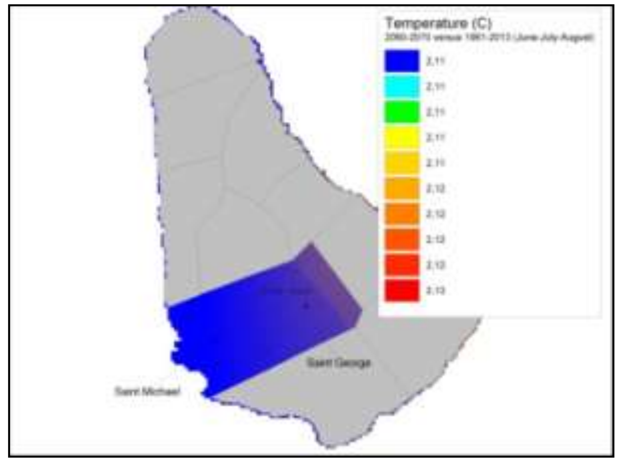
Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the June-July-August season, we now see that, on average, modelled temperature for the current period (1961-2013) is again 27.75 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 29.86 ^{0}C, thereby indicating a seasonal temperature increase of 2.11 ^{0}C (Figure 16b and Table 12).

But, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the September-October-November season, we now see that, on average, modelled temperature for the current period (1961-2013) is again 28.04 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 30.21 ^{0}C, thereby indicating a seasonal temperature increase of 2.05 ^{0}C (Figure 16c and Table 12).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal temperature for the December-January-February season, we now see that, on average, modelled temperature for the current period (1961-2013) is again 26.87 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 28.92 ^{0}C, thereby indicating a seasonal temperature increase of 2.05 ^{0}C (Figure 16d and Table 12).

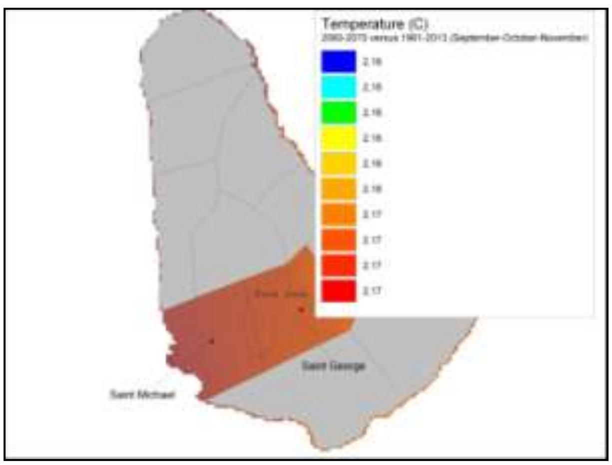
It is again evident then that average seasonal temperature increases for the far-term future (2060-2070) period, when compared to the current period (1961-2013) would be higher by > 2.0 ^{0}C, except for the March-April-May season (1.93 ^{0}C) with the highest temperature increase (2.17) ^{0}C now occurring in the September-October-November rainy season (Table 12).





a. b.

c. d.



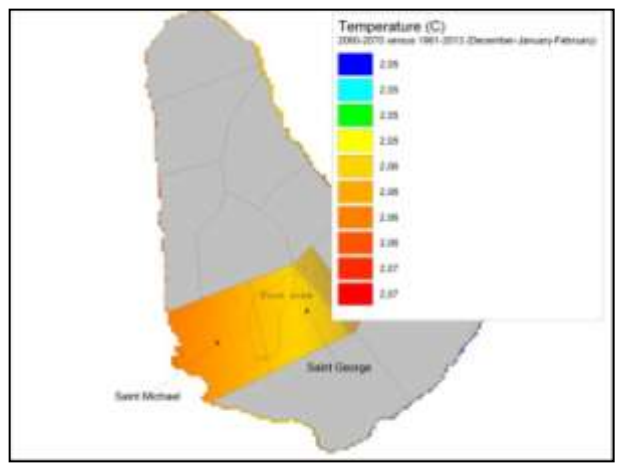


Figure 16: Mean seasonal temperature anomalies (2060-2070 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.3: ECHAM5: Mean Temperature - 2030-2040 versus 1961-2013

Similarly, using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the March-April-May season, we see that, on average, modelled temperature for the current period (1961-2013) is 26.57 ^{0}C, whereas modelled temperature for the future period (2030-2040) is 27.27 ^{0}C, thereby indicating a seasonal temperature increase of 0.70 ^{0}C (Figure 17a and Table 12).

Also, using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the June-July-August season, we now see that, on average, modelled temperature for the current period (1961-2013) is 27.57 ^{0}C, whereas modelled temperature for the future period (2030-2040) is 28.58 ^{0}C, thereby indicating a seasonal temperature increase of 1.01 ^{0}C (Figure 17b and Table 12).

But when using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the September-October-November season, we now see that, on average, modelled temperature for the current period (1961-2013) is 27.87 ^{0}C, whereas modelled temperature for the future period (2030-2040) is 28.86 ^{0}C, thereby indicating a seasonal temperature increase of 0.99 ^{0}C (Figure 17c and Table 12).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the December-January-February season, we now see that, on average, modelled temperature for the current period (1961-2013) is 26.18 ^{0}C, whereas modelled temperature for the future period (2030-2040) is 27.18 ^{0}C, thereby indicating a seasonal temperature increase of 1.00 ^{0}C (Figure 17d and Table 12).

It is evident then that average seasonal temperature increases, according to the downscaled ECHAM 5 model, for the near-term future (2030-2040) period, when compared to the current period (1961-2013) would be higher by ~ 1.0 ^{0}C, with the highest temperature increase (1.01) ^{0}C occurring in the June-July-August rainy season. These temperature increases for the near-term future (2030-2040) period are therefore slightly lower for the ECHAM5 model compared to the HadCM3/AEXSM climate model (Table 12).

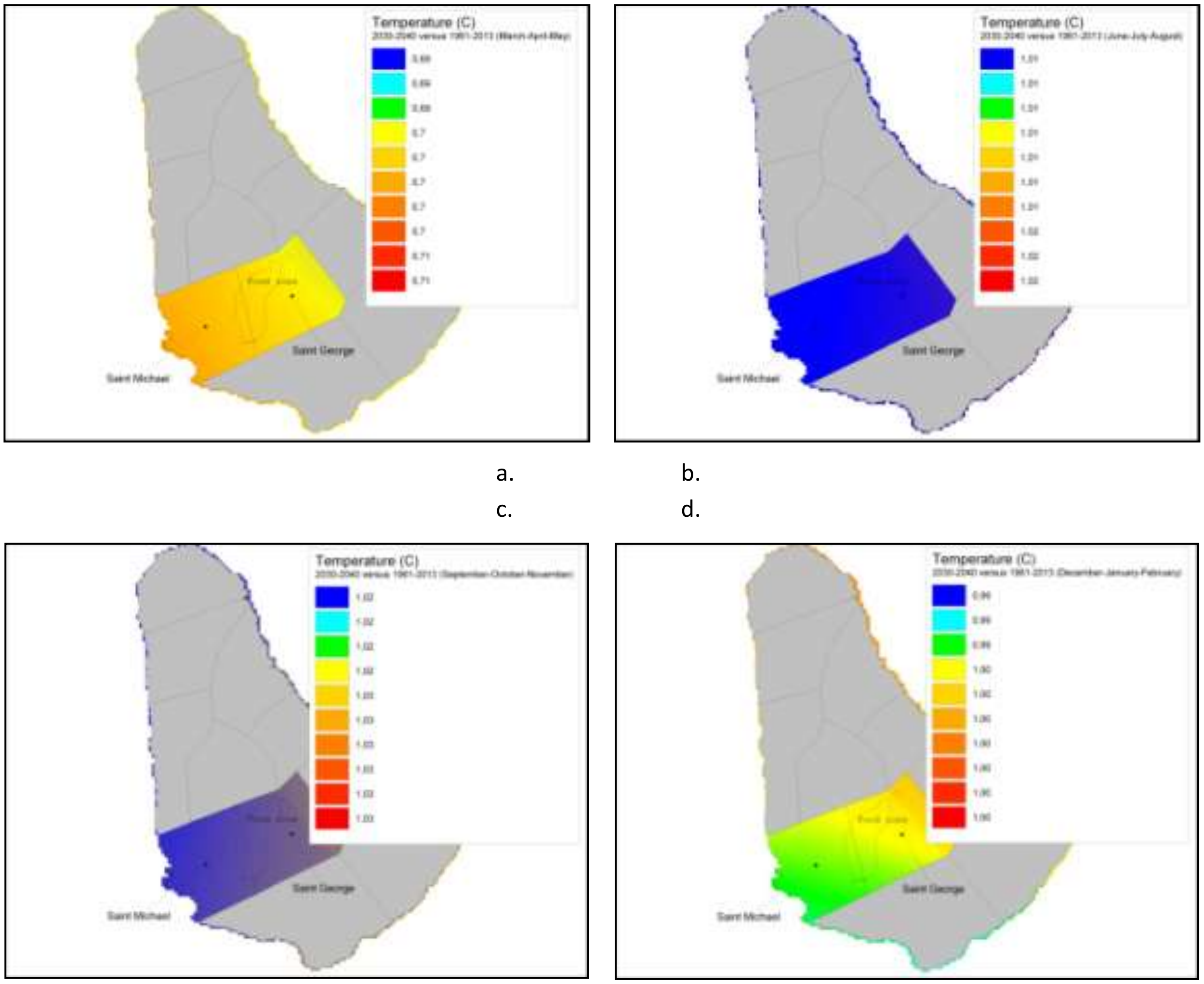


Figure 17: Mean seasonal temperature anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.4: ECHAM5: Mean Temperature - 2060-2070 versus 1961-2013

But when using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the March-April-May season, we see that, on average, modelled temperature for the current period (1961-2013) is again 26.57 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 28.52 ^{0}C, thereby indicating a seasonal temperature increase of 1.95 ^{0}C (Figure 18a and Table 12).

However, using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the June-July-August season, we now see that, on average, modelled temperature for the current period (1961-2013) is 27.57 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 29.72 ^{0}C, thereby indicating a seasonal temperature increase of 2.15 ^{0}C (Figure 18b and Table 12).

But, when using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the September-October-November season, we now see that, on average, modelled temperature for the current period (1961-2013) is 27.87 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 29.92 ^{0}C, thereby indicating a seasonal temperature increase of 2.05 ^{0}C (Figure 18c and Table 12).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal temperature for the December-January-February season, we now see that, on average, modelled temperature for the current period (1961-2013) is 26.18 ^{0}C, whereas modelled temperature for the future period (2060-2070) is 28.31 ^{0}C, thereby indicating a seasonal temperature increase of 2.13 ^{0}C (Figure 18d and Table 12).

It is evident then that average seasonal temperature increases, according to the downscaled ECHAM 5 model, for the far-term future (2060-2070) period, when compared to the current period (1961-2013) would be higher by > 2.0 ^{0}C, except for the March-April-May season, with the highest temperature increase (2.15) ^{0}C occurring in the June-July-August rainy season. These temperature increases for the far-term future (2060-2070) period are therefore very similar for both the ECHAM5 and HadCM3/AEXSM climate models (Table 12).

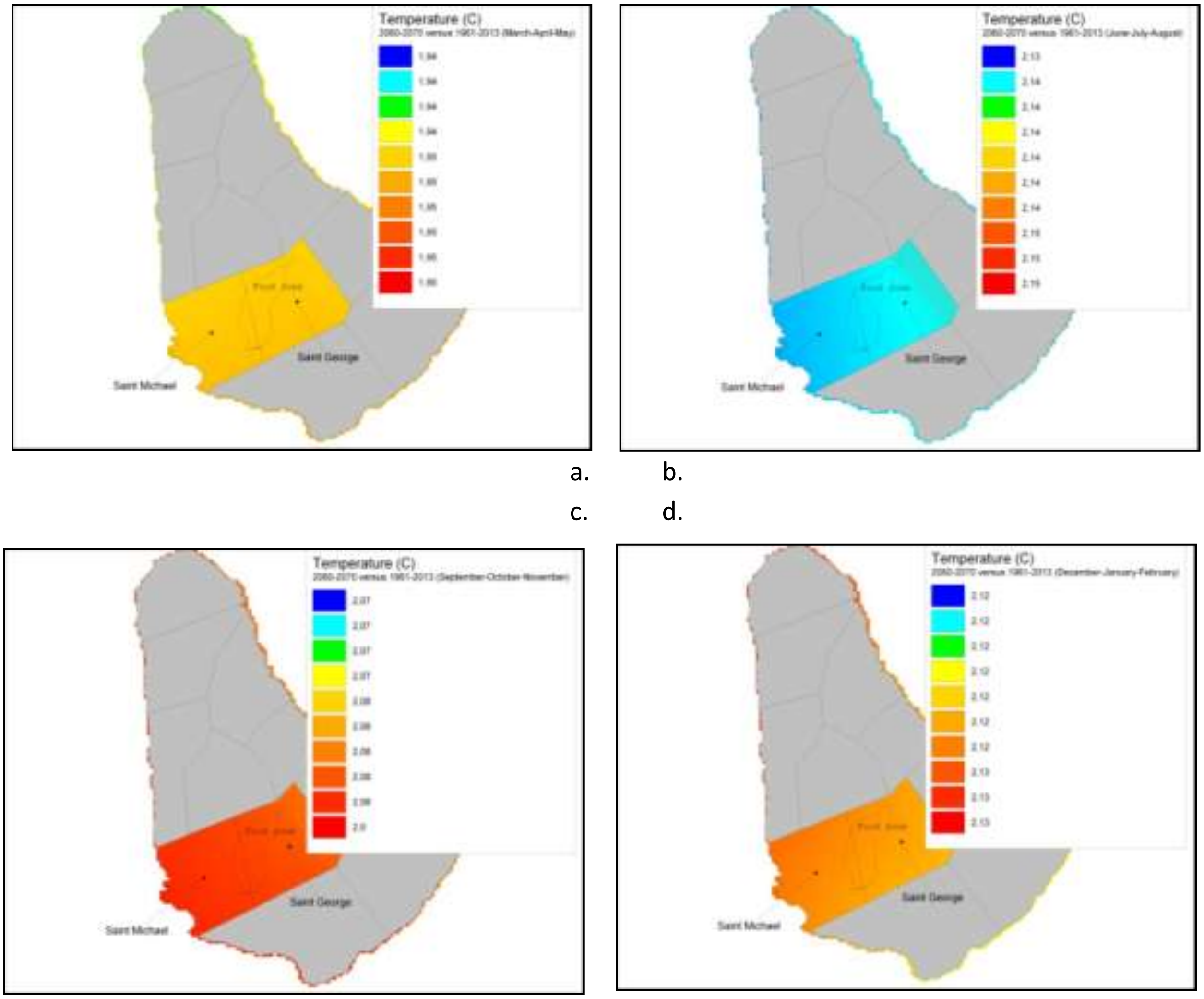


Figure 18: Mean seasonal temperature anomalies (2060-2070 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

Table 12: HadCM3/AEXSM and ECHAM5: Mean Temperature Anomalies (^{0}C)

Climate Model		Modelled Temperature: 1961-2013 (^{0}C)	Modelled Temperature: 2030-2040 (^{0}C)	Temperature Change: 2030-2040 (^{0}C)	Modelled Temperature: 2060-2070 (^{0}C)	Temperature Change: 2060-2070 (^{0}C)
HadCM3/AEXSM						
	March-April-May	26,96	28,12	1,16	28,89	1,93
	June-July-August	27,75	29,09	1,34	29,86	2,11
	September-October-November	28,04	29,34	1,30	30,21	2,17
	December-January-February	26,87	28,07	1,20	28,92	2,05
ECHAM5						
	March-April-May	26,57	27,27	0,70	28,52	1,95
	June-July-August	27,57	28,58	1,01	29,72	2,15
	September-October-November	27,87	28,86	0,99	29,92	2,05
	December-January-February	26,18	27,18	1,00	28,31	2,13

3.2.5: HadCM3/AEXSM: Mean Maximum Temperature - 2030-2040 versus 1961-2013

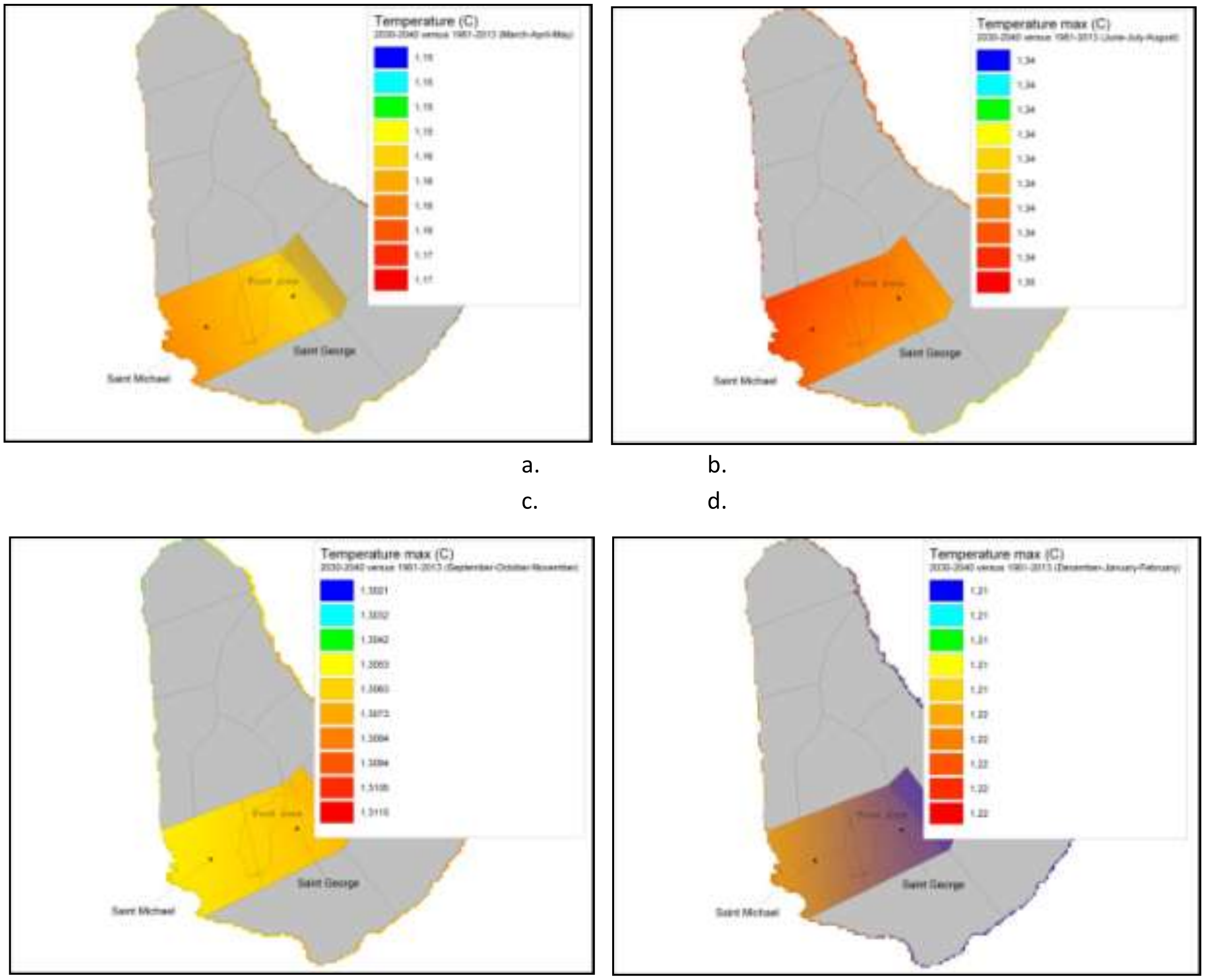
As for maximum temperature, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the March-April-May season, we see that, on average, modelled maximum temperature for the current period (1961-2013) is 27.16 ^{0}C, whereas modelled maximum temperature for the future period (2030-2040) is 28.32 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.16 ^{0}C (Figure 19a and Table 13).

Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the June-July-August season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is 27.96 ^{0}C, whereas modelled maximum temperature for the future period (2030-2040) is 29.31 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.35 ^{0}C (Figure 19b and Table 13).

But when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the September-October-November season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is 28.22 ^{0}C, whereas modelled maximum temperature for the future period (2030-2060) is 29.53 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.31 ^{0}C (Figure 19c and Table 13).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the December-January-February season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is 27.04 ^{0}C, whereas modelled maximum temperature for the future period (2030-2040) is 28.26 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.22 ^{0}C (Figure 19d and Table 13).

It is evident then that average seasonal maximum temperature increases for the near-term future (2030-2040) period, when compared to the current period (1961-2013) would be higher by > 1.0 ^{0}C, with the highest maximum temperature increase (1.35) ^{0}C occurring in the June-July-August rainy season (Table 13).



a. b.

c. d.

Figure 19: Mean maximum seasonal temperature anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: Sept-October-November; d: December-January-February).

3.2.6: HadCM3/AEXSM: Mean Maximum Temperature - 2060-2070 versus 1961-2013

For maximum temperature, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the March-April-May season, we see that, on average, modelled maximum temperature for the current period (1961-2013) is again 27.16 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 29.09 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.93 ^{0}C (Figure 20a and Table 13).

However, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the June-July-August season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is again 27.96 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 30.41 ^{0}C, thereby indicating a seasonal maximum temperature increase of 2.12 ^{0}C (Figure 20b and Table 13).

But, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the September-October-November season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is again 28.22 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 30.41 ^{0}C, thereby indicating a seasonal maximum temperature increase of 2.19 ^{0}C (Figure 20c and Table 13).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal maximum temperature for the December-January-February season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is again 27.04 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 29.11 ^{0}C, thereby indicating a seasonal maximum temperature increase of 2.07 ^{0}C (Figure 20d and Table 13).

It is evident then that average seasonal maximum temperature increases for the near-term future (2030-2040) period, according to the HadCM3/AEXSM downscaled model, when compared to the current period (1961-2013) would be higher by ~ 2.0 ^{0}C, with the highest maximum temperature increase (2.19) ^{0}C occurring in the September-October-November rainy season (Table 13).

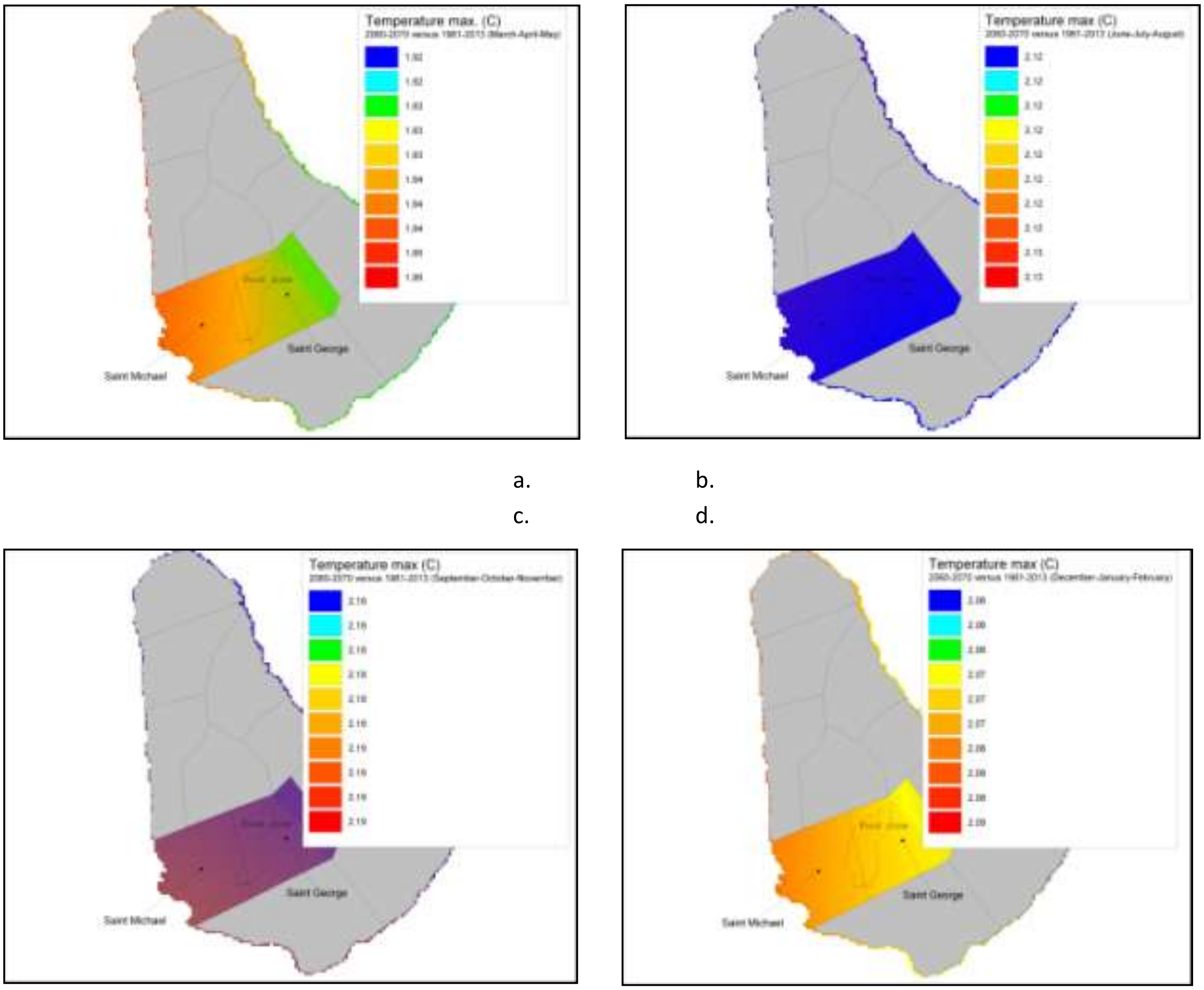


Figure 20: Mean maximum seasonal temperature anomalies (2060-2070 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: Sept-October-November; d: December-January-February).

3.2.7: ECHAM5: Mean Maximum Temperature - 2030-2040 versus 1961-2013

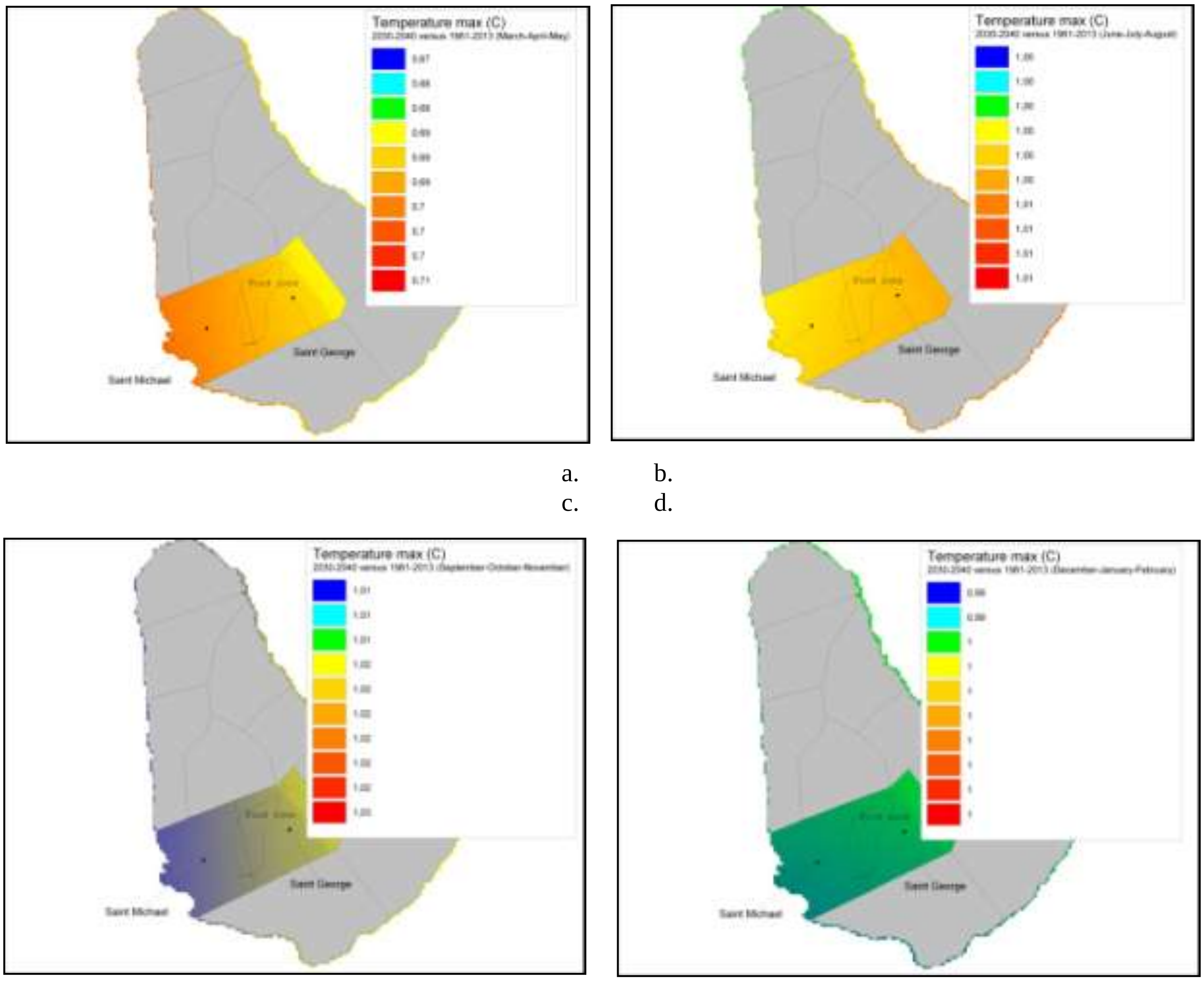
Now for maximum temperature, using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the March-April-May season, we see that, on average, modelled maximum temperature for the current period (1961-2013) is 26.80 ^{0}C, whereas modelled maximum temperature for the future period (2030-2040) is 27.49 ^{0}C, thereby indicating a seasonal maximum temperature increase of 0.69 ^{0}C (Figure 21a and Table 13).

Next, using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the June-July-August season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is 27.82 ^{0}C, whereas modelled maximum temperature for the future period (2030-2040) is 28.83 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.01 ^{0}C (Figure 21b and Table 13).

But, when using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the September-October-November season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is 28.07 ^{0}C, whereas modelled maximum temperature for the future period (2030-2060) is 29.09 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.02 ^{0}C (Figure 21c and Table 13).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the December-January-February season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is 26.38 ^{0}C, whereas modelled maximum temperature for the future period (2030-2040) is 27.38 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.00 ^{0}C (Figure 21d and Table 13).

It is therefore evident that average seasonal maximum temperature increases for the near-term future (2030-2040) period, when compared to the current period (1961-2013) would be higher by ~ 1.0 ^{0}C, with the highest maximum temperature increase (1.01) ^{0}C occurring in the June-July-August rainy season (Table 13).



a. b.
c. d.

Figure 21: Mean maximum seasonal temperature anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.8: ECHAM5: Mean Maximum Temperature - 2060-2070 versus 1961-2013

Next, by examining maximum temperature, using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the March-April-May season, we see that, on average, modelled maximum temperature for the current period (1961-2013) is again 26.80 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 28.72 ^{0}C, thereby indicating a seasonal maximum temperature increase of 1.92 ^{0}C (Figure 22a and Table 13).

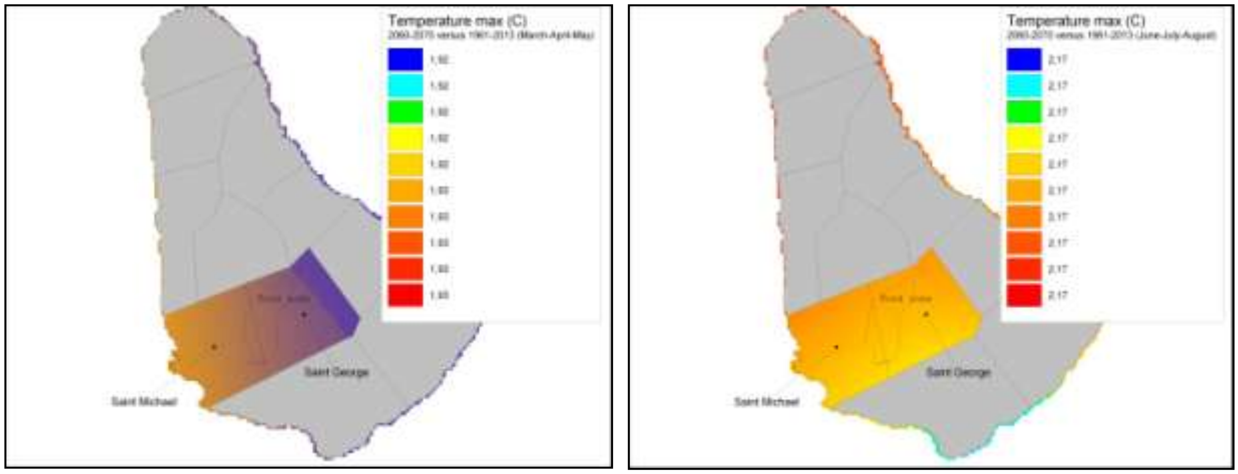
But when using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the June-July-August season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is again 27.82 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 30.00 ^{0}C, thereby indicating a seasonal maximum temperature increase of 2.18 ^{0}C (Figure 22b and Table 13).

However, when using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the September-October-November season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is again 28.07 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 30.17 ^{0}C, thereby indicating a seasonal maximum temperature increase of 2.10 ^{0}C (Figure 22c and Table 13).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal maximum temperature for the December-January-February season, we now see that, on average, modelled maximum temperature for the current period (1961-2013) is again 26.38 ^{0}C, whereas modelled maximum temperature for the future period (2060-2070) is 28.61 ^{0}C, thereby indicating a seasonal maximum temperature increase of 2.23 ^{0}C (Figure 22d and Table 13).

It is evident then that average seasonal maximum temperature increases for the far-term future (2060-2070) period, when compared to the current period (1961-2013) would be higher by ~ 2.0 ^{0}C, with the highest maximum temperature increase (2.18) ^{0}C occurring in the June-July-August rainy season (Table 13).

Furthermore, the maximum temperature increases (~ 2.0 ^{0}C) for the far-term future (2060-2070) period, when compared to the current period (1961-2013), are very similar for both the HadCM3/AEXSM and ECHAM5 climate models.



a. b.
c. d.

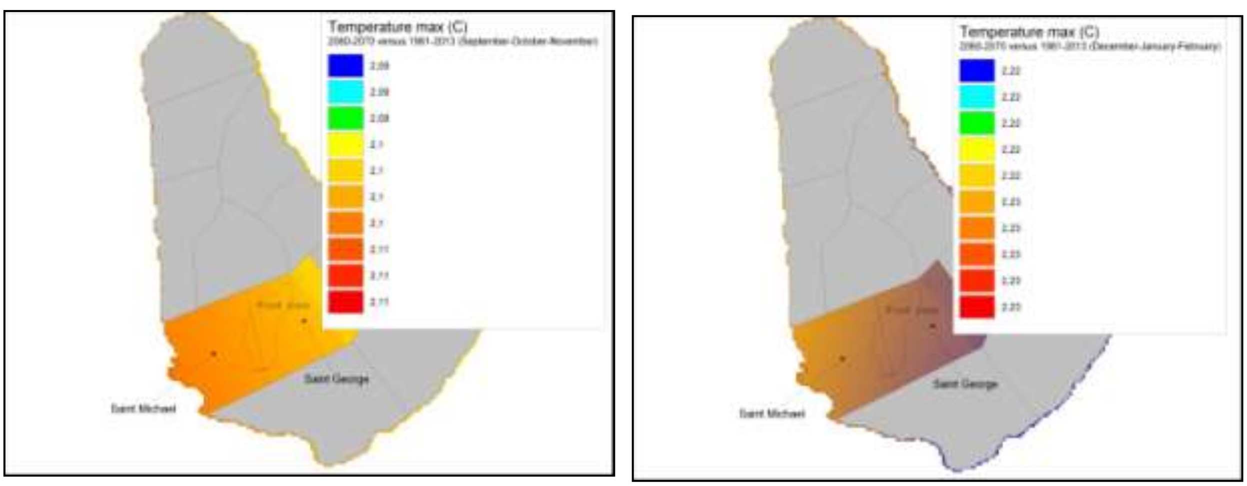


Figure 22: Mean maximum seasonal temperature anomalies (2060-2070 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

Table 13: HadCM3/AEXSM and ECHAM5: Mean Maximum Temperature Anomalies

Climate Model		Modelled Temperature: 1961-2013 (^{0}C)	Modelled Temperature: 2030-2040 (^{0}C)		Temperature Change: 2030-2040 (^{0}C)	Modelled Temperature: 2060-2070 (^{0}C)	Temperature Change: 2060-2070 (^{0}C)
HadCM3/AEXSM							
	March-April-May	27,16	28,32		1,16	29,09	1,93
	June-July-August	27,96	29,31		1,35	30,08	2,12
	September-October-November	28,22	29,53		1,31	30,41	2,19
	December-January-February	27,04	28,26		1,22	29,11	2,07
ECHAM5							
	March-April-May	26,80	27,49		0,69	28,72	1,92
	June-July-August	27,82	28,83		1,01	30	2,18
	September-October-November	28,07	29,09		1,02	30,17	2,10
	December-January-February	26,38	27,38		1,00	28,61	2,23

3.2.9: HadCM3/AEXSM: Mean Minimum Temperature - 2030-2040 versus 1961-2013

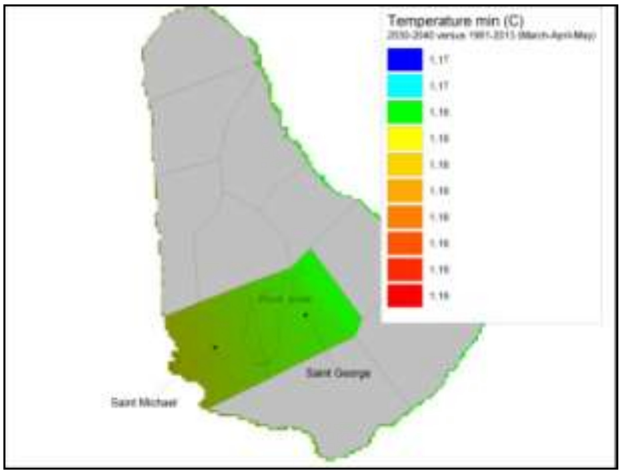
At first, for minimum temperature, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the March-April-May season, we see that, on average, modelled minimum temperature for the current period (1961-2013) is 26.74 ^{0}C, whereas modelled minimum temperature for the future period (2030-2040) is 27.92 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.18 ^{0}C (Figure 23a and Table 14).

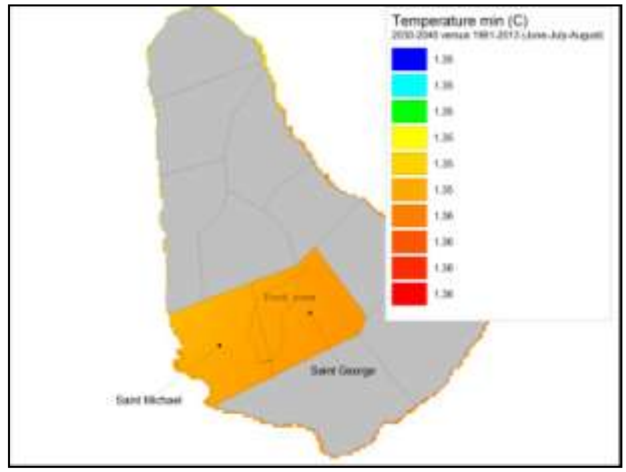
Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the June-July-August season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is 27.53 ^{0}C, whereas modelled minimum temperature for the future period (2030-2040) is 28.89 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.36 ^{0}C (Figure 23b and Table 14).

Also, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the September-October-November season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is 27.82 ^{0}C, whereas modelled minimum temperature for the future period (2030-2060) is 29.15 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.24 ^{0}C (Figure 23c and Table 14).

Furthermore, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the December-January-February season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is 26.64 ^{0}C, whereas modelled minimum temperature for the future period (2030-2040) is 27.88 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.24 ^{0}C (Figure 23d and Table 14).

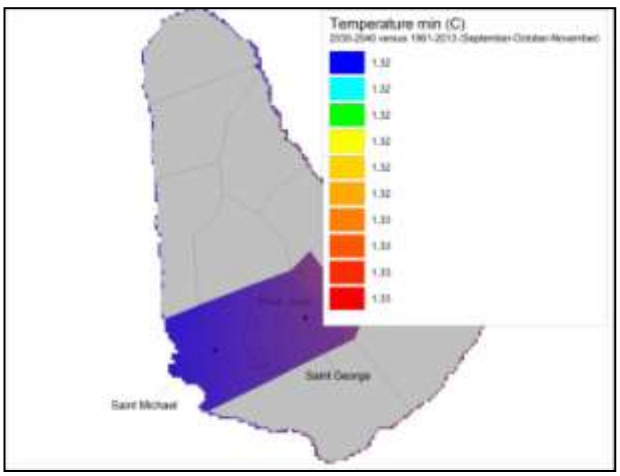
It is evident then that average seasonal minimum temperature increases for the near-term future (2030-2040) period, when compared to the current period (1961-2013) would be higher for all seasons by > 1.0 ^{0}C, with the highest minimum temperature increase (1.33) ^{0}C occurring in the September-October-November rainy season (Table 14).





a. b.

c. d.



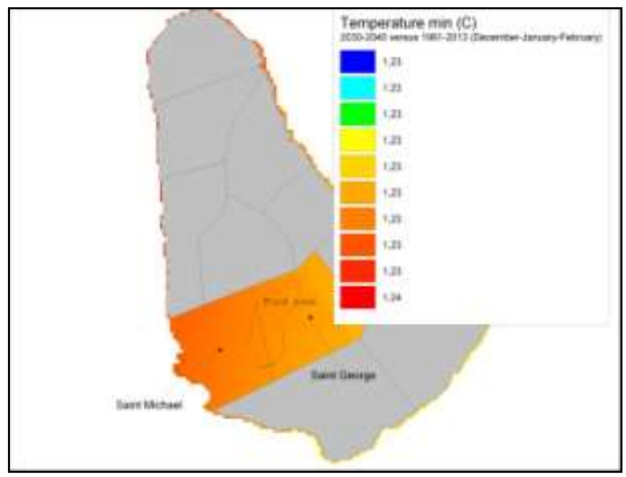


Figure 23: Mean minimum seasonal temperature anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.10: HadCM3/AEXSM: Mean Minimum Temperature - 2060-2070 versus 1961-2013

As for minimum temperature, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the March-April-May season, we see that, on average, modelled minimum temperature for the current period (1961-2013) is again 26.74 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 29.68 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.94 ^{0}C (Figure 24a and Table 14).

But, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the June-July-August season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is again 27.53 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 29.65 ^{0}C, thereby indicating a seasonal minimum temperature increase of 2.12 ^{0}C (Figure 24b and Table 14).

However, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the September-October-November season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is again 27.82 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 30.02 ^{0}C, thereby indicating a seasonal minimum temperature increase of 2.20 ^{0}C (Figure 24c and Table 14).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal minimum temperature for the December-January-February season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is again 26.64 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 28.73 ^{0}C, thereby indicating a seasonal minimum temperature increase of 2.09 ^{0}C (Figure 24d and Table 14).

It is evident then that average seasonal minimum temperature increases for the far-term future (2060-2070) period, according to the HadCM3/AEXSM downscaled model, when compared to the current period (1961-2013) would be higher by ~ 2.0 ^{0}C, with the highest minimum temperature increase (2.20) ^{0}C also occurring in the September-October-November rainy season (Table 14).

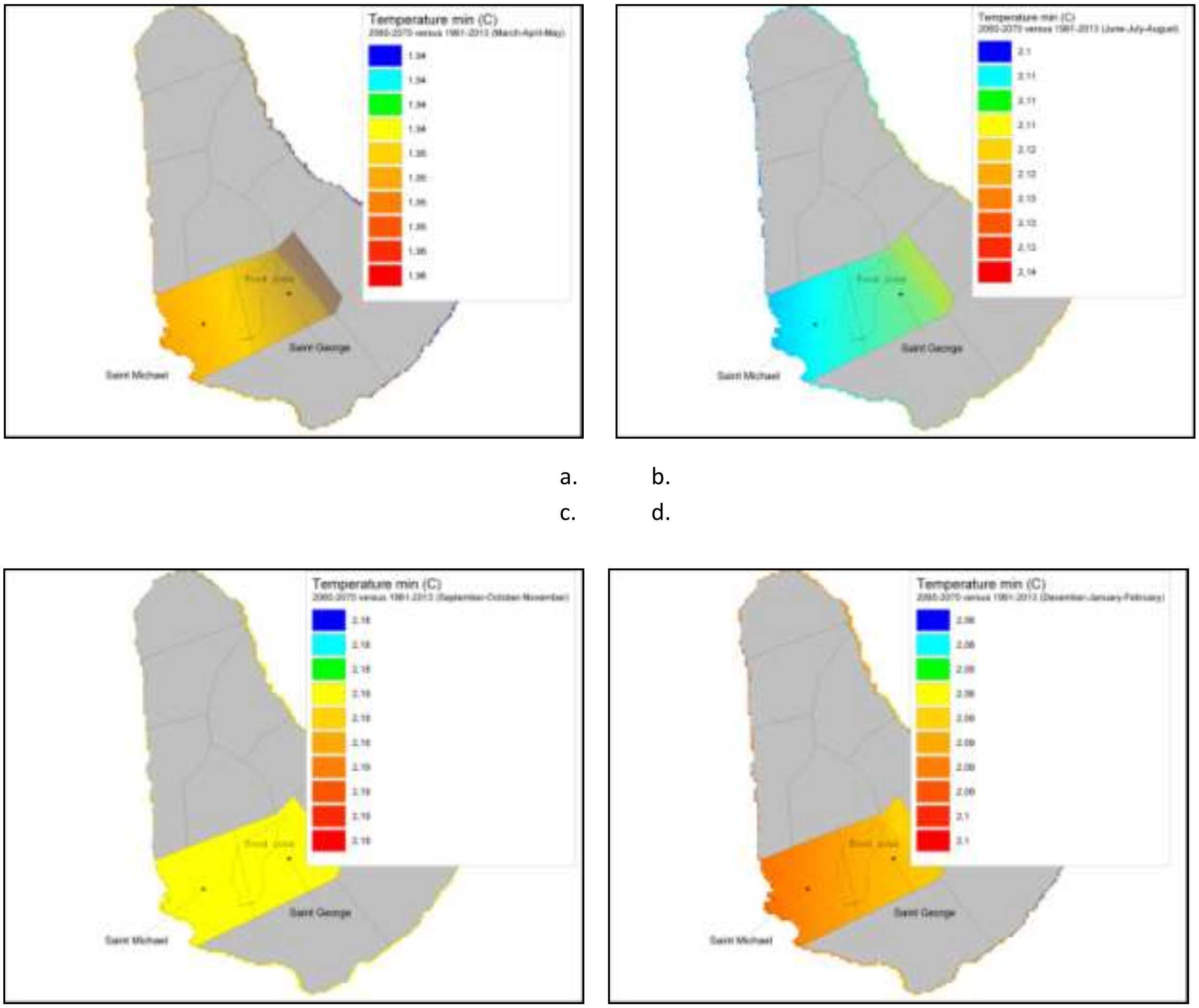


Figure 24: Mean minimum seasonal temperature anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.11: ECHAM5: Mean Minimum Temperature - 2030-2040 versus 1961-2013

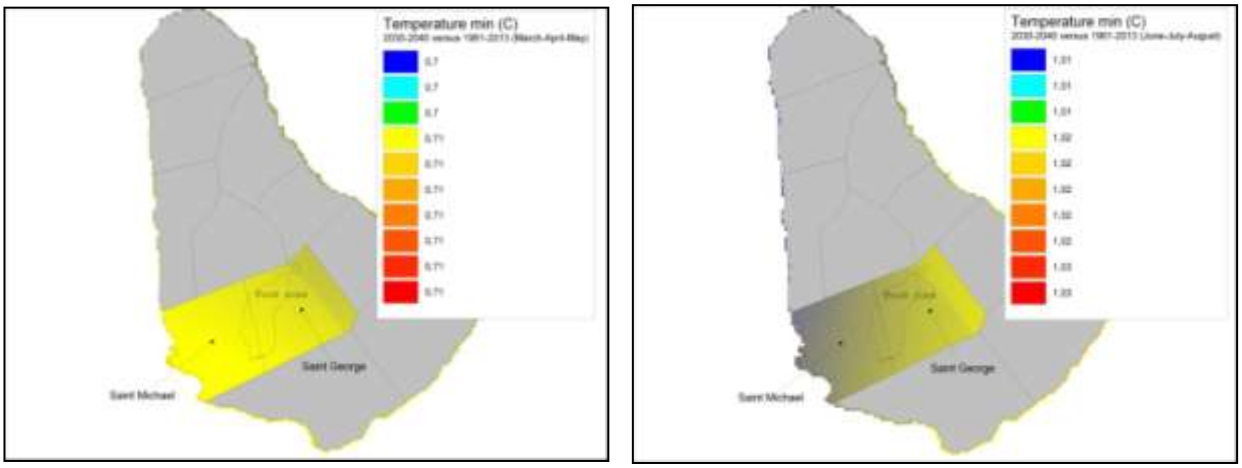
As for minimum temperature, using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the March-April-May season, we see that, on average, modelled minimum temperature for the current period (1961-2013) is 26.34 ^{0}C, whereas modelled minimum temperature for the future period (2030-2040) is 27.05 ^{0}C, thereby indicating a seasonal minimum temperature increase of 0.71 ^{0}C (Figure 25a and Table 14).

Also, using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the June-July-August season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is 27.34 ^{0}C, whereas modelled minimum temperature for the future period (2030-2040) is 28.36 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.02 ^{0}C (Figure 25b and Table 14).

Next, when using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the September-October-November season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is 27.61 ^{0}C, whereas modelled minimum temperature for the future period (2030-2060) is 28.54 ^{0}C, thereby indicating a seasonal minimum temperature increase of 0.93 ^{0}C (Figure 25c and Table 14).

Lastly, when using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the December-January-February season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is 25.97 ^{0}C, whereas modelled minimum temperature for the future period (2030-2040) is 26.98 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.01 ^{0}C (Figure 25d and Table 14).

It is evident then, that average seasonal minimum temperature increases for the near-term future (2030-2040) period, when compared to the current period (1961-2013) would be higher by ~ 1.0 ^{0}C, with the highest minimum temperature increase (1.02) ^{0}C also occurring in the June-July-August rainy season (Table 14).



a. b.

c. d.

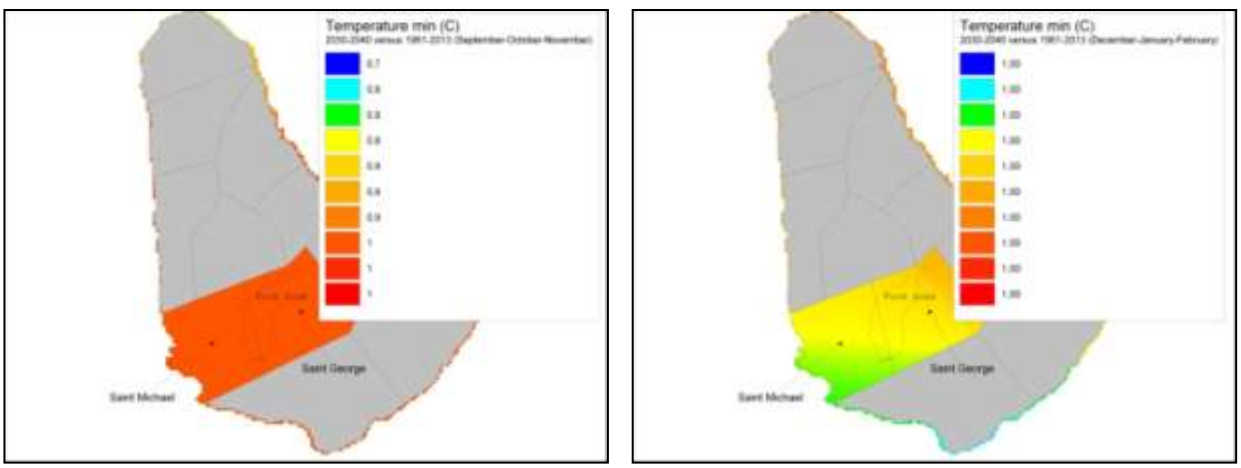


Figure 25: Mean minimum seasonal temperature anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November, d: December-January-February).

3.2.12: ECHAM5: Mean Minimum Temperature - 2060-2070 versus 1961-2013

Next, by examining minimum temperature, using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the March-April-May season, we see that, on average, modelled minimum temperature for the current period (1961-2013) is again 26.34 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 29.70 ^{0}C, thereby indicating a seasonal minimum temperature increase of 1.97 ^{0}C (Figure 26a and Table 14).

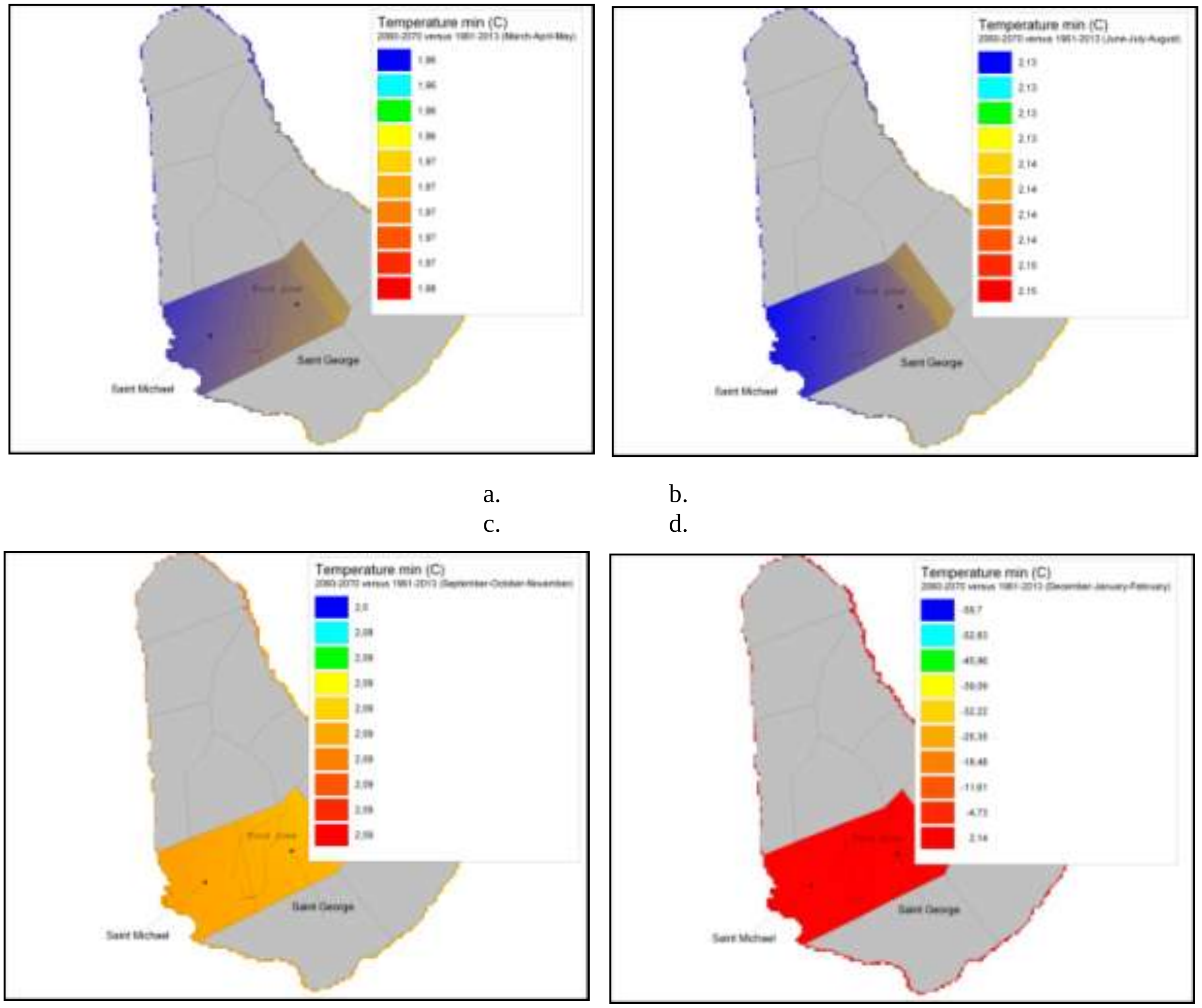
When next using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the June-July-August season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is again 27.34 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 29.47 ^{0}C, thereby indicating a seasonal minimum temperature increase of 2.13 ^{0}C (Figure 26b and Table 14).

Also, when using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the September-October-November season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is again 27.61 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 29.70 ^{0}C, thereby indicating a seasonal minimum temperature increase of 2.09 ^{0}C (Figure 26c and Table 14).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal minimum temperature for the December-January-February season, we now see that, on average, modelled minimum temperature for the current period (1961-2013) is again 25.97 ^{0}C, whereas modelled minimum temperature for the future period (2060-2070) is 28.11 ^{0}C, thereby indicating a seasonal minimum temperature increase of 2.14 ^{0}C (Figure 26d and Table 14).

It is again evident that average seasonal minimum temperature increases for the far-term future (2060-2070) period, when compared to the current period (1961-2013) would be higher by ~ 2.0 ^{0}C, with the highest minimum temperature increase (2.14) ^{0}C occurring in the December-January-February dry season (Table 14).

Furthermore, the minimum temperature increases (~ 2.0 ^{0}C) for the far-term future (2060-2070) period, when compared to the current period (1961-2013), are very similar for both the HadCM3/AEXSM and ECHAM5 climate models.



a. b.
c. d.

Figure 26: Mean minimum seasonal temperature anomalies (2060-2070 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

Table 14: HadCM3/AEXSM and ECHAM5: Mean Minimum Temperature Anomalies

Climate Model		Modelled Temperature: 1961-2013 (^{0}C)	Modelled Temperature: 2030-2040 (^{0}C)	Temperature Change: 2030-2040 (^{0}C)	Modelled Temperature: 2060-2070 (^{0}C)	Temperature Change: 2060-2070 (^{0}C)
HadCM3/AEXSM						
	March-April-May	26,74	27,92	1,18	28,68	1,94
	June-July-August	27,53	28,89	1,36	29,65	2,12
	September-October-November	27,82	29,15	1,33	30,02	2,2
	December-January-February	26,64	27,88	1,24	28,73	2,09
ECHAM5						
	March-April-May	26,34	27,05	0,71	28,31	1,97
	June-July-August	27,34	28,36	1,02	29,47	2,13
	September-October-November	27,61	28,54	0,93	29,7	2,09
	December-January-February	25,97	26,98	1,01	28,11	2,14

3.2.13: Maximum and Minimum Temperature Counts and Changes (Δ %)

This section at the ranges, counts and the changes for the future decadal periods (2030-2040 and 2060-2070) compared to a current decadal period (1980-1990) of maximum and minimum temperature (^{0}C) and rainfall (mm/day). In order to maintain consistency in the number of years and days, especially in regards to rainfall, the current decadal period, namely 1980-1990, in that it falls in the middle of the current climatological reference period (1971-2000).

HadCM3/AEXSM Maximum Temperature Ranges, Counts and Changes (Δ %) – 2030-2040 versus 1980-1990

When examining the HadCM3/AEXSM Maximum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2030-2040 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (1160: 29.29 %) of maximum temperature falls in the range of 27.5 ^{0}C to 28.0 ^{0}C, whereas for the near-term future decadal period (2030-2040) the highest frequency/count (985: 24.87 %) of maximum temperature falls in the range of 29.0 ^{0}C to 29.5 ^{0}C, an increase in frequency (Δ) of 10, 844 % (Table 15).

Table 15: HadCM3/AEXSM Maximum Temperature (0C) 2030-2040 vs 1980-1990

Maximum Temperature Range (^{0}C)	**1980-1990**		**2030-2040**		**Δ**
	Count	% of all	Count	% of all	
x=25,0	0	0,00	0	0,00	0
25,0<x<=25,5	3	0,08	0	0,00	-100,00
25,5<x<=26,0	41	1,04	0	0,00	-100,00
26,0<x<=26,5	305	7,70	0	0,00	-100,00
26,5<x<=27,0	555	14,02	2	0,05	-99,64
27,0<x<=27,5	880	22,22	100	2,53	-88,64
27,5<x<=28,0	1160	29,29	578	14,60	-50,17
28,0<x<=28,5	810	20,45	782	19,75	-3,46
28,5<x<=29,0	197	4,97	725	18,31	+268,02
29,0<x<=29,5	9	0,23	985	24,87	+10844,44
29,5<x<=30,0	0	0,00	680	17,17	---
30,0<x<=30,5	0	0,00	106	2,68	---
30,5<x<=31,0	0	0,00	2	0,05	---
Missing	0	---	0	---	---

HadCM3/AEXSM Maximum Temperature Ranges, Counts and Changes (Δ %) – 2060-2070 versus 1980-1990

Next, when examining the HadCM3/AEXSM Maximum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2060-2070 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (1160: 29.29 %) of maximum temperature again falls in the range of 27.5 ^{0}C to 28.0 ^{0}C, whereas for the far-term future decadal period (2060-2070) the highest frequency/count (851: 21.49 %) of maximum temperature falls in the range of 30.0 ^{0}C to 30.5 ^{0}C. There is no change in frequency (Δ) of this range (30.0 ^{0}C to 30.5 ^{0}C) of maximum temperature, since it did not occur during the current decadal period (1980-1990) (Table 16).

Table 16: HadCM3/AEXSM Maximum Temperature (0C) 2060-2070 vs 1980-1990

Maximum Temperature Range (^{0}C)	1980-1990		2060-2070		Δ
	Count	% of all	Count	% of all	
x=25,0	0	0,00	0	0,00	0
25,0<x<=25,5	3	0,08	0	0,00	-100,00
25,5<x<=26,0	41	1,04	0	0,00	-100,00
26,0<x<=26,5	305	7,70	0	0,00	-100,00
26,5<x<=27,0	555	14,02	0	0,00	-100,00
27,0<x<=27,5	880	22,22	0	0,00	-100,00
27,5<x<=28,0	1160	29,29	8	0,20	-99,31
28,0<x<=28,5	810	20,45	185	4,67	-77,16
28,5<x<=29,0	197	4,97	799	20,18	+305,58
29,0<x<=29,5	9	0,23	699	17,65	+7666,67
29,5<x<=30,0	0	0,00	797	20,13	---
30,0<x<=30,5	0	0,00	851	21,49	---
30,5<x<=31,0	0	0,00	569	14,37	---
31,0<x<=31,5	0	0,00	52	1,31	---
Missing	0	---	0	---	---

HadCM3/AEXSM Minimum Temperature Ranges, Counts and Changes (Δ %) – 2030-2040 versus 1980-1990

Also, when examining the HadCM3/AEXSM Minimum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2030-2040 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency (1108: 27.98 %) of minimum temperature falls in the range of 27.0 ^{0}C to 27.5 ^{0}C, whereas for the near-term future decadal period (2030-2040) the highest frequency (961: 24.27 %) of minimum temperature falls in the range of 28.5 ^{0}C to 29.0 ^{0}C, an increase in frequency (Δ) of 5, 552.94 % (Table 17).

Table 17: HadCM3/AEXSM Minimum Temperature (0C) 2030-2040 vs 1980-1990

Minimum Temperature Range (^{0}C)	**1980-1990**		**2030-2040**		**Δ**
	Count	% of all	Count	% of all	
x=24,0	0	0,00	0	0,00	0
24,0<x<=24,5	2	0,05	0	0,00	-100,00
24,5<x<=25,0	8	0,20	0	0,00	-100,00
25,0<x<=25,5	57	1,44	0	0,00	-100,00
25,5<x<=26,0	256	6,46	0	0,00	-100,00
26,0<x<=26,5	517	13,06	12	0,30	-97,68
26,5<x<=27,0	789	19,92	112	2,83	-85,80
27,0<x<=27,5	1108	27,98	476	12,02	-57,04
27,5<x<=28,0	908	22,93	738	18,64	-18,72
28,0<x<=28,5	298	7,53	711	17,95	+138,59
28,5<x<=29,0	17	0,43	961	24,27	+5552,94
29,0<x<=29,5	0	0,00	752	18,99	---
29,5<x<=30,0	0	0,00	194	4,90	---
30,0<x<=30,5	0	0,00	4	0,10	---
Missing	0	---	0	---	---

HadCM3/AEXSM Minimum Temperature Ranges, Counts and Changes (Δ %) – 2060-2070 versus 1980-1990

Next, when examining the HadCM3/AEXSM Minimum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2060-2070 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (1108: 27.98 %) of minimum temperature again falls in the range of 27.0 ^{0}C to 27.5 ^{0}C, whereas for the far-term future decadal period (2060-2070) the highest frequency/count (840: 21.21 %) of minimum temperature falls in the range of 29.5 ^{0}C to 30.0 ^{0}C. There is no change in frequency (Δ) of this range (29.5 ^{0}C to 30.0 ^{0}C) of minimum temperature, since it did not occur during the current decadal period (1980-1990) (Table 18).

Table 18: HadCM3/AEXSM Maximum Temperature (0C) 2060-2070 vs 1980-1990

Minimum Temperature Range (^{0}C)	1980-1990		2060-2070		Δ
	Count	% of all	Count	% of all	
x=24,0	0	0,00	0	0,00	0
24,0<x<=24,5	2	0,05	0	0,00	-100,00
24,5<x<=25,0	8	0,20	0	0,00	-100,00
25,0<x<=25,5	57	1,44	0	0,00	-100,00
25,5<x<=26,0	256	6,46	0	0,00	-100,00
26,0<x<=26,5	517	13,06	0	0,00	-100,00
26,5<x<=27,0	789	19,92	1	0,03	-99,87
27,0<x<=27,5	1108	27,98	23	0,58	-97,92
27,5<x<=28,0	908	22,93	210	5,30	-76,87
28,0<x<=28,5	298	7,53	689	17,40	131,21
28,5<x<=29,0	17	0,43	699	17,65	4011,76
29,0<x<=29,5	0	0,00	733	18,51	---
29,5<x<=30,0	0	0,00	840	21,21	---
30,0<x<=30,5	0	0,00	652	16,46	---
30,5<x<=31,0	0	0,00	113	2,85	---
Missing	0	---	0	---	---

ECHAM5 Maximum Temperature Ranges, Counts and Changes (Δ %) – 2030-2040 versus 1980-1990

At first, when examining the ECHAM5 Maximum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2030-2040 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (940: 23.39 %) of maximum temperature falls in the range of 27.5 ^{0}C to 28.0 ^{0}C, whereas for the near-term future decadal period (2030-2040) the highest frequency/count (768: 19.11 %) of maximum temperature falls in the range of 28.5 ^{0}C to 29.0 ^{0}C, an increase in frequency (Δ) of 540 %. But also, for the near-term future decadal period (2030-2040) the next highest frequency/count (727: 18.09 %) of maximum temperature falls in the range of 29.0 ^{0}C to 29.5 ^{0}C, an increase in frequency (Δ) of 18, 075 % (Table 19).

Table 19: ECHAM5 Maximum Temperature (0C) 2030-2040 vs 1980-1990

Maximum Temperature Range (^{0}C)	1980-1990		2030-2040		Δ
	Count	% of all	Count	% of all	
x=24,5	0	0,00	0	0,00	0
24,5<x<=25,0	12	0,30	0	0,00	-100,00
25,0<x<=25,5	116	2,89	3	0,07	-97,41
25,5<x<=26,0	376	9,36	50	1,24	-86,70
26,0<x<=26,5	543	13,51	207	5,15	-61,88
26,5<x<=27,0	459	11,42	371	9,23	-19,17
27,0<x<=27,5	826	20,56	414	10,30	-49,88
27,5<x<=28,0	940	23,39	500	12,44	-46,81
28,0<x<=28,5	622	15,48	601	14,96	-3,38
28,5<x<=29,0	120	2,99	768	19,11	+540,00
29,0<x<=29,5	4	0,10	727	18,09	+18075,00
29,5<x<=30,0	0	0,00	338	8,41	---
30,0<x<=30,5	0	0,00	38	0,95	---
30,5<x<=31,0	0	0,00	1	0,02	---
Missing	0	---	0	---	---

ECHAM5 Maximum Temperature Ranges, Counts and Changes (Δ %) – 2060-2070 versus 1980-1990

Next, when examining the ECHAM5 Maximum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2060-2070 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (940: 23.39 %) of maximum temperature again falls in the range of 27.5 ^{0}C to 28.0 ^{0}C, whereas for the far-term future decadal period (2060-2070) the highest frequency/count (785: 19.54 %) of maximum temperature falls in the range of 29.5 ^{0}C to 30.0 ^{0}C. Furthermore, for the near-term future decadal period (2030-2040) the next highest frequency/count (724: 18.02 %) of maximum temperature falls in the range of 30.0 ^{0}C to 30.5 ^{0}C. There is no change in frequency (Δ) of theses ranges (29.5 ^{0}C to 30.0 ^{0}C and 30.0 ^{0}C to 30.5 ^{0}C) of maximum temperature, since it did not occur during the current decadal period (1980-1990) (Table 20).

Table 20: ECHAM5 Maximum Temperature (0C) 2060-2070 vs 1980-1990

Maximum Temperature Range (^{0}C)	1980-1990		2060-2070		Δ
	Count	% of all	Count	% of all	
x=24,5	0	0,00	0	0,00	0
24,5<x<=25,0	12	0,30	0	0,00	-100,00
25,0<x<=25,5	116	2,89	0	0,00	-100,00
25,5<x<=26,0	376	9,36	0	0,00	-100,00
26,0<x<=26,5	543	13,51	0	0,00	-100,00
26,5<x<=27,0	459	11,42	1	0,02	-99,78
27,0<x<=27,5	826	20,56	59	1,47	-92,86
27,5<x<=28,0	940	23,39	297	7,39	-68,40
28,0<x<=28,5	622	15,48	469	11,67	-24,60
28,5<x<=29,0	120	2,99	486	12,10	+305,00
29,0<x<=29,5	4	0,10	607	15,11	+15075,00
29,5<x<=30,0	0	0,00	785	19,54	---
30,0<x<=30,5	0	0,00	724	18,02	---
30,5<x<=31,0	0	0,00	507	12,62	---
31,0<x<=31,5	0	0,00	83	2,07	---
Missing	0	---	0	---	---

ECHAM5 Minimum Temperature Ranges, Counts and Changes (Δ %)
– 2030-2040 versus 1980-1990

Now, when examining the ECHAM5 Minimum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2030-2040 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency (893: 22.22 %) of minimum temperature again falls in the range of 27.0 ^{0}C to 27.5 ^{0}C, whereas for the near-term future decadal period (2030-2040) the highest frequency (761: 18.94 %) of minimum temperature falls in the range of 28.0 ^{0}C to 28.5 ^{0}C, an increase in frequency (Δ) of 424.83 %. Furthermore, for the near-term future decadal period (2030-2040) the next highest frequency/count (755: 18.79 %) of minimum temperature falls in the range of 28.5 ^{0}C to 29.0 ^{0}C, an increase in frequency (Δ) of 18,775 % (Table 21).

Table 21: ECHAM5 Minimum Temperature (0C) 2030-2040 vs 1980-1990

Minimum Temperature Range (^{0}C)	1980-1990		2030-2040		Δ
	Count	% of all	Count	% of all	
x=24,00000	3	0,07	0	0,00	-100,00
24,0<x<=24,5	30	0,75	0	0,00	-100,00
24,5<x<=25,0	122	3,04	6	0,15	-95,08
25,0<x<=25,5	367	9,13	63	1,57	-82,83
25,5<x<=26,0	522	12,99	198	4,93	-62,07
26,0<x<=26,5	454	11,30	349	8,69	-23,13
26,5<x<=27,0	801	19,94	415	10,33	-48,19
27,0<x<=27,5	893	22,22	467	11,62	-47,70
27,5<x<=28,0	677	16,85	589	14,66	-13,00
28,0<x<=28,5	145	3,61	761	18,94	+424,83
28,5<x<=29,0	4	0,10	755	18,79	+18775,00
29,0<x<=29,5	0	0,00	363	9,03	---
29,5<x<=30,0	0	0,00	52	1,29	---
Missing	0	---	0	---	---

HadCM3/AEXSM Minimum Temperature Ranges, Counts and Changes (Δ %) – 2060-2070 versus 1980-1990

Next, when examining the ECHAM5 Minimum Temperature Ranges, Counts/Frequencies and Changes (Δ %) for the 2060-2070 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (893: 22.22 %) of minimum temperature again falls in the range of 27.0 ^{0}C to 27.5 ^{0}C, whereas for the far-term future decadal period (2060-2070) the highest frequency/count (769: 19.14 %) of minimum temperature falls in the range of 29.5 ^{0}C to 30.0 ^{0}C. There is no change in frequency (Δ) of this range (29.5 ^{0}C to 30.0 ^{0}C) of minimum temperature, since it did not occur during the current decadal period (1980-1990) (Table 22).

Table 22: ECHAM5 Minimum Temperature (0C) 2060-2070 vs 1980-1990

Minimum Temperature Range (^{0}C)	1980-1990		2060-2070		Δ
	Count	% of all	Count	% of all	
x=24,00000	3	0,07	0	0,00	-100,00
24,0<x<=24,5	30	0,75	0	0,00	-100,00
24,5<x<=25,0	122	3,04	0	0,00	-100,00
25,0<x<=25,5	367	9,13	0	0,00	-100,00
25,5<x<=26,0	522	12,99	1	0,02	-99,81
26,0<x<=26,5	454	11,30	7	0,17	-98,46
26,5<x<=27,0	801	19,94	58	1,44	-92,76
27,0<x<=27,5	893	22,22	267	6,65	-70,10
27,5<x<=28,0	677	16,85	485	12,07	-28,36
28,0<x<=28,5	145	3,61	461	11,47	+217,93
28,5<x<=29,0	4	0,10	598	14,88	+14850,00
29,0<x<=29,5	0	0,00	750	18,67	---
29,5<x<=30,0	0	0,00	769	19,14	---
30,0<x<=30,5	0	0,00	495	12,32	---
30,5<x<=31,0	0	0,00	124	3,09	---
31,0<x<=31,5	0	0,00	3	0,07	---
Missing	0	---	0	---	---

3.2.14: HadCM3/AEXSM Precipitation/Rainfall - 2030-2040 versus 1961-2013

At first, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal precipitation/rainfall for the March-April-May season, we see that, on average, modelled rainfall for the current period (1961-2013) is 126 mm/season, whereas modelled seasonal rainfall for the near-term future period (2030-2040) is 119 mm/season, thereby indicating a slight seasonal rainfall decrease of – 7 mm/season (- 5.56 %) (Figure 27a and Table 23).

Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal rainfall for the June-July-August season, we now see that, on average, modelled rainfall for the current period (1961-2013) is 474 mm/season, whereas modelled seasonal rainfall for the future period (2030-2040) is 473 mm/season, thereby indicating a negligible seasonal rainfall decrease of – 1 mm/season (- 0.21 %) (Figure 27b and Table 23).

When however using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal rainfall for the September-October-November season, we now see that, on average, modelled rainfall for the current period (1961-2013) is 474 mm/season, whereas modelled rainfall for the future period (2030-2040) is 512 mm/season, thereby indicating a moderate seasonal rainfall increase of + 38 mm/season (+ 8.02 %) (Figure 27c and Table 23).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal rainfall for the December-January-February season, we now see that, on average, modelled rainfall for the current period (1961-2013) is 169 mm/season, whereas modelled rainfall for the future period (2030-2040) is 135 mm/season, thereby indicating a significant seasonal rainfall decrease of – 34 mm/season (-20.12 %) (Figure 27d and Table 23).

It is evident then that, with the exception of the September-October-November season, average seasonal rainfall decreases for the near-term future (2030-2040) period, when compared to the current period (1961-2013), with the highest rainfall decrease (-34 mm/season: -20.12 %) occurring in the December-January-February dry season (Table 23).

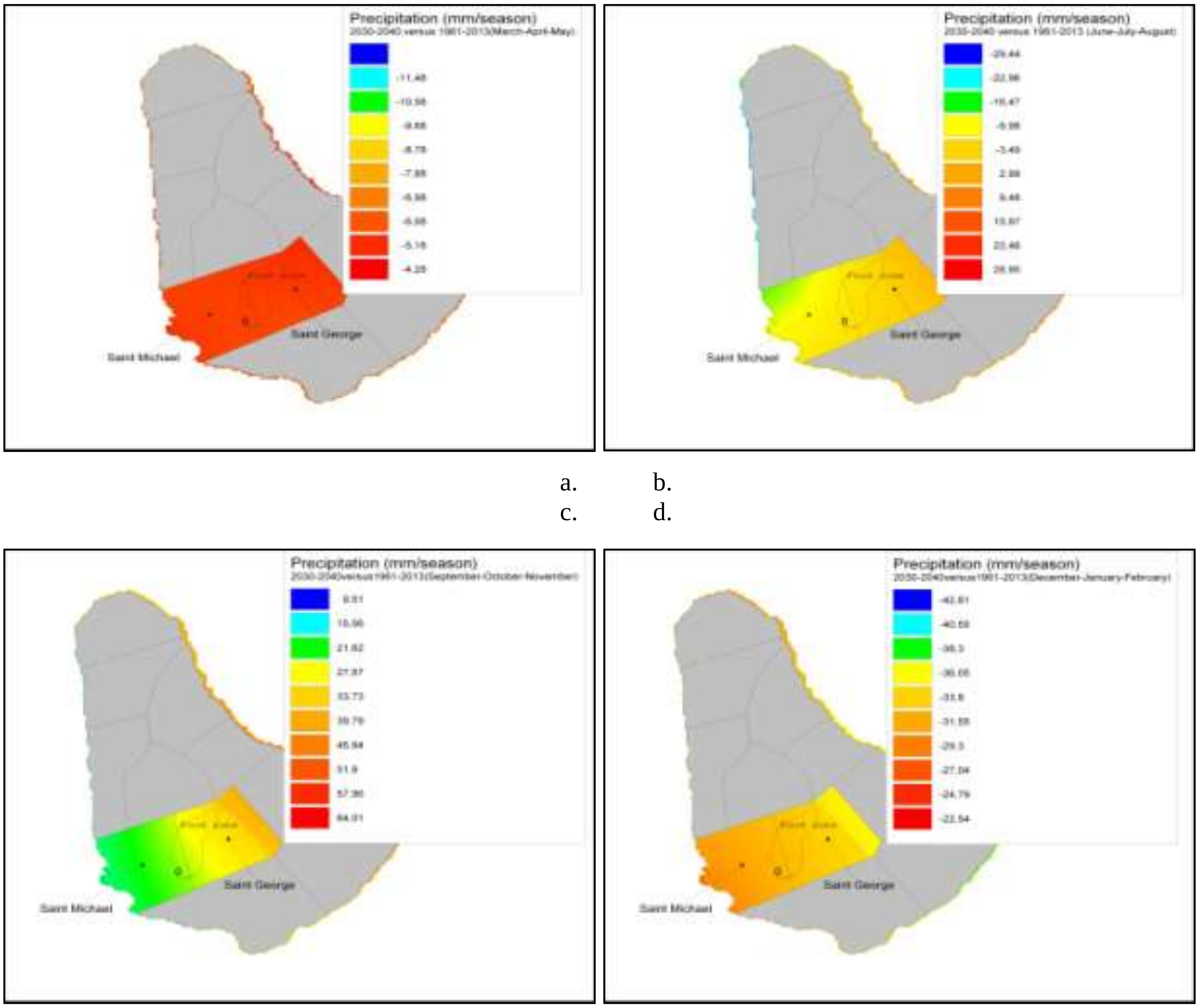


Figure 27: Mean monthly-seasonal precipitation anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.15: HadCM3/AEXSM Precipitation/Rainfall - 2060-2070 versus 1961-2013

Now, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal precipitation/rainfall for the March-April-May season, we see that, on average, modelled rainfall for the current period (1961-2013) is again 126 mm/season, whereas modelled seasonal for the far-term future period (2060-2070) is 90 mm/season, thereby indicating a moderate seasonal rainfall decrease of – 36 mm/season (- 28.57 %) (Figure 28a and Table 23).

Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal rainfall for the June-July-August season, we now see that, on average, modelled rainfall for the current period (1961-2013) is 474 mm/season, whereas modelled seasonal rainfall for the future period (2060-2070) is 398 mm/season, thereby indicating a moderate seasonal rainfall decrease of – 76 mm/season (- 16.03 %) (Figure 28b and Table 23).

Also, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal rainfall for the September-October-November season, we now see that, on average, modelled rainfall for the current period (1961-2013) is again 474 mm/season, whereas modelled rainfall for the future period (2060-2070) is 448 mm/season, thereby indicating a slight seasonal rainfall decrease of - 26 mm/season (- 5.49 %) (Figure 28c and Table 23).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal rainfall for the December-January-February season, we now see that, on average, modelled rainfall for the current period (1961-2013) is again 169 mm/season, whereas modelled rainfall for the future period (2060-2070) is 122 mm/season, thereby indicating a significant seasonal rainfall decrease of – 47 mm/season (-27.81 %) (Figure 28d and Table 23).

It is again evident then that average seasonal rainfall decreases during all seasons for the far-term future (2060-2070) period, when compared to the current period (1961-2013), with the highest rainfall decrease (-36 mm/season: -28.57 %) occurring in the March-April-May dry season (Table 23).

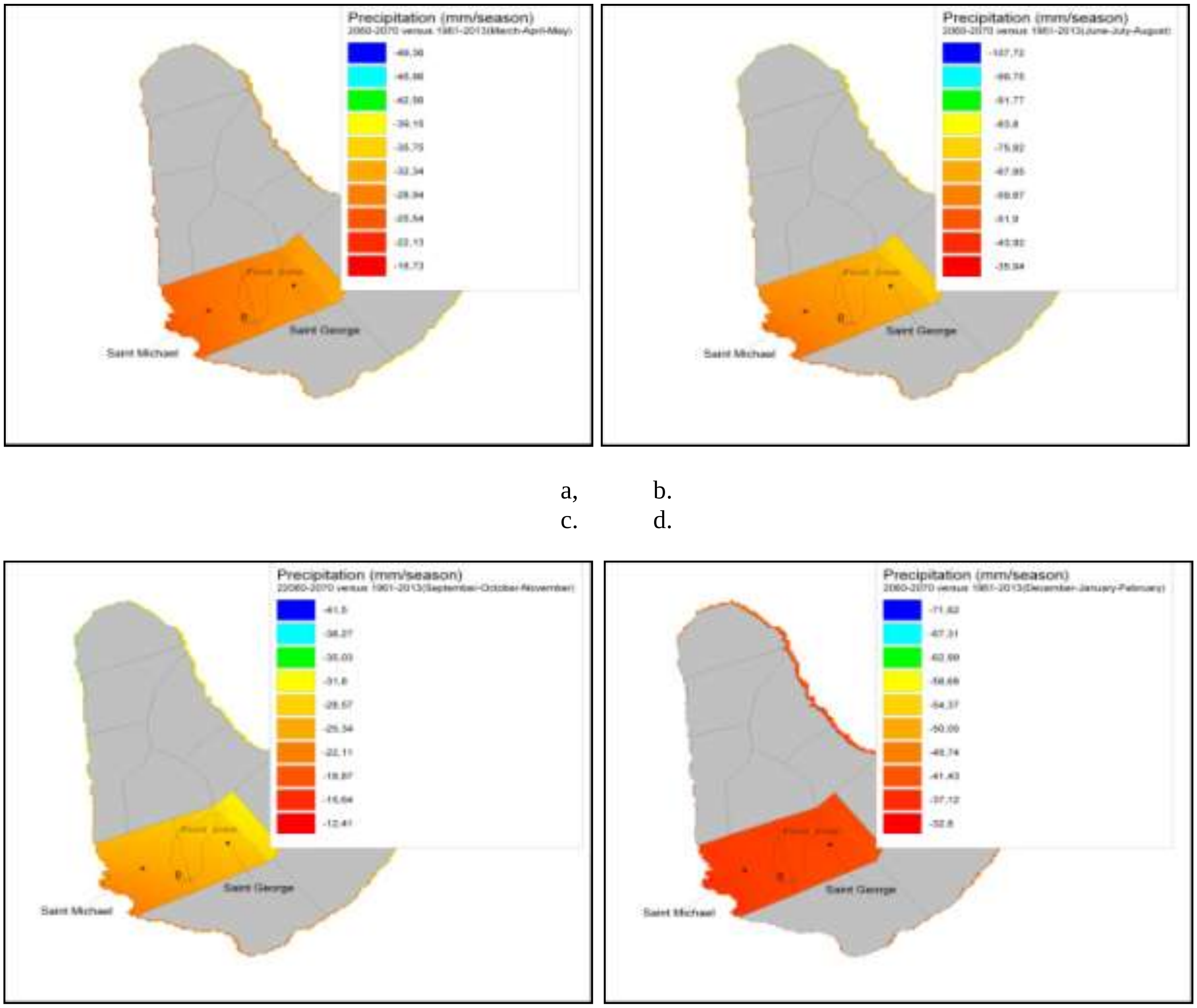


Figure 28: Mean monthly-seasonal precipitation anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled HadCM3/AEXSM climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.16: ECHAM5 Precipitation/Rainfall - 2030-2040 versus 1961-2013

At first, using the downscaled ECHAM5 model to examine changes in mean seasonal precipitation/rainfall for the March-April-May season, we see that, on average, modelled rainfall for the current period (1961-2013) is 195 mm/season, whereas modelled seasonal rainfall for the near-term future period (2030-2040) is 128 mm/season, thereby indicating a moderate seasonal rainfall decrease of – 67 mm/season (- 34.36 %) (Figure 29a and Table 23).

Next, using the downscaled ECHAM5 model to examine changes in mean seasonal rainfall for the June-July-August season, we now see that, on average, modelled rainfall for the current period (1961-2013) is 736 mm/season, whereas modelled seasonal rainfall for the future period (2030-2040) is 668 mm/season, thereby indicating a slight seasonal rainfall decrease of – 68 mm/season (- 9.24 %) (Figure 29b and Table 23).

But when using the downscaled ECHAM5 model to examine changes in mean seasonal rainfall for the September-October-November season, we now see that, on average, modelled rainfall for the current period (1961-2013) is 618 mm/season, whereas modelled rainfall for the future period (2030-2040) is 675 mm/season, thereby indicating a moderate seasonal rainfall increase of + 57 mm/season (+ 9.22 %) (Figure 29c and Table 23).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal rainfall for the December-January-February season, we now see that, on average, modelled rainfall for the current period (1961-2013) is 212 mm/season, whereas modelled rainfall for the future period (2030-2040) is 268 mm/season, thereby indicating a significant seasonal rainfall increase of + 56 mm/season (+26.42 %) (Figure 29d and Table 23).

It is evident then that for the March-April-May season, average seasonal rainfall decreases (-34.36 %) and for the December-January-February average seasonal rainfall increases (+26.42 %) during the near-term future (2030-2040) period, when compared to the current period (1961-2013). On the other hand for the June-July-August season there is a slight seasonal rainfall decrease (- 9.25 %), while for the September-October November season there is a slight seasonal rainfall increase (+ 9.22 %) (Table 23).

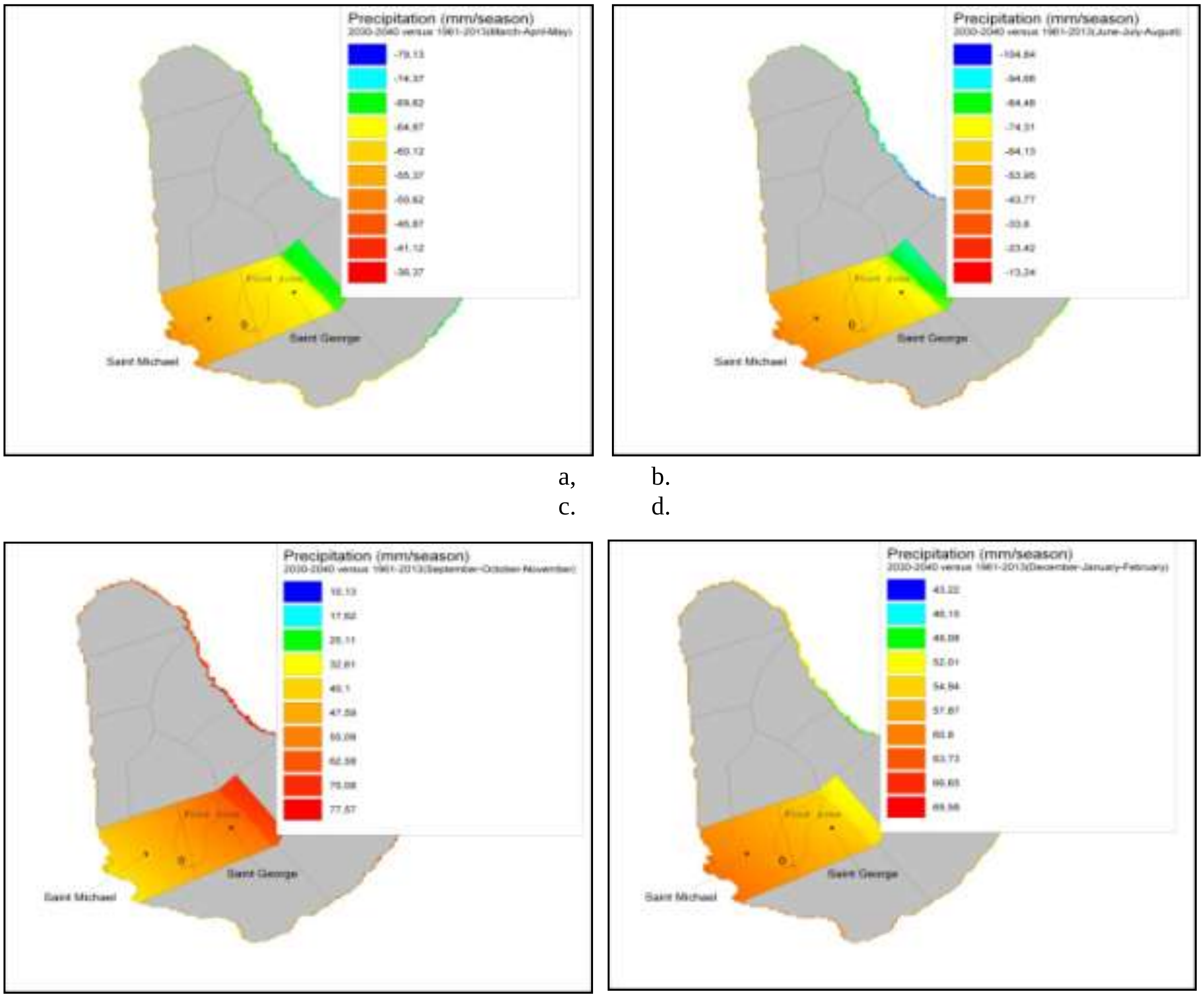


Figure 29: Mean monthly-seasonal precipitation anomalies (2030-2040 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

3.2.17: ECHAM5 Precipitation/Rainfall - 2060-2070 versus 1961-2013

At first, using the downscaled ECHAM5 model to examine changes in mean seasonal precipitation/rainfall for the March-April-May season, we see that, on average, modelled rainfall for the current period (1961-2013) is again 195 mm/season, whereas modelled seasonal rainfall for the far-term future period (2060-2070) is 144 mm/season, thereby indicating a significant seasonal rainfall decrease of – 51 mm/season (- 26.15 %) (Figure 30a and Table 23).

Next, using the downscaled ECHAM5 model to examine changes in mean seasonal rainfall for the June-July-August season, we now see that, on average, modelled rainfall for the current period (1961-2013) is again 736 mm/season, whereas modelled seasonal rainfall for the future period (2060-2070) is 702 mm/season, thereby indicating a slight seasonal rainfall decrease of – 34 mm/season (- 4.62 %) (Figure 30b and Table 23).

But when using the downscaled ECHAM5 model to examine changes in mean seasonal rainfall for the September-October-November season, we now see that, on average, modelled rainfall for the current period (1961-2013) is again 618 mm/season, whereas modelled rainfall for the future period (2060-2070) is 669 mm/season, thereby indicating a slight seasonal rainfall increase of + 51 mm/season (+ 8.25 %) (Figure 30c and Table 23).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal rainfall for the December-January-February season, we now see that, on average, modelled rainfall for the current period (1961-2013) is again 212 mm/season, whereas modelled rainfall for the future period (2060-2070) is 206 mm/season, thereby indicating a negligible seasonal rainfall decrease of - 6 mm/season (- 2.83 %) (Figure 30d and Table 23).

It is evident then that for the future period (2060-2070), with the exception of the September-October-November season, when there is slight increase in seasonal rainfall (+ 8.25 %), average seasonal rainfall decreases for the other three seasons, varying from – 2.83 % in December-January-February to – 26.15 % in the March-April-May season (Table 23).

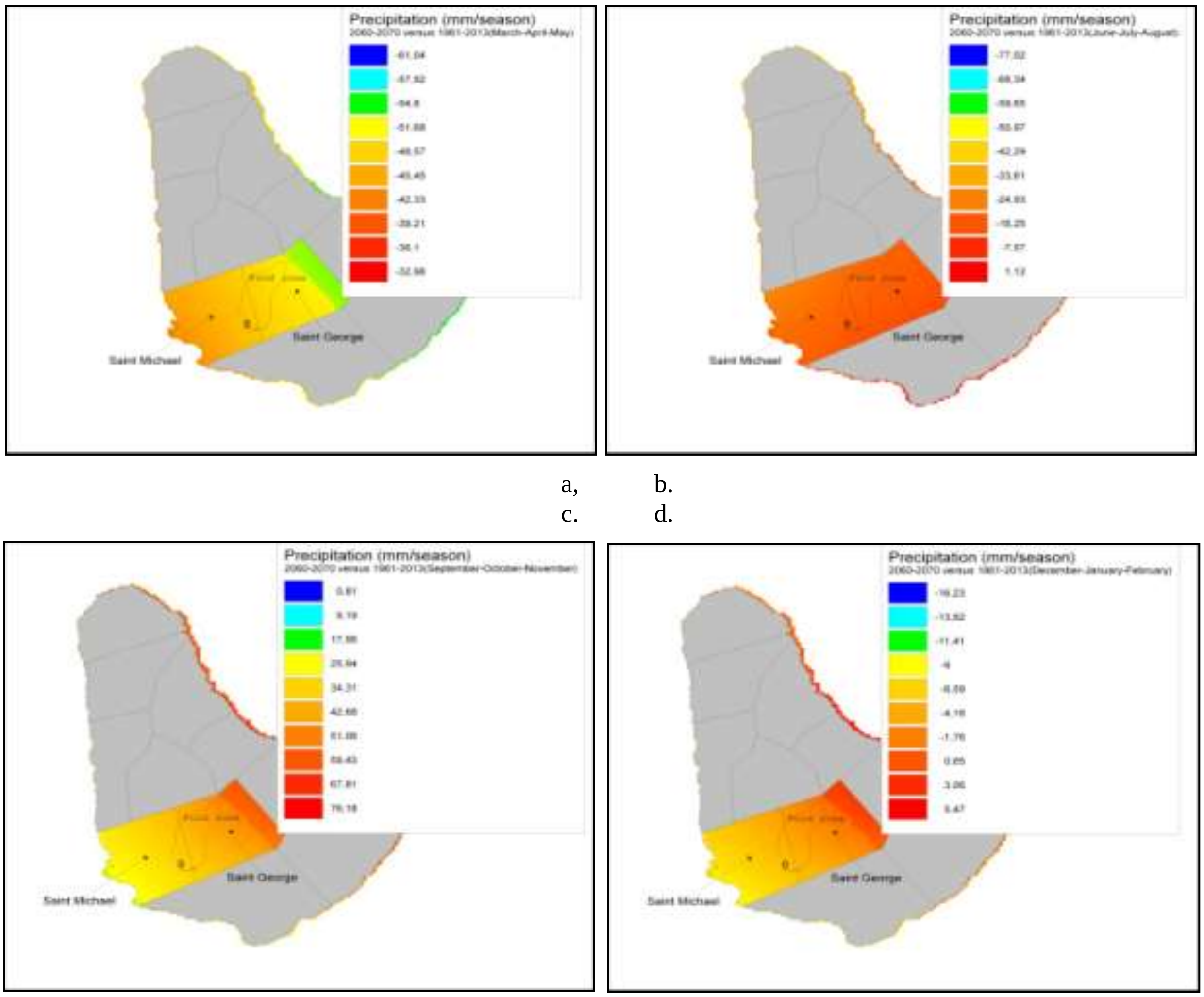


Figure 30: Mean monthly-seasonal precipitation anomalies (2060-2070 versus 1961-2013) for the Parishes of Saint Michael and Saint George including the Food Zone according to the downscaled ECHAM5 climate model (a: March-April-May; b: June-July-August; c: September-October-November; d: December-January-February).

Table 23: HadCM3/AEXSM and ECHAM5: Precipitation Anomalies

Climate Model		Modelled Precipitation: 1961-2013 (mm/season)	Modelled Precipitation: 2030-2060 (mm/season)	Precipitation Change: 2030-2060 (mm/season)	Precipitation Change: 2030-2060 (%)	Modelled Precipitation: 2060-2070 (mm/season)	Precipitation Change: 2060-2070 (mm/season)	Precipitation Change: 2060-2070 (%)
HadCM3/AEXSM								
	March-April-May	126	119	-7	-5,56	90	-36	-28,57
	June-July-August	474	473	-1	-0,21	398	-76	-16,03
	September-October-November	474	512	+38	+8,02	448	-26	-5,49
	December-January-February	169	135	-34	-20,12	122	-47	-27,81
ECHAM5								
	March-April-May	195	128	-67	-34,36	144	-51	-26,15
	June-July-August	736	668	-68	-9,24	702	-34	-4,62
	September-October-November	618	675	+57	+9,22	669	+51	+8,25
	December-January-February	212	268	+56	+26,42	206	-6	-2,83

3.2.18: Rainfall Counts/Frequencies and Changes (Δ %)

HadCM3/AEXSM Rainfall Ranges, Counts and Changes (Δ %) – 2030-2040 versus 1980-1990

When examining the HadCM3/AEXSM Rainfall Ranges, Counts/Frequencies and Changes (Δ %) for the 2030-2040 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (3,669: 92.65 %) of rainfall (mm/day) falls in the range of 0 to 5.0 mm/day, whereas for the near-term future decadal period (2030-2040) the highest frequency/count (3,675: 92.80 %) of rainfall (mm/day) also falls in the range of 0 to 5.0 mm/day, but with a slight increase in frequency (Δ) of + 0.16 %. But what is noteworthy is that for the more intense rainfall range of 15 to 20 mm/day the frequency/count for the current (1980-1990) period is 4 (0.10 %), whereas for the near-term future decadal period (2030-2040) the highest frequency/count is 11 (0.27 %), an increase of + 175.00 % (Table 24).

Table 24: HadCM3/AEXSM Rainfall (mm/day) 2030-2040 vs 1980-1990

Range of Daily Rainfall (mm/day)	1980-1990		2030-2040		Δ
	Count	% of all	Count	% of all	
x=0,0	0	0	31	0,78	+31,00
0,0<x<=5,0	3669	92,65	3675	92,80	+0,16
5,0<x<=10,0	214	5,40	198	5,00	-7,48
10,0<x<=15,0	33	0,83	40	1,01	+21,21
15,0<x<=20,0	4	0,10	11	0,27	+175,00
20,0<x<=25,0	1	0,02	1	0,02	0,00
25,0<x<=30,0	1	0,025	4	0,10	+300,00
Missing	38	---	0	---	---

HadCM3/AEXSM Rainfall Ranges, Counts and Changes (Δ %) – 2030-2040 versus 1980-1990

Next, when examining the HadCM3/AEXSM Rainfall Ranges, Counts/Frequencies and Changes (Δ %) for the 2060-2070 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (3,669: 92.65 %) of rainfall (mm/day) again falls in the range of 0 to 5.0 mm/day, whereas for the far-term future decadal period (2060-2070) the highest frequency/count (3,718: 93.88 %) of rainfall (mm/day) also falls in the range of 0 to 5.0 mm/day, but with a slight increase in frequency (Δ) of + 1.34 %. But what is again noteworthy is that for the more intense rainfall range of 15 to 20 mm/day the frequency/count for the current (1980-1990) period is 4 (0.10 %), whereas for the far-term future decadal period (2060-2070) the highest frequency/count is 5 (0.13 %), a slight increase of + 25.00 % (Table 25).

Table 25: HadCM3/AEXSM Rainfall (mm/day) 2060-2070 vs 1980-1990

Range of Daily Rainfall (mm/day)	**1980-1990**		**2060-2070**		**Δ**
	Count	% of all	Count	% of all	
x=0,0	0	0	0	0	0,00
0,0<x<=5,0	3669	92,65	3718	93,88	+1,34
5,0<x<=10,0	214	5,40	168	4,24	-21,50
10,0<x<=15,0	33	0,83	28	0,707071	-15,15
15,0<x<=20,0	4	0,10	5	0,126263	+25,00
20,0<x<=25,0	1	0,02	1	0,025253	0,00
25,0<x<=30,0	1	0,02	0	0	-100,00
Missing	38	---	40	---	---

ECHAM5 Rainfall Ranges, Counts and Changes (Δ %) – 2030-2040 versus 1980-1990

As for the ECHAM5 Rainfall Ranges, Counts/Frequencies and Changes (Δ %) for the 2030-2040 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (3,605: 89.72 %) of rainfall (mm/day) again falls in the range of 0 to 5.0 mm/day, whereas for the near-term future decadal period (2030-2040) the highest frequency/count (3,619: 90.07 %) of rainfall (mm/day) also falls in the range of 0 to 5.0 mm/day, but with a slight increase in frequency (Δ) of + 0.39 %. But what is noteworthy is that for the more intense rainfall range of 10 to 15 mm/day the frequency/count for the current (1980-1990) period is 44 (1.10 %), whereas for the near-term future decadal period (2030-2040) the highest frequency/count is 49 (1.22 %), a slight increase of + 12.36 % (Table 26).

Table 26: ECHAM5 Rainfall (mm/day) 2030-2040 vs 1980-1990

Range of Daily Rainfall (mm/day)	**1980-1990**		**2030-2040**		**Δ**
	Count	% of all	Count	% of all	
x=0,0	0	0,00	0	0,00	0
0,0<x<=5,0	3605	89,72	3619	90,07	+0,39
5,0<x<=10,0	300	7,47	258	6,42	-14,00
10,0<x<=15,0	44	1,10	49	1,22	+11,36
15,0<x<=20,0	14	0,35	12	0,30	-14,29
20,0<x<=25,0	12	0,30	9	0,22	-25,00
25,0<x<=30,0	8	0,20	3	0,07	-62,50
30,0<x<=35,0	2	0,05	0	0,00	-100,00
35,0<x<=40,0	1	0,02	0	0,00	-100,00
40,0<x<=45,0	0	0,00	0	0,00	0
45,0<x<=50,0	0	0,00	0	0,00	0
50,0<x<=55,0	1	0,02	0	0,00	-100,00
Missing	31	---	68	---	---

ECHAM5 Rainfall Ranges, Counts and Changes (Δ %) – 2030-2040 versus 1980-1990

But for the ECHAM5 Rainfall Ranges, Counts/Frequencies and Changes (Δ %) for the 2060-2070 versus the 1980-1990 decadal periods, we see that for the current (1980-1990) decadal period the highest frequency/count (3,605: 89.72 %) of rainfall (mm/day) again falls in the range of 0 to 5.0 mm/day, whereas for the far-term future decadal period (2060-2070) the highest frequency/count (3,632: 90.39 %) of rainfall (mm/day) also falls in the range of 0 to 5.0 mm/day, but with a slight increase in frequency (Δ) of + 0.75 %. But what is noteworthy is that for the more intense rainfall range of 10 to 15 mm/day the frequency/count for the current (1980-1990) period is again 44 (1.10 %), whereas for the far-term future decadal period (2060-2070) the highest frequency/count is 52 (1.29 %), an increase of + 18.18 %. But for the even more intense rainfall range of 15 to 20 mm/day the frequency/count for the current (1980-1990) period is 14 (0.35 %), whereas for the far-term future decadal period (2060-2070) the highest frequency/count drops to 11 (0.27 %), a decrease of - 21.43 % (Table 27).

Table 27: ECHAM5 Rainfall (mm/day) 2060-2070 vs 1980-1990

Range of Daily Rainfall (mm/day)	1980-1990		2060-2070		Δ
	Count	% of all	Count	% of all	
x=0,0	0	0,00	0	0,00	0
0,0<x<=5,0	3605	89,72	3632	90,39	+0,75
5,0<x<=10,0	300	7,47	265	6,60	-11,67
10,0<x<=15,0	44	1,10	52	1,29	+18,18
15,0<x<=20,0	14	0,35	11	0,27	-21,43
20,0<x<=25,0	12	0,30	3	0,07	-75,00
25,0<x<=30,0	8	0,20	1	0,02	-87,50
30,0<x<=35,0	2	0,05	2	0,05	0,00
35,0<x<=40,0	1	0,02	2	0,05	+100,00
40,0<x<=45,0	0	0,00	0	0,00	0
45,0<x<=50,0	0	0,00	0	0,00	0
50,0<x<=55,0	1	0,02	0	0,00	-100,00
Missing	31	---	50	---	---

3.2.19: Modelled seasonal Evaporation and Anomalies

For purposes of brevity, and in view of the fact that there is little or no spatial variation within the small Food Zone area, we only present summary tabular results (Table 28) and not maps.

HadCM3/AEXSM Evaporation - 2030-2040 versus 1961-2013

At first, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the March-April-May season, we see that, on average, modelled evaporation for the current period (1961-2013) is 224 mm/season, whereas modelled seasonal evaporation for the near-term future period (2030-2040) is 220 mm/season, thereby indicating a slight seasonal evaporation decrease of – 4 mm/season (- 1.79 %) (Table 28).

Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the June-July-August season, we now see that, on average, modelled evaporation for the current period (1961-2013) is 109 mm/season, whereas modelled seasonal evaporation for the future period (2030-2040) is 110 mm/season, thereby indicating a negligible seasonal evaporation increase of 1 mm/season (+ 0.92 %) (Table 28).

When however using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the September-October-November season, we now see that, on average, modelled evaporation for the current period (1961-2013) is 112 mm/season, whereas modelled evaporation for the future period (2030-2040) is also 112 mm/season, thereby indicating no change in evaporation (0 mm/season: 0.00 %) (Table 28).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the December-January-February season, we now see that, on average, modelled evaporation for the current period (1961-2013) is 214 mm/season, whereas modelled evaporation for the future period (2030-2040) is 215 mm/season, thereby indicating little or no change in evaporation (1 mm/season: 0.47 %) (Table 28).

It is evident then that, the changes in modelled seasonal evaporation between the near-term future (2030-2040) and the current period (1961-2013) are minimal. This can be attributed to the fact that the slightly higher temperatures in the future (2030-2040) may be balanced out by other factors that determine the evaporation rate, namely cloudiness, rainfall and solar radiation.

HadCM3/AEXSM Evaporation - 2060-2070 versus 1961-2013

Firstly, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the March-April-May season, we see that, on average, modelled evaporation for the current period (1961-2013) is again 224 mm/season, whereas modelled seasonal evaporation for the far-term future period (2060-2070) is 186 mm/season, thereby indicating a moderate seasonal evaporation decrease of – 38 mm/season (- 16.96 %) (Table 28).

Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the June-July-August season, we now see that, on average, modelled evaporation for the current period (1961-2013) is again 109 mm/season, whereas modelled seasonal evaporation for the future period (2060-2070) is 103 mm/season, thereby indicating a slight seasonal evaporation decrease of - 6 mm/season (- 5.50 %) (Table 28).

But when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the September-October-November season, we now see that, on average, modelled evaporation for the current period (1961-2013) is again 112 mm/season, whereas modelled evaporation for the future period (2060-2070) is 114 mm/season, thereby indicating a negligible change in evaporation (2 mm/season: + 1.79 %) (Table 28).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal evaporation for the December-January-February season, we now see that, on average, modelled evaporation for the current period (1961-2013) is again 214 mm/season, whereas modelled evaporation for the future period (2060-2070) is 218 mm/season, thereby again indicating little or no change in evaporation (4 mm/season: 1.87 %) (Table 28).

It is evident then that, except for the March-April-May season, the changes in modelled seasonal evaporation between the far-term future (2060-2070) and the current period (1961-2013) are minimal. This again can be attributed to the fact that the slightly higher temperatures in the future (2060-2070) may be balanced out by other factors that determine the rate of evaporation, namely cloudiness, rainfall and solar radiation.

ECHAM5 Evaporation - 2030-2040 versus 1961-2013

At first, using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the March-April-May season, we see that, on average, modelled evaporation for the current period (1961-2013) is 230 mm/season, whereas modelled seasonal evaporation for the near-term future period (2030-2040) is 228 mm/season, thereby indicating a slight seasonal evaporation decrease of – 2 mm/season (- 0.87 %) (Table 28).

But when using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the June-July-August season, we now see that, on average, modelled evaporation for the current period (1961-2013) is 82 mm/season, whereas modelled seasonal evaporation for the future period (2030-2040) is 100 mm/season, thereby indicating a moderate seasonal evaporation increase of 18 mm/season (+ 21.95 %) (Table 28).

Next, when using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the September-October-November season, we now see that, on average, modelled evaporation for the current period (1961-2013) is 81 mm/season, whereas modelled evaporation for the future period (2030-2040) is 79 mm/season, thereby indicating a negligible decrease in evaporation (- 2 mm/season: - 2.47 %) (Table 28).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the December-January-February season, we now see that, on average, modelled evaporation for the current period (1961-2013) is 204 mm/season, whereas modelled evaporation for the future period (2030-2040) is 194 mm/season, thereby indicating little a slight decrease in evaporation (-10 mm/season: - 4.90 %) (Table 28).

It is evident then that, except for the June-July-August season, the changes in modelled seasonal evaporation between the near-term future (2030-2040) and the current period (1961-2013) are minimal. This again can be attributed to the fact that the slightly higher temperatures in the future (2030-2040) may be balanced out by other factors that determine the evaporation rate, namely cloudiness, rainfall and solar radiation.

ECHAM5 Evaporation - 2060-2070 versus 1961-2013

Firstly, using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the March-April-May season, we see that, on average, modelled evaporation for the current period (1961-2013) is again 230 mm/season, whereas modelled seasonal evaporation for the far-term future period (2060-2070) is 212 mm/season, thereby indicating a slight seasonal evaporation decrease of – 18 mm/season (- 7.83 %) (Table 28).

Next, when using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the June-July-August season, we now see that, on average, modelled evaporation for the current period (1961-2013) is again 82 mm/season, whereas modelled seasonal evaporation for the future period (2060-2070) is 95 mm/season, thereby indicating a moderate seasonal evaporation increase of 13 mm/season (+ 15.85 %) (Table 28).

Also, when using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the September-October-November season, we now see that, on average, modelled evaporation for the current period (1961-2013) is again 81 mm/season, whereas modelled evaporation for the future period (2060-2070) is 86 mm/season, thereby indicating a slight increase in seasonal evaporation (+ 5 mm/season: + 6.17 %) (Table 28).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal evaporation for the December-January-February season, we now see that, on average, modelled evaporation for the current period (1961-2013) is again 204 mm/season, whereas modelled evaporation for the future period (2060-2070) is 188 mm/season, thereby indicating little a slight decrease in evaporation (-16 mm/season: - 7.84 %) (Table 28).

It is again evident that, except for the June-July-August season, the changes in modelled seasonal evaporation between the far-term future (2060-2070) and the current period (1961-2013) are minimal. This again can be attributed to the fact that the slightly higher temperatures in the future (2060-2070) may be balanced out by other factors that determine the evaporation rate, namely cloudiness, rainfall and solar radiation.

Table 28: HadCM3/AEXSM and ECHAM5 Evaporation Anomalies

Climate Model		Modelled Evaporation: 1961-2013 (mm/season)	Modelled Evaporation: 2030-2060 (mm/season)	Evaporation Change: 2030-2060 (mm/season)	Evaporation Change: 2030-2060 (%)	Modelled Evaporation: 2060-2070 (mm/season)	Evaporation Change: 2060-2070 (mm/season)	Evaporation Change: 2060-2070 (%)
HadCM3/AEXSM								
	March-April-May	224	220	-4	-1,79	186	-38	-16,96
	June-July-August	109	110	1	+0,92	103	-6	-5,50
	September-October-November	112	112	0	+0,00	114	2	+1,79
	December-January-February	214	215	1	+0,47	218	4	+1,87
ECHAM5								
	March-April-May	230	228	-2	-0,87	212	-18	-7,83
	June-July-August	82	100	18	+21,95	95	13	+15,85
	September-October-November	81	79	-2	-2,47	86	5	+6,17
	December-January-February	204	194	-10	-4,90	188	-16	-7,84

3.2.20 HadCM3/AEXSM and ECHAM5 P-E Anomalies and Trends

In this section, we focus on the seasonal and monthly variations and trends of major water balance components, namely precipitation (rainfall), evaporation and water excess or water deficits for the current (1961-2013) and the two future (2030-2040 and 2060-2070) according to the downscaled HadCM3/AEXSM and ECHAM5 climate models.

HadCM3/AEXSM Seasonal P-E Anomalies - 2030-2040 versus 1961-2013

At first, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the March-April-May season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is 68 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is - 191 mm/season (water deficit), thereby indicating a significant decrease in seasonal water excess/deficit, namely a higher water deficit (- 259 mm/season: - 380.88 %) (Table 29 and Figures 31; 32; 33 and 34).

Next, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the June-July-August season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is 468 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is 27 mm/season (excess), thereby indicating a significant decrease in seasonal water excess, namely a higher water deficit (- 441 mm/season: - 94.23 %) (Table 29 and Figures 31; 32; 33 and 34).

Also, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the September-October-November season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is 389 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is only 6 mm/season (excess), thereby indicating a significant decrease in seasonal water excess, namely a higher water deficit (- 383 mm/season: - 98.46 %) (Table 29 and Figures 31; 32; 33 and 34).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the December-January-February season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is – 9.0 mm/season (water deficit), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is - 180 mm/season (deficit), thereby indicating a significant decrease in seasonal water deficit, namely a higher water deficit (- 171 mm/season: - 1,900 %) (Table 29 and Figures 31; 32; 33 and 34).

The tendency then in modelled seasonal water excess/deficit between the near-term future (2030-2040) and the current period (1961-2013) is increasing water deficits for all seasons in the future (2030-2040, due to a combination of decreasing rainfall (P) and increasing evaporation (E).

HadCM3/AEXSM Seasonal P-E Anomalies - 2060-2070 versus 1961-2013

Firstly, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the March-April-May season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again 68 mm/season (water excess), whereas modelled seasonal water excess/deficit for the far-term future period (2060-2070) is - 79 mm/season (water deficit), thereby indicating a significant decrease in seasonal water excess/deficit, namely a higher water deficit (- 147 mm/season: - 216.18 %) (Table 29 and Figures 31; 32; 33 and 34).

But, using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the June-July-August season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again 468 mm/season (water excess), whereas modelled seasonal water excess/deficit for the far-term future period (2060-2070) is 55 mm/season (water excess), thereby indicating a significant decrease in seasonal water excess, namely a higher water deficit (- 413 mm/season: - 88.25 %) (Table 29 and Figures 31; 32; 33 and 34).

Also, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the September-October-November season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again 389 mm/season (water excess), whereas modelled seasonal water excess/deficit for the far-term future period (2060-2070) is only 36 mm/season (excess), thereby indicating a significant decrease in seasonal water excess, namely a higher water deficit (- 353 mm/season: - 90.75 %) (Table 29 and Figures 31; 32; 33 and 34).

Finally, when using the downscaled HadCM3/AEXSM model to examine changes in mean seasonal water excess/deficit (P-E) for the December-January-February season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again – 9.0 mm/season (water deficit), whereas modelled seasonal water excess/deficit for the far-term future period (2060-2070) is - 87 mm/season (deficit), thereby indicating a significant decrease in seasonal water deficit, namely a higher water deficit (- 78 mm/season: - 866.67 %) (Table 29 and Figures 31; 32; 33 and 34).

The tendency then again in modelled seasonal water excess/deficit between the far-term future (2060-2070) and the current period (1961-2013) is increasing water deficits for all seasons in the future (2060-2070, due to a combination of decreasing rainfall (P) and increasing evaporation (E).

Table 29: HadCM3/AEXSM and ECHAM5 P-E Anomalies

Climate Model		Modelled P-E: 1961-2013 (mm/season)	Modelled P-E: 2030-2040 (mm/season)	P-E Change: 2030-2040 (mm/season)	P-E Change: 2030-2040 (%)	Modelled P-E: 2060-2070 (mm/season)	P-E Change: 2060-2070 (mm/season)	P-E Change: 2060-2070 (%)
HadCM3/ AEXSM								
	March-April-May	68	-191	-259	-380,88	-79	-147	-216,18
	June-July-August	468	27	-441	-94,23	55	-413	-88,25
	September-October-November	389	6	-383	-98,46	36	-353	-90,75
	December-January-February	-9	-180	-171	-1900,00	-87	-78	-866,67
ECHAM5							0	
	March-April-May	68	-4	-72	-105,88	14	-54	-79,41
	June-July-August	732	662	-70	-9,56	699	-33	-4,51
	September-October-November	466	502	36	+7,73	455	-11	-2,36
	December-January-February	54	117	63	116,67	56	2	+3,70

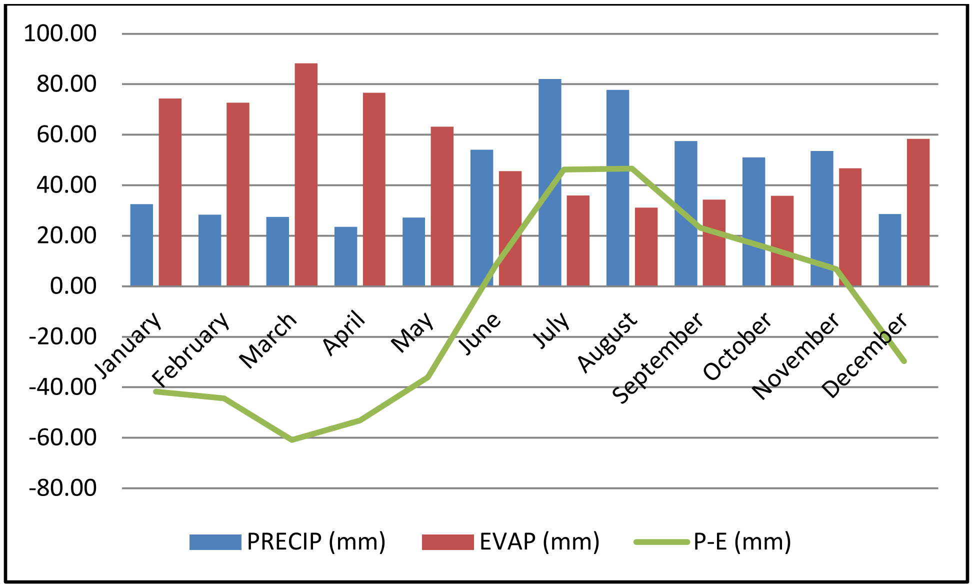


Figure 31: Mean monthly Precipitation (P), Evaporation and Water Excess/Deficit (P-E) – (1961-2013) according to the downscaled HadCM3/AEXSM climate model

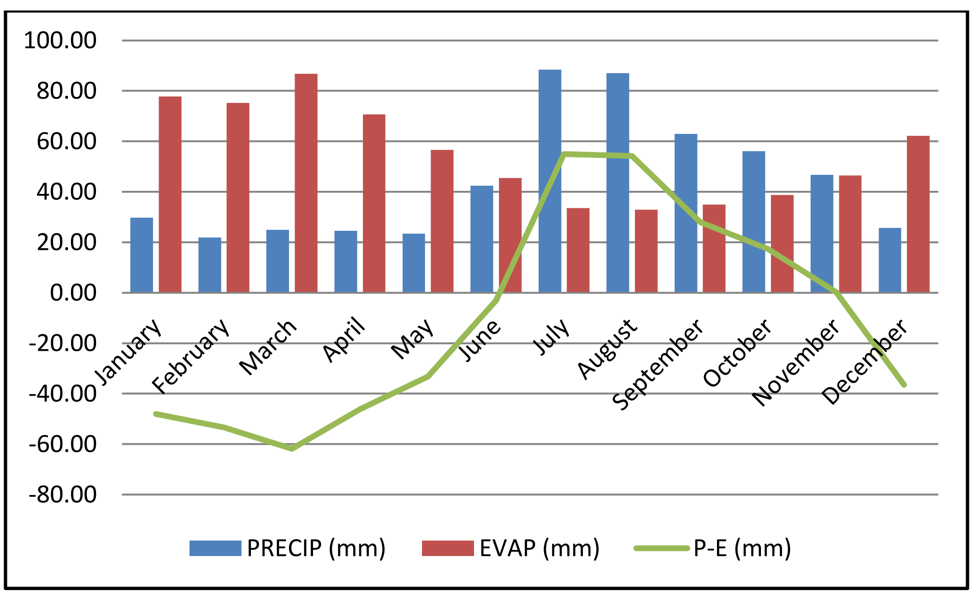


Figure 32: Mean monthly Precipitation (P), Evaporation and Water Excess/Deficit (P-E) – (2030-2040) according to the downscaled HadCM3/AEXSM climate model

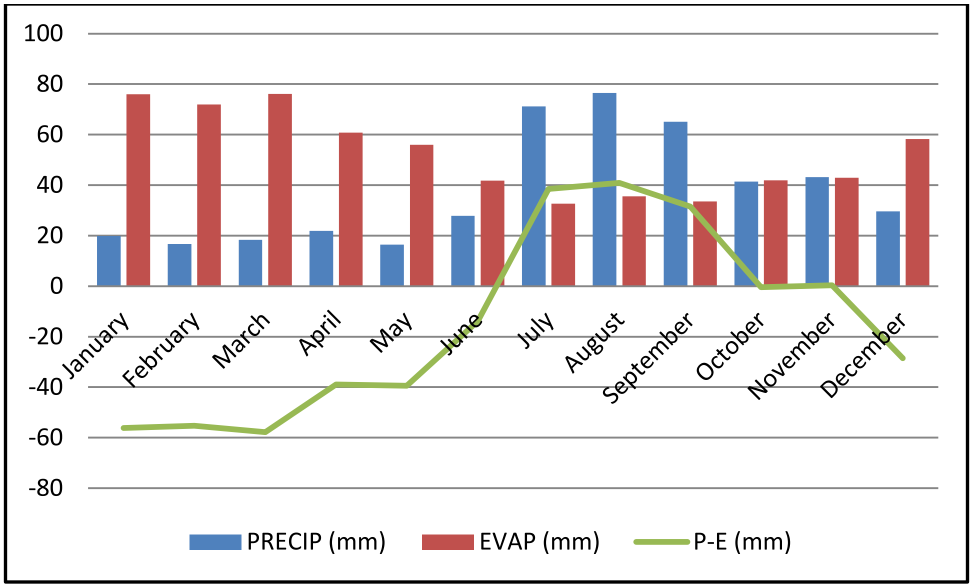


Figure 33: Mean monthly Precipitation (P), Evaporation and Water Excess/Deficit (P-E) – (2060-2070) according to the downscaled HadCM3/AEXSM climate model

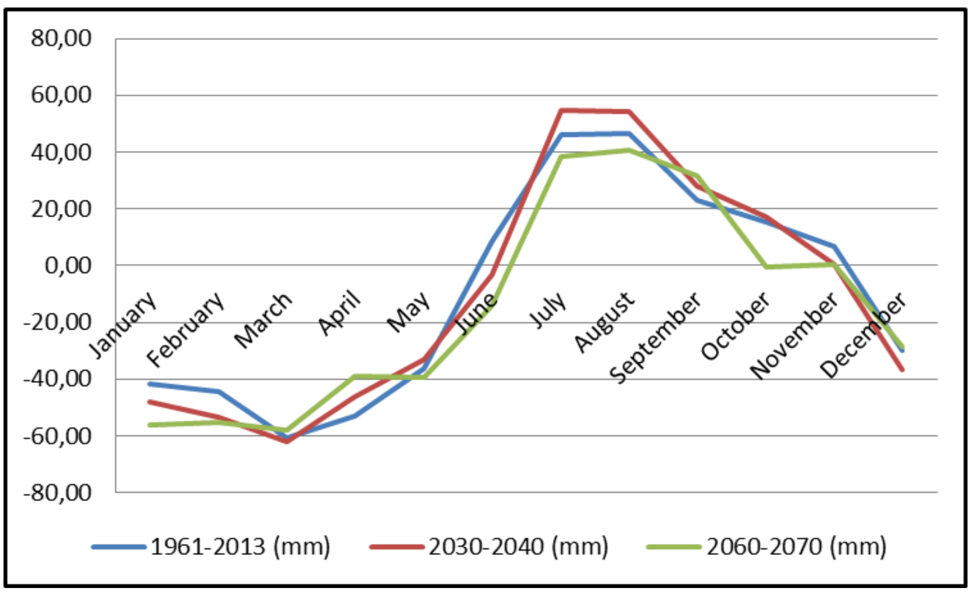


Figure 34: Mean monthly Water Excess/Deficit (P-E: mm) for the current (1961-2013) and future (2030-2040 and 2060-2070) according to the downscaled HadCM3/AEXSM climate model

ECHAM5 Seasonal P-E Anomalies - 2030-2040 versus 1961-2013

When at first, using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the March-April-May season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is also 68 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is - 4 mm/season (water deficit), thereby indicating a significant decrease in seasonal water excess/deficit, namely a higher water deficit (- 72 mm/season: - 105.88 %) (Table 29 and Figures 35; 36; 37 and 38).

But, when using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the June-July-August season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is 732 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is 662 mm/season (excess), thereby indicating a slight decrease in seasonal water excess, namely a lower water excess (- 70 mm/season: - 9.56 %) (Table 29 and Figures 35; 36; 37 and 38).

However, when using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the September-October-November season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is 466 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is 502 mm/season (excess), thereby indicating a slight increase in seasonal water excess, namely a higher water excess (+ 36 mm/season: + 7.73 %) (Table 29 and Figures 35; 36; 37 and 38).

Also, when using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the December-January-February season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is 54.0 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is + 63 mm/season (excess), thereby indicating a slight increase in seasonal water excess, namely a higher water excess (+ 63 mm/season: + 116.67 %) (Table 29 and Figures 35; 36; 37 and 38).

In general then, the tendency then in modelled seasonal water excess/deficit between the near-term future (2030-2040) and the current period (1961-2013) is increasing water deficits for the March-April-May and June-July-August seasons, due to a combination of decreasing rainfall (P) and increasing evaporation (E), but slightly increasing water excess during the September-October-November and December-January-February seasons, due most likely to higher rainfalls in the future (2030-2040).

ECHAM5 Seasonal P-E Anomalies - 2060-2070 versus 1961-2013

At first, using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the March-April-May season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again 68 mm/season (water excess), whereas modelled seasonal water excess/deficit for the far-term future period (2060-2070) is 14 mm/season (water excess), thereby indicating a slight decrease in seasonal water excess/deficit, namely a lower water excess (- 54 mm/season: - 79.41 %) (Table 29 and Figures 35; 36; 37 and 38).

However, when using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the June-July-August season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again 732 mm/season (water excess), whereas modelled seasonal water excess/deficit for the far-term future period (2060-2070) is 699 mm/season (excess), thereby again indicating a slight decrease in seasonal water excess, namely a lower water excess (- 33 mm/season: - 4.51 %) (Table 29 and Figures 35; 36; 37 and 38).

Also, when using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the September-October-November season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again 466 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is 455 mm/season (excess), thereby indicating a slight decrease in seasonal water excess, namely a lower water excess (- 11 mm/season: - 2.36 %) (Table 29 and Figures 35; 36; 37 and 38).

Finally, when using the downscaled ECHAM5 model to examine changes in mean seasonal water excess/deficit (P-E) for the December-January-February season, we see that, on average, modelled water excess/deficit (P-E) for the current period (1961-2013) is again 54.0 mm/season (water excess), whereas modelled seasonal water excess/deficit for the near-term future period (2030-2040) is + 56 mm/season (excess), thereby indicating a very slight increase in seasonal water excess, namely a slightly higher water excess (+ 2 mm/season: + 3.7 %) (Table 29 and Figures 35; 36; 37 and 38).

In general then, the tendency then in modelled seasonal water excess/deficit between the near-term future (2030-2040) and the current period (1961-2013) is, except for the December-January-February season, when seasonal water excess increases slightly, due most likely to slightly higher rainfalls, is increasing water deficits for the other three seasons, due to a combination of decreasing rainfall (P) and increasing evaporation (E) in the future (2030-2040).

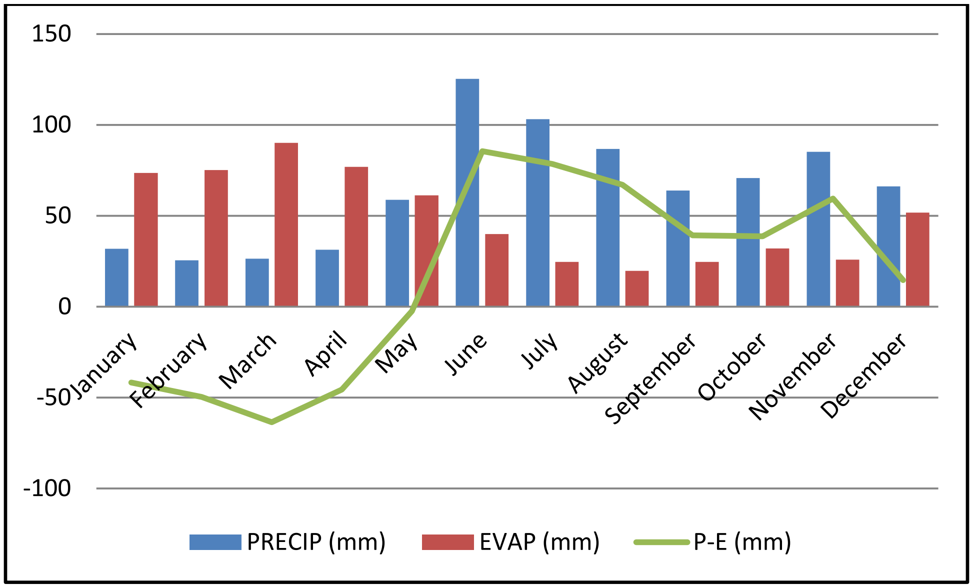


Figure 35: Mean monthly Precipitation (P), Evaporation and Water Excess/Deficit (P-E) – (1961-2013) according to the downscaled ECHAM5 climate model

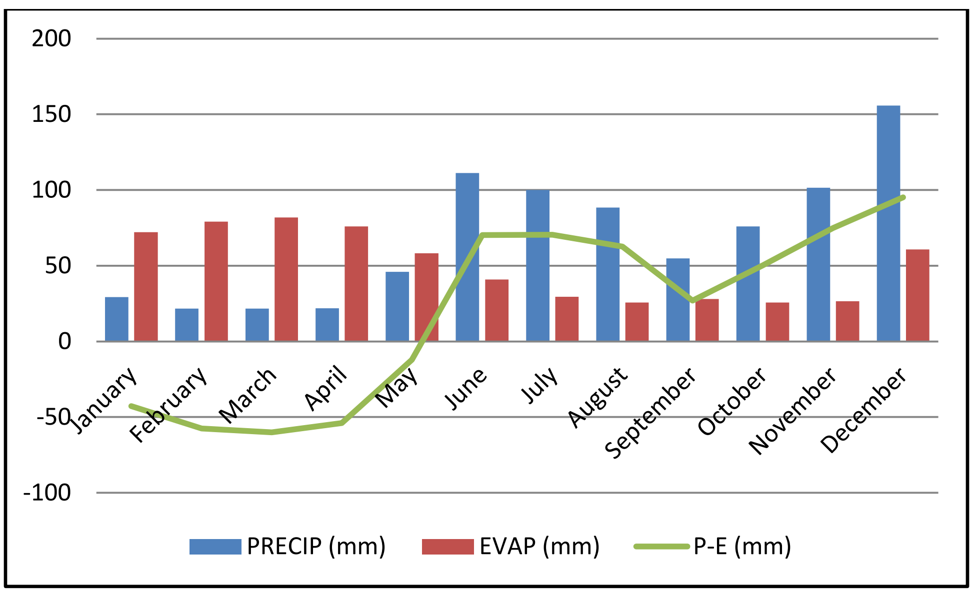


Figure 36: Mean monthly Precipitation (P), Evaporation and Water Excess/Deficit (P-E) – (2030-2040) according to the downscaled ECHAM5 climate model

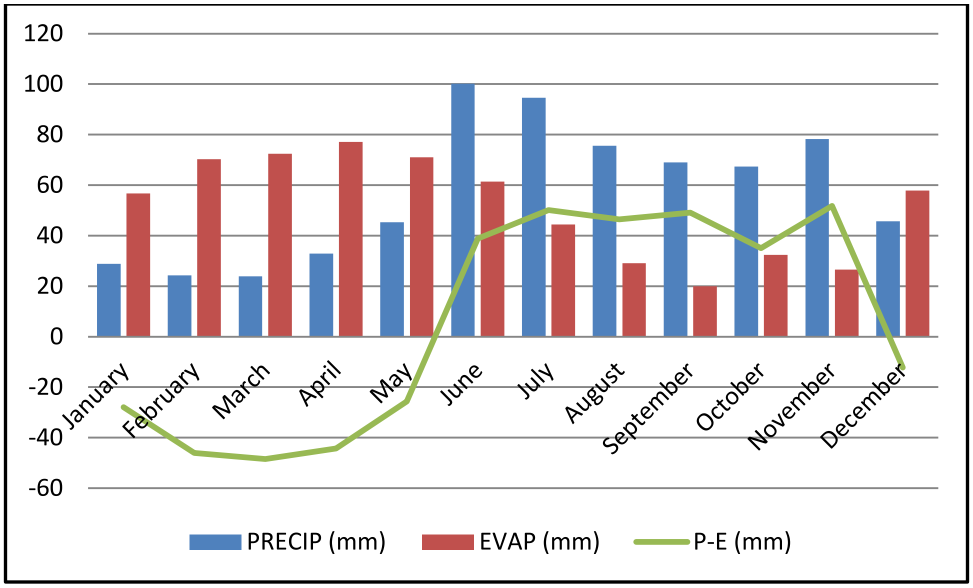


Figure 37: Mean monthly Precipitation (P), Evaporation and Water Excess/Deficit (P-E) – (2030-2040) according to the downscaled ECHAM5 climate model

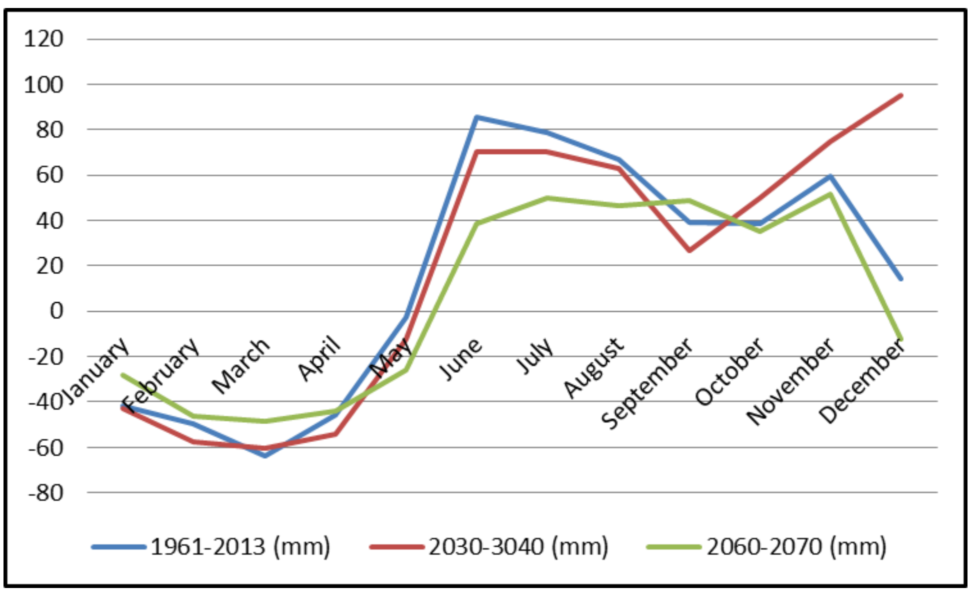


Figure 38: Mean monthly Water Excess/Deficit (P-E: mm) for the current (1961-2013) and future (2030-2040 and 2060-2070) according to the downscaled ECHAM5 climate model

Summary

For purposes of comparison and validation, the climate scenarios data for the current (1961-2013) and future (2030-3040 and 2060-2070) time periods and for the two downscaled global climate models (HadCM3/AEXSM and ECHAM5) are corroborated by similar studies done previously for the island of Barbados. Prominent amongst these previous studies is the United Nations Development Programme (UNDP) Climate Change Country Profiles project (McSweeney *et al.* 2008; 2009) that provides country-scale data files and easily accessible analyses of up-to-date observed data and multi-model scenario-based projections for 52 developing countries in Africa, Asia the Caribbean and Central America, including Barbados. The project facilitates the use of observed and modeled climate data in climate impact assessment and exploration by providing observed data and future climate projections modeled using the SRES scenarios (Nakicenovic, N., and Coauthors, 2000) in the IPCC Fourth Assessment Report for each country, including Barbados in a standard format that is more manageable than the large global fields that are directly available from the Program for Climate Model Diagnosis and Inter-comparison (PCMDI) (McSweeney *et al*, 2008, 2009, 2010).

The data on current and future climates and climate scenarios (temperature and rainfall) together with time series climatologies (1961-2100) are extracted from ensemble coupled Atmosphere-Ocean General Circulation Models (A-OGCMs) forced by three of the Special Report on Emissions Scenarios (SRES) marker scenarios used in the IPCC Fourth Assessment Report (2007), namely a high (A2), a low (B1) and a medium (A1B) emissions scenario that produce high, low and medium climate forcings and changes.

These country profiles and climate change scenarios were prepared by the University of Oxford in collaboration with the Tyndall Centre for Climate Change Studies (University of East Anglia) UNDP (McSweeney et al, 2009; 2010).The profiles were developed to address the climate change information gap in many developing countries by making use of existing climate data to generate country-level data plots from the most up-to-date climate observations and the multi-model projections from the WCRP CMIP3 archive (Meehl *et al.*, 2007).

3.2.20: Coastal Zone Inundation

As for the effects of storm surges, particularly in regard to the part of the Food Zone that lies in Saint Michael Parrish, we used the storm surge and hurricane categories data from the Caribbean Disaster Management Project (CDEMA, 2005) (Table 3.2.18). We used the storm surge projections for a category 2 and a category 5 hurricane. Furthermore, the final values of the storm surges were derived by incorporating the sea level rise and the highest tide level for the 2046-2065 and 2081-2100, the two future time periods suggested by the IPCC (2013; 2014) (See Table 30).

Table 30: Storm surge levels according to hurricane categories (Source: Caribbean Disaster Mitigation Project, 2005)

STORM SURGE AND HURRICANE CATEGORIES (SOURCE: CARIBBEAN DISASTER MITIGATION PROJECT, 2005).

Category	Pressure (mb)	Winds (km/hr)	Storm Surge (m)	Damage	Rounded Value of Relevant Storm Surges (m)
0: Tropical Storm	> 995	61-119	0.5-1.2	Some	
1: Hurricane	980-995	119-153	1.2-1.5	Minimal	
2 Hurricane	965-979	154-177	1.6-2.4	Moderate	2
3: Hurricane	945-964	178-209	2.5-3.6	Extensive	
4: Hurricane	920-944	210-250	3.7-5.4	Extreme	
5: Hurricane	<920	> 250	> 5.4	Catastrophic	5

At first, by examining the coastal zones of Saint Michael Parrish and the Food Zone at risk of inundation due to a 2.47 m Category 2 Hurricane Storm Surge and the Land Use classes that may be affected, it is evident that climate-driven sea level rise would have a minimal impact (0 km^2), for both future time periods (2040-2065: 0.47 m) and (2081-2100: 0.91 m) (Table 31).

However, when considering, the effects of future sea level rise, combined with a storm surges caused by a category 2 hurricane (2.47 m: 2040-2065) and (2.91 m: 2081-2100), it is clear that inundation is only evident along a narrow coastal zone of Saint Michael Parrish (2040-2065: 1.29 km^2) and (2081-2100: 1.3 km^2), and the Food Zone is not at risk (Table 31 and Figures 39; 40; 41 and 42).

On the other hand, when considering, the effects of future sea level rise, combined with a storm surges caused by a category 5 hurricane (5.87 m: 2040-2065) and (6.31 m: 2081-2100), it is again clear that inundation is only evident along a narrow coastal zone of Saint Michael Parrish (2040-2065: 2.83 km^2) and (2081-2100: 3.31 km^2), and the Food Zone is again not at risk (Table 31 and Figures 39; 40; 41 and 42).

Table 31: Final values of future sea level and storm surge scenarios for a Category 2 and a Category 5 Hurricane: Barbados

Sea Level Rise (RCP 8.5) (m)		Contribution of MHHW (Mean Higher High Water) (m)	**Final Values of Future Sea Levels**	*Storm Surge Scenarios Category 2 Hurricane Mid Value	**Final Storm Surge Scenarios Category 2 Hurricane: Mid Value plus Sea Level Rise**	*Storm Surge Scenarios (m) Category 5 Hurricane (Minimum Value)	**Final Storm Surge Scenarios Category 5 Hurricane: Minimum Value plus Sea Level Rise**
			(m)	(m)	(m)	(m)	(m)
2040-2065	0.38	0.9	0.47	2.00	**2.47**	5.4	**5.87**
Inundated : (km^2)	---	0	0	---	**1.29**	---	**2.83**
2081-2100	0.82	0.9	0.91	2.00	**2.91**	5.4	**6.31**
Inundated : (km^2)	---	0	0	---	**1.33**	---	**3.31**

*By adding the sea levels to the mid-value storm surges

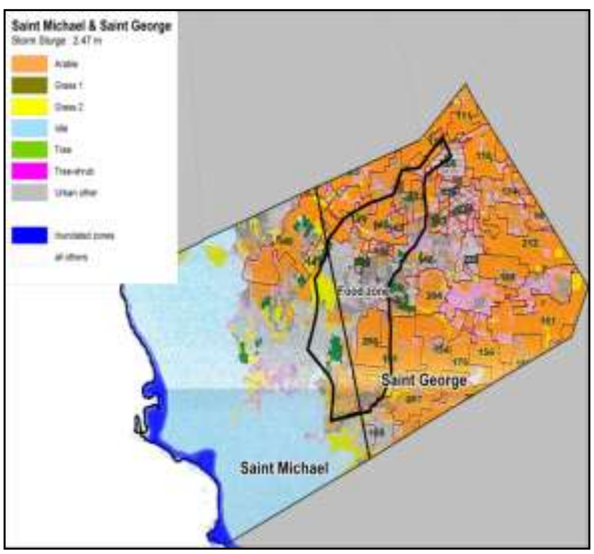


Figure 39: Inundation due to a 2.47 m Category 2 Hurricane Storm Surge and Land Use classes at risk in Saint Michael Parrish and the Food Zone

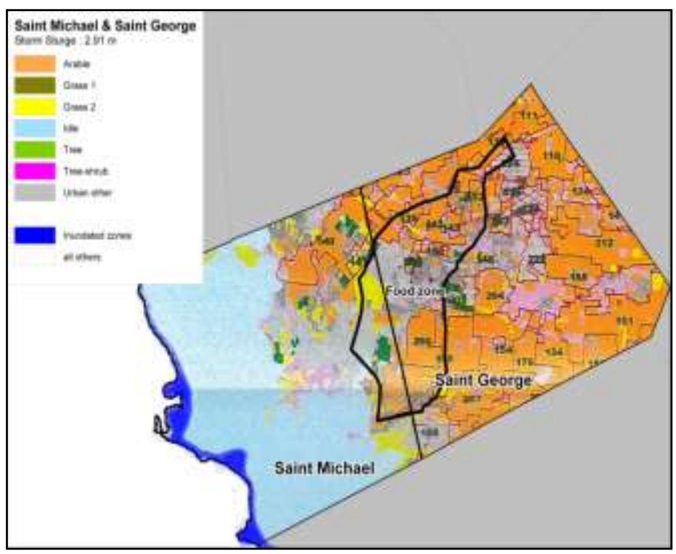


Figure 40: Inundation due to a 2.91 m Category 2 Hurricane Storm Surge and Land Use classes at risk in Saint Michael Parrish and the Food Zone

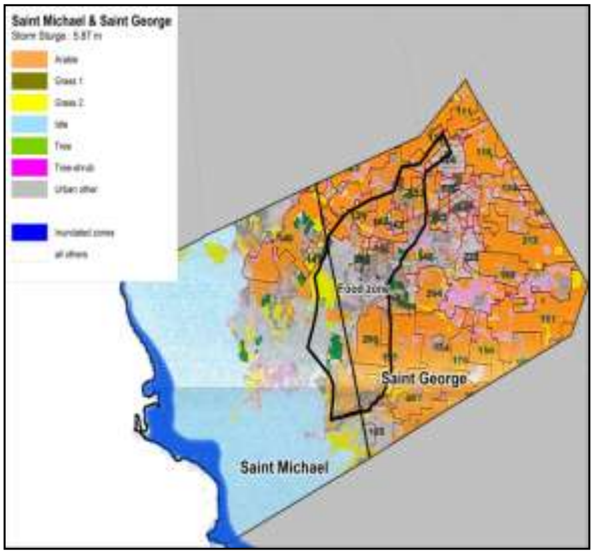


Figure 41: Inundation due to a 5.87 m Category 5 Hurricane Storm Surge and Land Use classes at risk in Saint Michael Parrish and the Food Zone

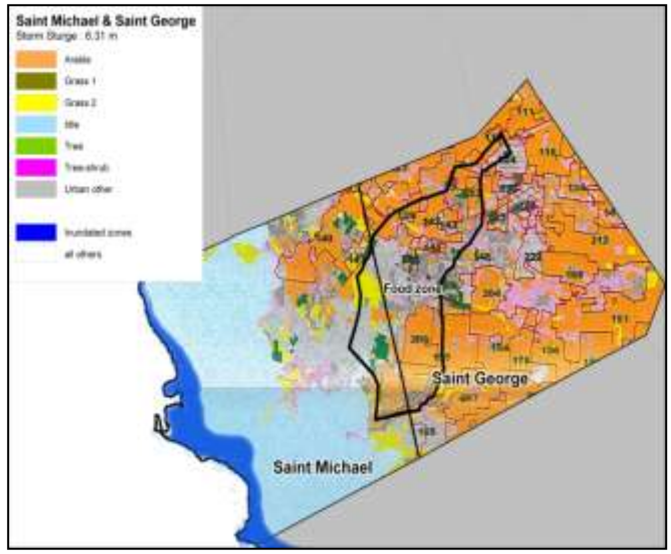


Figure 42: Inundation due to a 6.31 m Category 5 Hurricane Storm Surge and Land Use classes at risk in Saint Michael Parrish and the Food Zone

However, although climate-driven storm surges may not directly affect the Food Zone, indirect impacts such as saline intrusions into coastal aquifers and wells such as Waterford and Belle PS on the coast of Saint Michael may occur and this may have an indirect effect on good quality water supply for irrigation in the Food Zone. Furthermore, suppliers of critical inputs such as imported fertilizers and seeds for agriculture in the Food Zone located along the coast, most importantly Bridgetown the capital and main port may be negatively affected by climate-driven storm surges.

4 Assessment of Socio-economic Trends and Conditioning Factors and key Development Trends

In view of the future climate-related risks described above, the equivalent socio-economic development scenarios are formulated by assessing trends and changes in the development of Barbados, but focussing on the Food Zone in the Parishes of Saint Michael and Saint George. These scenarios are expectations that describe alternative futures and can be used as a tool for structuring discussion amongst stakeholders and raise awareness of the future connections between different agricultural problems and illustrate how different policy directions can achieve their targets.

Furthermore, these scenarios provide mechanisms for collaborative or co-produced insights between the VCA team and stakeholders to initiate discussion on commonly formulated questions on expected trends and plausible pathways for the community in the Food Zone of Barbados. The types of trends that are considered include past and present supply and demand management practices such as controls on access to fresh water and increased levies on certain goods.

Furthermore the national (Barbados) and local (Food Zone) development trends include such factors as population growth, urbanisation, rural migration, dependency on imported good and potential climate change impacts such as loss of coastal agricultural land through sea level rise, storm surges, erosion and salinization).

For instance, the current population trend is used to determine how many people might be affected by future climate change and variability of similar severity as experienced in the past, while at the same time factoring in the adaptation measures taken to reduce vulnerability.

4.1 Adaptive Capacity Index

The adaptive capacity index represents the average of the individual adaptive capacity determinant values. To calculate future scenarios of indicators, we first need to develop an indicator of adaptive capacity for the reference period (2004-2014). The reference adaptive capacity index was obtained using the following formula

$$\mathbf{AC_{ref} = \Sigma^{n}_{i=1} Xi / n}$$

where:

AC_{ref} is the adaptive capacity index;
Xi is the weighted average for each of the nine major determinants (see Figure 4.1);
n is the number of key determinants.

Thus, the overall adaptive capacity for the Barbadian food zone for the 2004- 2014 reference period is estimated at **0.1231.** An adaptive capacity index of **one** suggests high adaptive capacity, and an index of **zero** suggests **low** adaptive capacity.

This result therefore shows that the adaptive capacity of the agricultural sector in the Food Zone of Barbados is low.

4.2 Scenarios indicators for adaptive capacity of agriculture in the future period 2014-2034

Different types of scenarios are valuable for varying applications in research on the human dimensions of climate change. Climate scenarios, especially those in which various assumptions about social conditions around the globe are used to speculate about greenhouse gas emissions, are commonly used in assessing the physical impacts of climate change (Nakicenovic et al. 2000). Socioeconomic scenarios are therefore useful in vulnerability and adaptive capacity assessments.

Guideline of greenhouse gas emission (GHG) storyline A1B SRES (Special Report on Emission Scenarios) were considered in the development of scenarios of the adaptive capacity index in this study for the near-term future period 2014-2034.

According to Nakicenovic et al (2000), the assumptions for GHG emissions for the A1B forcing scenario are as follows:

- Population growth: growth of the world population to a maximum towards the middle of the century, followed by a decrease;
- Socio-economic development of very rapid economic growth, facing a more pronounced global economic globalization;
- Technological change: the introduction of more efficient technologies and a balance between different energy sources.

For the Barbadian Food Zone, all the key determinants identified during the multi-criteria analysis process are likely to be influenced by the changing vectors considered in the definition of the A1B storyline emission.

So in order to develop these scenarios of future adaptive capacity, the same order of priority of the nine main determinants were maintained, and then new weighting values were considered for each of the determinants. These new values have been defined on the basis of the potential influences of changes in drivers for the nine determinants of adaptive capacity.

Thereafter, the calculation of indicators of adaptive capacity scenarios is done by using the same formula previously used to calculate the adaptive capacity index for the reference period (2004-2014). A new weighting value for indicators of adaptive capacity of agriculture in the Food Zone was therefore made. The allocation of these values and their weightings were based on respondents' answers during interviews, as well as on the personal perception of the Consultants. The development of new determinants of adaptive capacity according to A1B socio-economic scenario considered during the future period (2014-2034) for the Food Zone of Barbados, is therefore mainly guided the allocation of these new values weighting.

Thus, given the socio-economic development scenario of very rapid economic growth, and a more global pronounced economic globalization, plus the introduction of more efficient technologies and a balance between different energy sources that characterize the A1B scenario, the new weighting modifies the order of priority established for the reference period (2004-

2014). Thus, unlike the reference period (2004-2014) the future (2014-2034) socio-economic development puts less importance on the market conditions and financial resources (Figure 43).

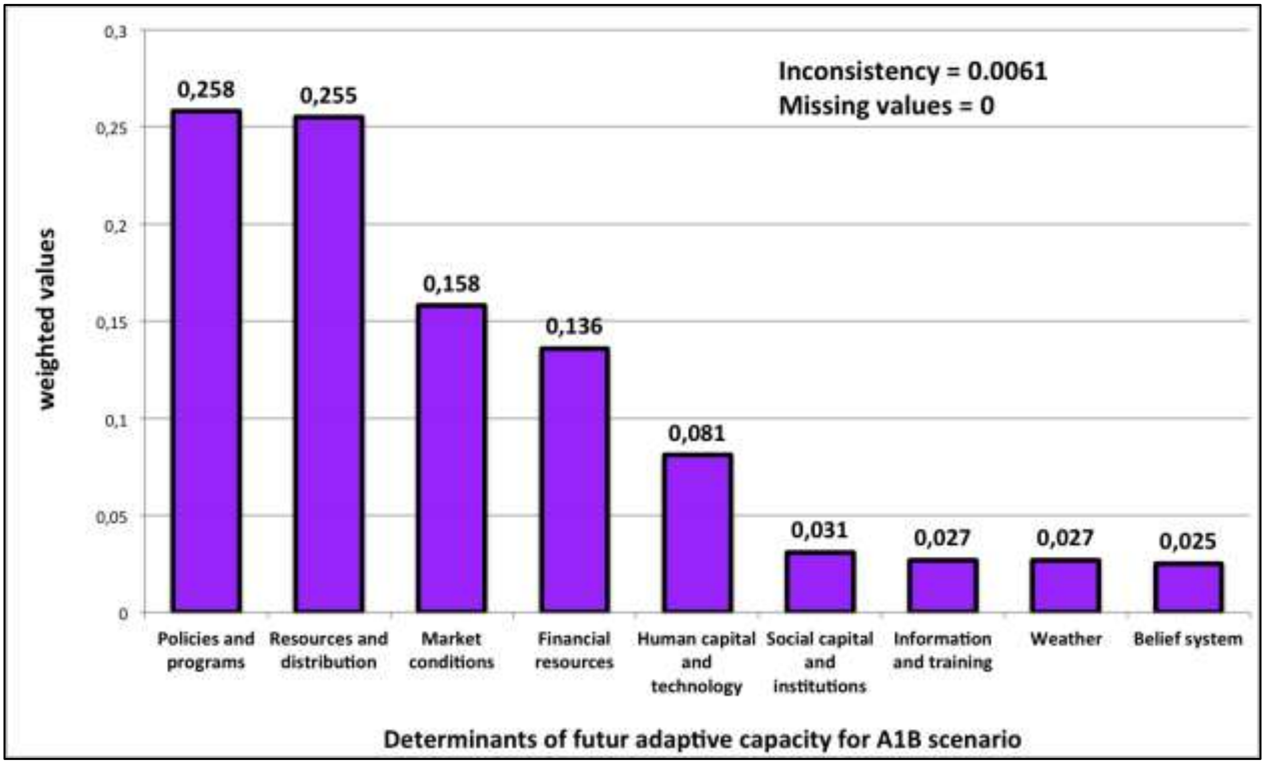


Figure 43: Determinants of future adaptive capacity for A1B scenario in the Food Zone of Barbados

However, the most significant items that stand out are the considerable importance of « policies and programs » and « resources and distributions» in the future resilience of agriculture to climate change and variability in the Food Zone. This may be explained by the threat to agriculture that would result from very rapid economic growth globally, and a more pronounced global economic globalization, that is inherent in the A1B SRES forcing scenario.

Such a perspective will put increasing pressure on the agriculture sector, especially in terms of the loss of arable lands or competing uses for available. For instance, agricultural land will likely compete with the tourism industry which would claim more land space to accommodate increasing numbers of tourists). Also, water constraints for agriculture may arise due to the competition with other economic sectors that depend on water.

Hence the central role of policies and programs, particularly to strengthen and enforce laws on zoning and farmland protection, but also to protect the local market against the massive arrival of imported agricultural products as a result of a more pronounced economic globalization.

Thus by taking account of the new weighting values lead to the development of a new indicator of adaptive capacity that reveals an adaptive capacity indicator higher for the reference period (2004-2014) compared to the future (2014-2034) period. This indicates that the prospects for the future are less favorable for agriculture in the Food Zone of Barbados (Table 32)

Table 32: Adaptive Capacity Index for the reference (2004-2014) and future (20014-2034) periods

Adaptive Capacity Index	
Reference period (2004-2014)	Future period 2014-2034
0.1231	**0.1109**

Consequently, the Government of Barbados, as well as stakeholders in agriculture must therefore act by considering the main factors, namely, « policy and programs » as well as « resources and distribution », which may determine the future ability of Barbadian agriculture, including the Food Zone, to adapt to multiple stressors.

4.3 Refinement of Database Development and Preliminary Data Analysis: Crop Yields

This section focusses on the indicators of how climate change may affect the yields of the three crops chosen, namely, sugarcane (plantation crop), cassava (root crop) and tomatoes (vegetable crop.

In undertaking the crop modelling, we tried to find the best and most realistic combination of management practices and genetic coefficients for the three crops that provided the lowest gap or error when compared to the estimated yield data.

4.4 Data and Methods

Four types of data were collected in order to assess, under the specific conditions of agricultural production of Barbados, biophysical models for cassava, tomato and sugarcane available into the Decision Support System for Agrotechnology Transfer (DSSAT, version 4.5). These data referred to time series of yields for the above mentioned three crops, weather data (maximum and minimum temperatures, solar radiation and rainfall), soil data and management practices. As indicated in the following table, several sources were used during the collection of these data, including the FAOSTAT database for crop yields, the MICH for weather data at HUSBANDS climate station, the closest one to the Food Zone, discussions with representatives of the Soil Conservation Unit of the Ministry of Agriculture of Barbados and the soil map presented in the Cane Growers manual of the BAMC for soil data, information sheets or pamphlets of the Ministry of Agriculture of Barbados and the Canes Grower manual of BAMC for information related to management practices (Table 33).

Table 33: Types and Sources of Data for Crop Modelling

Type of data	Source
Weather	CIMH
Soil	Soil Conservation Unit and BAMC
Management practices	Ministry of Agriculture and BAMC
Yield	FAO and BAMC

The assessment of the mechanistic crop models was carried out using estimated yield by FAO's for the years 2000 to 2010 in the case of cassava and tomatoes, and those collected by the BAMC in the case of sugarcane. Generally, 5 or 6 years have been used to calibrate the models, while the remaining years of the series were used to validate them. During the calibration process, we tried to find the best and most realistic combination of management practices and genetic coefficients for the three crops that provided the lowest gap or error when compared to the estimated yield data. It is important to highlight that due to a lack of soil data specific to the Food Zone, a generic type of soil based on texture (shallow silty clay loam) was considered during the calibration and the validation processes of the models.

4.5 Crop Models Calibration and Evaluation

In order to assess the differences between the simulated yields and those estimated or reported for the 3 aforementioned crops, two parameters were considered: the Root Mean Square Error (RMSE) and the Relative Difference (RD). The RMSE were used during the calibration process and the RD during the validation stage. These parameters were computed using the following formula:

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}$$

Pi : Simulated values

Oi : Estimated (or reported values)

n: number of measurements (data)

$$\mathbf{RD = [\sum (O_i - P_i) / P_i) * 100] / n}$$

Oi, Pi and an n already defined, and i goes from 1 to n

4.6 Results and Discussions: crops

Based on the values of RD, the crop models were able to reproduce satisfactorily the estimated or reported yield collected at the different sources mentioned above. Indeed, except for tomatoes, RD values for the other two crops were between 11% and 13%. When using reliable experimental data, RD values between +- 5% to 15% of measured yields are highly acceptable (Ritchie et al. 1998). In the context of this study, the RD values obtained with the reported or calculated data and with a generic type of soil were fairly acceptable. By considering the results of the validation process, the differences observed between the simulated and the reported or estimated yields in the figures below can be explained by several factors, notably quality of input data, consideration of yield determinants, and reliability of estimated or reported yields. With respect to yield determinants, it is important to note that the simulations did not take into account the influence of diseases, insects and weeds on yields of the selected crops, namely sugarcane, cassava, and tomatoes. Consequently, it was almost impossible to reproduce the estimated or reported yields for these years when productivity was greatly influenced by these factors (Figures 44; 45 and 46).

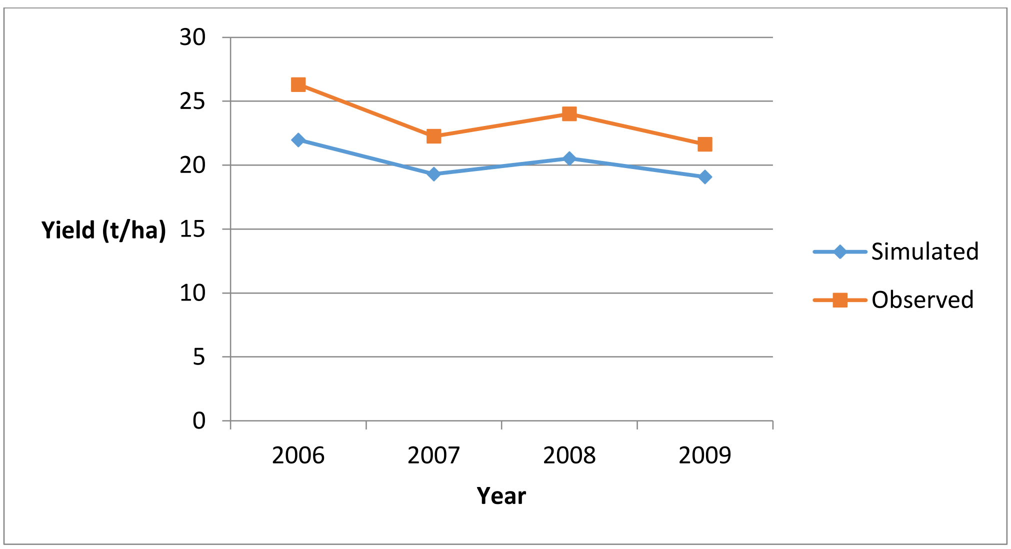


Figure 44: Comparison between observed and DSSAT-simulated yields for sugarcane

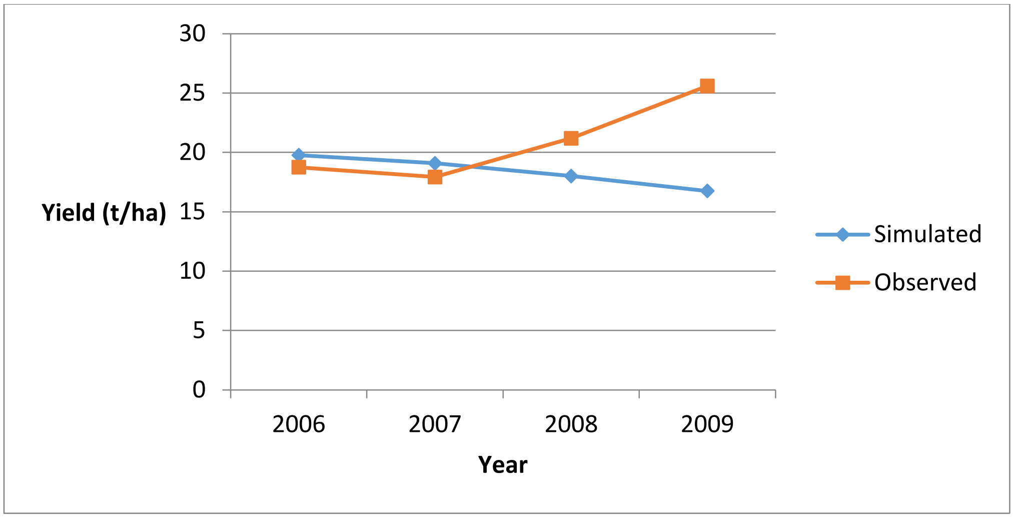


Figure 45: Comparison between observed and DSSAT-simulated yields for cassava

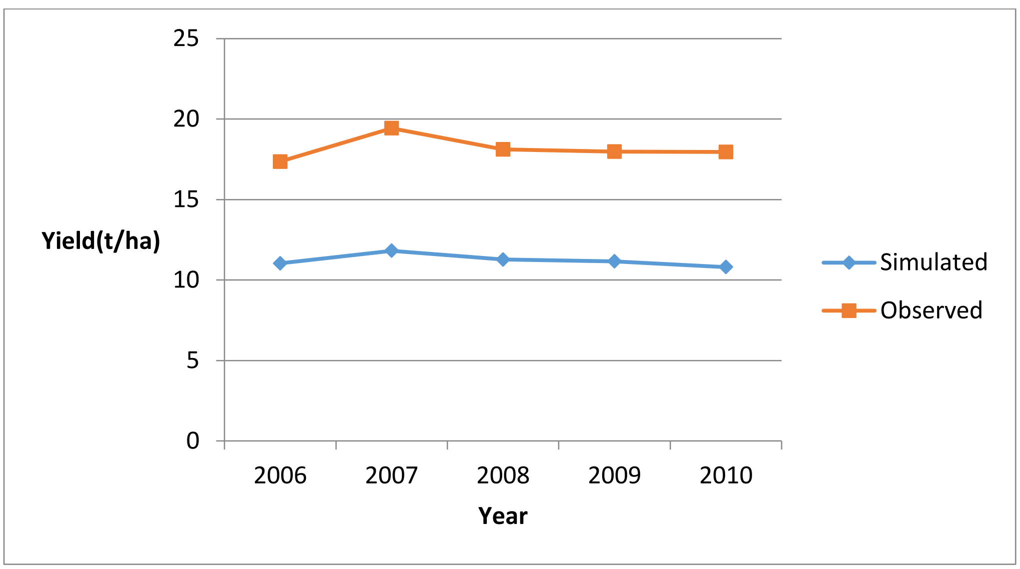


Figure 46: Comparison between observed and DSSAT-simulated yields for tomatoes

The figures below present the anticipated yields for each crop using both climate scenarios. A shown in these figures, except for cassava, anticipated yields with ECHAM-based climate scenarios will be higher than the ones with HadCM3-AEXSM. When considering each crop separately, anticipated yields of the 60s will be lower than the ones anticipated for the 30s. This could be explained by a warmer and drier climate during the 60s (Figure 47; Figure 48 and Figure 49).

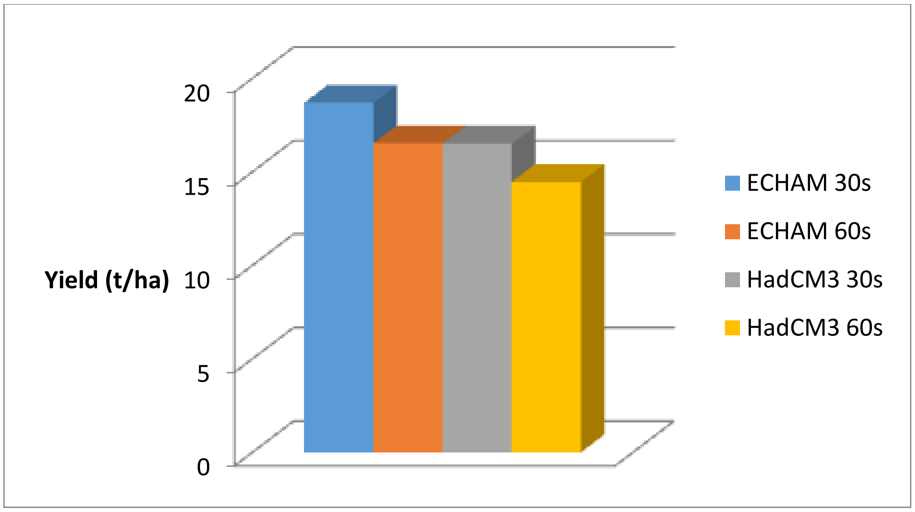


Figure 47: Comparison between observed and DSSAT-simulated yields for tomatoes

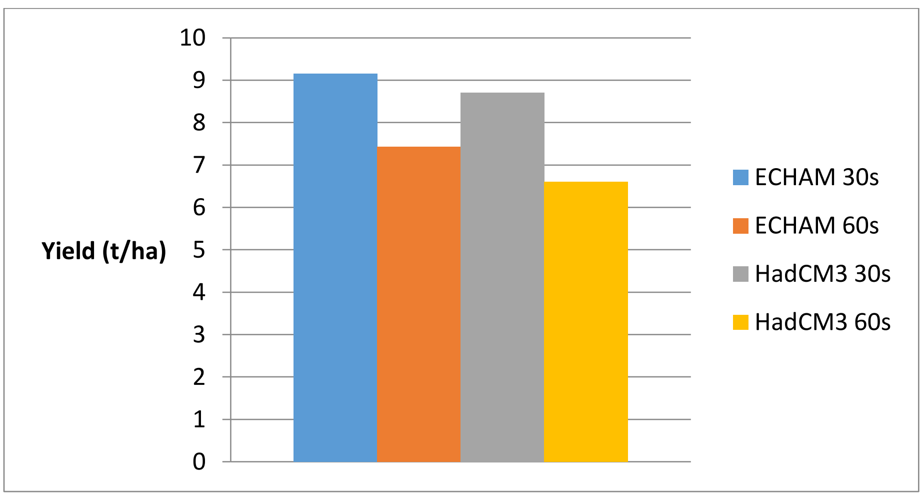


Figure 48: DSSAT-simulated anticipated yields of tomatoes for the 2030s and 2030s according to the HadCM3/AEXSM and ECHAM5 climate scenarios.

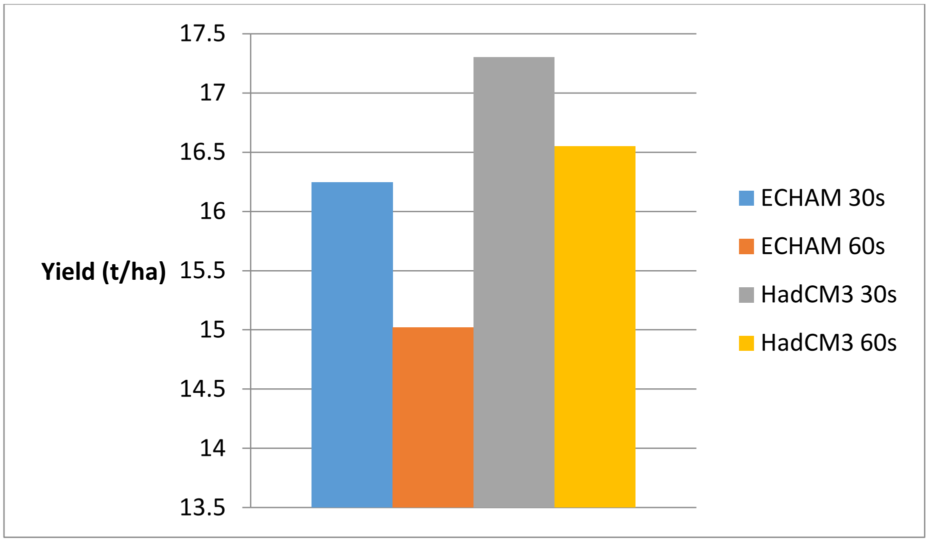


Figure 49: DSSAT-simulated anticipated yields of cassava for the 2030s and 2030s according to the HadCM3/AEXSM and ECHAM5 climate scenarios.

The following tables (Tables 34; 35 and 36) show the anticipated changes for the 3 crops using two climate scenarios. Generally, a yield decrease is anticipated for all 3 crops using both climate scenarios. The only yield increase is anticipated for cassava when considering the HadCM3-AEXSM scenarios. On a temporal basis, yield decreases are anticipated to be higher in 2060s compared to 2030s. The anticipated yield decrease is mainly due to water deficit and high night temperatures during critical phonological stages of the crops.

Independently of the climate scenarios considered, the average minimum temperature during Emergence to Stalk elongation is estimated at 27.5^{0}C compared to an average of 23^{0}C during the reference period. Average temperatures will be closer to the highest threshold of the optimum temperature for sugarcane estimated at about 30^{0}C (FAO, 2014a). This anticipated increase in night temperatures is also detrimental to tomatoes growth and yield. The optimal night temperature for tomatoes is between 10 and 20^{0}C (FAO, 2014b).

Unlike the anticipated decrease in yields of sugarcane obtained in this report, Marin et al. (2013) and Knox et al (2010) found a positive yield response of sugarcane mainly due to the CO2-fertilisation effect with an increase in WUE (Water Use Efficiency).

Unlike sugarcane and tomatoes, there are no clear trends of the potential impacts of climate change on cassava productivity. As shown in Table 35, a decrease in yield of cassava is projected with the ECHAM-climate scenarios while a slight increase is anticipated when considering the HadCM3-AEXSM climate scenarios. These findings are similar to those found Jarvis et al. (2012) for the 2030 horizon.

As tomato growth and yield are very sensitive to optimal night temperatures (Sato et al. 2000), the anticipated increase in minimum temperatures are likely to negatively impact this crop. As indicated in Table 36, this decrease in tomato yield could be as high as 60% under the HadCM3-AEXSM climate scenarios.

Further investigations based on experimental data are needed in order to better explain the main factors that contribute to these anticipated yield changes. Moreover, no CO_2 effect has been considered during the simulation exercises. When using experimental data, this aspect can provide important insights on the anticipated impacts of climate change on crop growth and yield.

Due to the type of the data used to calibrate and validate the crop models, these anticipated yield changes should be taken as indicative rather than absolute values. It is also important to note that no adjustments were considered during the simulation exercise. From this perspective, it would be very helpful to carry out and collect reliable experimental data that will allow a better evaluation of the models and consequently more realistic projections of climate change impacts on crop productivity likely to better inform any process of identification of more suitable and sustainable management practices.

However, as seen earlier, these yield changes for tomatoes, in particular, could be reversed by choosing better varieties, but using more inputs such as irrigation and fertilizers, by controlling diseases and by making greater use of greenhouses, although these adaptation measures may increase the costs of production.

Furthermore, the yield changes for sugarcane are validated by other similar studies in the region (Singh and El Maayar, 1998; Meyer et al., 2011). The optimal temperature for sugarcane production in Barbados is ~ 30.0 ^{0}C. But in the future (2060-2069) temperatures are expected to rise to ~ 1.0 ^{0}C (2030s) and to ~ 2.0 ^{0}C (2060s) At higher temperatures reversion of sucrose into fructose and glucose may occur besides enhancement of photorespiration thus leading to less accumulation of sugars (Ramirez et al. 2013).

Table 34: Changes (%) in Sugarcane Yields for the 2030s (2030-2040) and 2060s (2060-2070) according to the HadCM3/AEXSM and ECHAM 5 downscaled climate models

Climate scenarios	**Change (%)**	
	2030s	**2060s**
AEXSM	-15	-34.28
ECHAM5	-3.73	-14.90

Table 35: Changes (%) in Cassava Yields for the 2030s (2030-2040) and 2060s (2060-2070) according to the HadCM3/AEXSM and ECHAM 5 downscaled climate models

Climate scenarios	Change (%)	
	2030s	2060s
AEXSM	4.82	0.28
ECHAM5	-1.57	-8.99

Table 36: Changes (%) in Tomato Yields for the 2030s (2030-2040) and 2060s (2060-2070) according to the HadCM3/AEXSM and ECHAM 5 downscaled climate models

Climate scenarios	Change (%)	
	2030s	2060s
AEXSM	-17.68	-59.91
ECHAM5	-13.37	-29.76

4.7 Potential impacts on climate change on livestock (poultry and cattle) in Barbados

The livestock industry in Barbados, notably poultry, beef cattle and dairy sub-sectors, is likely to be negatively impacted by the anticipated climate conditions. These impacts could be direct and/or indirect. The direct impacts will be triggered by the exposure of chicken, beef cattle and dairy cows to adverse climate conditions. Indeed, the anticipated high temperatures along with high humidity under both climate scenarios could have the following negative impacts on poultry: a reduced feed intake, reduced fertility levels, and increased mortality. For the beef cattle and dairy cow subsector, the negative impacts resulting from the aforementioned climate conditions could be: reduced feed intake, increase in body temperature, increase grazing time, increased sweating and panting, and weight loss. To account for the combined effects of heat stress and high humidity on dairy cow performance, an index based on temperature and relative humidity, commonly known as the Temperature-Humidity Index (THI) has been developed. Two common climate variables, namely air temperature and relative humidity, are used in the following equation which is used to calculate the THI:

THI= (Dry bulb temperature ^{o}C) + (0.36 x dew point temperature ^{o}C) + 41.2

The following figures (Figure 50 and Figure 51) present the values of THI for the reference period, 2030s and 2060s using both the ECHAM and HadCM3-AEXSM climate scenarios. As indicated the values of THI will be greater in the future with detrimental effects on livestock (Dairy Australia, 2014):

- When the THI exceeds 72, cows are likely to begin experiencing heat stress and their in-calf rates will be affected.
- When the THI exceeds 78, cow’s milk production is seriously affected.

- When the THI rises above 82, very significant losses in milk production are likely, cows show signs of severe stress and may ultimately die.

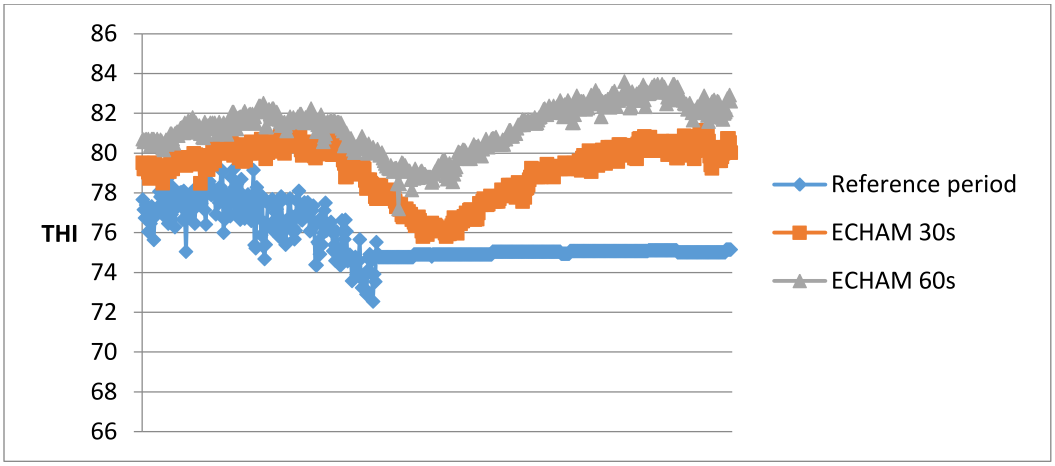


Figure 50: Temperature-Humidity Index (THI) for the Reference period and the 2030s and 2040s according to the ECHAM5 climate scenario.

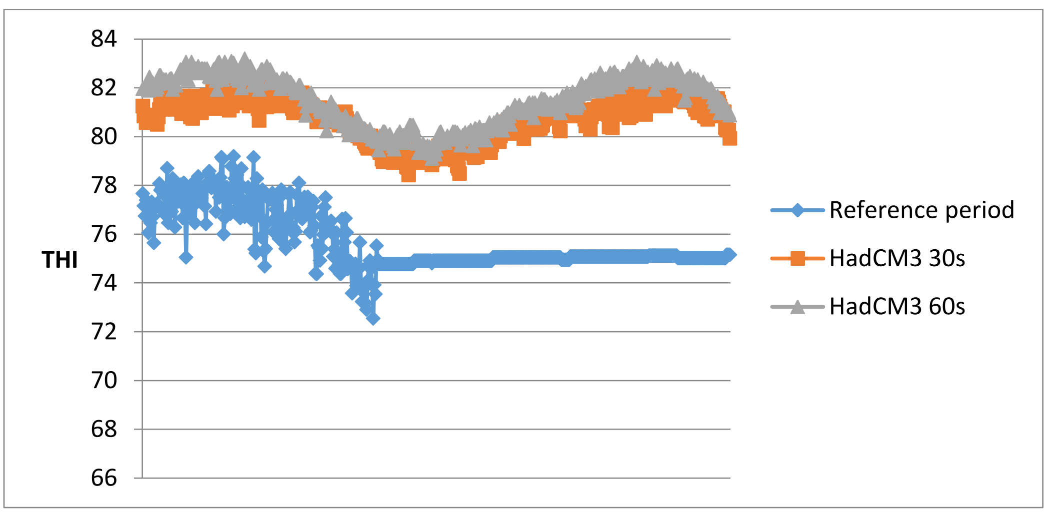


Figure 51: Temperature-Humidity Index (THI) for the Reference period and the 2030s and 2040s according to the HadCM3/AEXSM climate scenario.

5 Assessment of Social Capitals and Vulnerability: perception and decision making surveys

In this section, an assessment of the Social Capital Vulnerability of the agriculture sector of the Food Zone of Barbados to different time scales of climate and climate change, is assessed by considering the physical, economic, social and ecological trends and conditioning factors that are cross-linked with other relevant sectors such as water resources, tourism.

The overall objective of this section of the study is to conduct a vulnerability and capacity assessment of Barbados' agriculture sector to global change. We use term *global change* to characterize these dual forces which are rooted in macroeconomic and global environmental processes such as climate variability and change and socio-economic stressors. To this end, the survey conducted with farmers including various stakeholders was intended to gather information on farmers' livelihood strategies, social networks, sensitivity food and exposure, water scarcity, climate change perception, evidences of climatic and non-climatic impacts, such as praedial larceny, in order to see the pattern of socio-economic vulnerability of agriculture in the Food Zone of Barbados.

5.1 Survey Objectives and Methodology

The targeted territory for this study is the Food Zone located in the Parishes of Saint Michael and Saint George. Data collection was undertaken through a series of interviews conducted with various stakeholders in involved in the agriculture sector. A total of thirty two (32) structured interviews (see Appendix-2) were conducted using the snowball method (Bradshaw and Stratford, 2000; Gumuchian and Marois, 2000; Valentine, 2005), and which included twenty (20) practicing farmers. Each interview was one-on-one and lasted between 45 and 60 minutes. The criteria for selecting respondents were guided primarily by the sectoral distribution of production in order to have a reasonable representation of the diversity of agricultural sectors present in the food zone. Every attempt was made to obtain a broad cross-section as possible of farmers of different profiles (Table 37).

Table 37: Profiles of Respondents who participated in Survey

Farmer's (production sector)	Other stakeholders
Sugarcane Livestock and poultry Fishery Vegetable Dairy Cassava, tomato, lettuce Cucumber, Pumpkin, Melon Beans, okra, pepper Thyme, Hay	Ministry of agriculture • Market division • Soil conservation Unit • Plant pathology West Indies Central Sugarcane breeding research centre Barbados Agricultural Development Management Company (BADMC) Barbados Agricultural Society (BAS) Food and Agriculture Organization (FAO) Ministry of environment and drainage Barbados Agricultural Management Company (BAMC)
Total number: 20	Total number: 12

According to the IPCC (2001; 2007; 2014) the major components that contribute to vulnerability, in this case the agriculture sector are shown below (Table 38)

Table 38: Major components that contribute to vulnerability

Major component	**Vulnerability**
Exposure	Natural disasters and climate variability
Adaptive capacity	Socio demographic profile, livelihood strategies Social network
Sensitivity	Food, water and related systems

Adapted from IPCC 2001

5.2 Data Processing and Analysis

The data processing was done using the Expert Choice software (under license from the University of Montreal), a decision making software that is based on multicriteria decision making such as the Analytic Hierarchy Process (AHP). Descriptive analyses were then carried out in Microsoft Excel.

5.3 Socioeconomic Vulnerability Assessment: Mapping Decision Making Processes and Cross-cutting Issues and Responsibilities

In order to understand the level of social networks, the study assessed the extent of help provided and received by farmers in the past. The main areas of help given or received are related to activities such as land preparation, planting crop, harvesting, fishing equipment and loans. For the food zone, the ratio for the average help received to average help given is 1:1.15. This means that these farmers receive 1.15 help for every 1.0 help that they provides. Therefore the farmers are help recipients in the Food Zone. As a result, this indicates that they need more help to address the combined effects of climate change and socio-economic factors. As a source of income, only 35% reported to depend solely on agriculture as the primary source of income of their household. However, this does not mean that the source of income of these households is minimal as agriculture is a vast sector by itself and it can generate other sources of income (CARICOM Secretariat (2005).

Furthermore, the assessment of sensitivity or the degree to which the Food Zone is affected by exposure is described in terms of means of agricultural production and conflicts over the use of water. Based on statistics obtained from our field interviews, 54% of farmers interviewed reported to that they practice agriculture to produce cash crops for earning a livelihood, whereas, 33% of respondents expressed that they practise agriculture to obtain food crop. However, this result should be taken sparingly since the term « food crop » is somewhat ambiguous and cannot be necessarily differentiated from « cash crop ».

In order to resolve this issue, we calculate the crop diversity index to assess the degree of vulnerability of farmers' households to climate change and related shocks (UNDP and RSPN, 2012). The crop diversity index is a function of the number of crops grown by a household +1. The lower the index in the range of 0 to 1 means that more food varieties or diversity exist. It is assumed that better crop diversity enable farmers to be less sensitive to climate change related shocks. From our survey we have recorded 23 farming crops, although this is not exhaustive. Therefore, the Barbadian Food Zone level crop diversity is estimated at 0.04. This diversity crop index assumes that farmers in the Food Zone are less sensitive to climate change related shocks despite the fact that 60% of respondents reported to rely only on rain fed agriculture as a means of water supply for their farms (Table 39).

The wide use of machineries is another feature of Barbadian agriculture. In the Food Zone, 72% of surveyed farmers reported to use farm machinery in their farming operations (Table 5.3). The use of farm machineries to some extent has been found to reduce the harmful effect of temperature increase and other adverse effects associated with climate change and variability (Ernest et al. 2010).

The assessment of water sensitivity is done by looking at the proportion of farmers facing conflicts over the use of water in their community for agriculture and other domestic and economic uses. Overall 46% of farmers reported to encounter water conflicts sometimes, while 15% reported that they rarely face such conflicts (Table 39).

Table 39: Sensitivity exposure of agriculture in the Food Zone

Conflicts over the use of water (% of farmers)		Use of machinery (% of farmers)		Means of Water Supply (% of farmers)	
Never	14%	Yes	72%	Rain-fed	Irrigation
Rarely	25%	No	22%	60%	40%
Sometimes	46%	More or less	6%		
Often	7%	Other	0%		
Always	0%				
Other	7%				

The occurrence of major climate related disasters that are reported in the Food Zone include drought which is reported by 64% of respondents to be the most experienced climate event, followed by flood (20%), storm (10%) and others (6%). Furthermore, regarding the ability to cope with such extreme events, 65% of farmers believe that their farms are not prepared and ready to face up to these climate events. As a consequence, extreme climate events are likely to have significant damaging impacts on their farming activities (Table 40).

Existing institutional mechanisms to cope with these changes reveals that support from institutions such as the national government and NGOs does not exist, while only 11% of farmers received assistance from insurance companies. The bulk of farmers (44%) received assistance from neighbours and family members and the same proportion of farmers (44%) has not received assistance from anyone (Table 5.4). However, according to Sacramento et al (2010) weak representation of government institution and civil society are among the underlying drivers of vulnerability. Impacts and losses are even higher if there is lack of early warning prevention, as it seems to be the case here.

Table 40: Climate related disaster experienced, likelihood of withstanding disaster and early warning prevention

Most experienced climate events (% of farmers)				Perceived degree to withstand extreme events (% of farmers)		Early warning prevention			Estimated source of assistance received				
Drought	Flood	Storm	Other	Minor damage likely	Significant damage likely	Do receive early warning	receive early	Others	National government	Insurance companies	NGO	Family/ Neighbour	None
64%	20%	10%	6%	35%	65%	59%	35%	6%	0%	11%	0%	44%	44%

The issue of water demand for agricultural purposes is of great importance as water demand for agriculture and other economic activities is increasing while the water resource remains limited (see Table 41).

Table 41: Breakdown of Water Usage (1996) and Projected Water Demands for 2016

Use by Category	**Consumption 1996**			**Demand 2016**	
	m^3/day	**(mgd)***	**%**	**m^3 /day**	**(mgd)**
Domestic(metered & unmetered)	48,681	(10.71)	22.00	51,337	(11.29)
Industrial & Commercial	16,955	(3.73)	7.66	17,460	(3.84)
Hotels & Ships	5,200	(1.14)	2.34	10,821	(2.38)
Agriculture	52,091	(11.46)	23.54	63,545	(13.98)
Golf-course Irrigation	2,458	(0.54)	1.11	14,182	(3.12)
Unaccounted-for-water**	95,973	(21.11)	43.35	30,282	(6.66)
Total Consumption	**221,358**	**(48.69)**	**100.00**	**187,627**	**(41.27)**

Source: Barbados Water Authority (BWA), 1997

* mgd: millions of gallons per day

** Unaccounted-for-water includes leakage, standpipes, illegal connections and wastage.

However, these projections for water demand (Table 41) seem to be based on very optimistic scenarios: most of the reduction in demand (from 21.11 mgd to 6.66 mgd) would derive from unaccounted-for-water includes leakage, standpipes, illegal connections and wastage (Barbados Water Authority, 1997). Indeed, recent data collected from the Barbados Agricultural Development and Marketing Corporation (BADMC) which is the main operator of water for irrigation, show that the percentage of water use for irrigation in the food zone increased from 32% in 2001 to more than 40% in 2014, at the same time the proportion of farmers using irrigation in the area of the Food Zone increased to 43% (BADMC, 2014). If we assume an increase in drought conditions in the future, as the climate scenarios seem to show, combined with an increased water demand for other economic and domestic uses, it is obvious that one of the main threats to agriculture in the Food Zone in terms of vulnerability is access to water both in quantity and quality.

It is therefore imperative to conduct studies to generate quality data and information that will help to increase knowledge and understanding of the situation of water resources in Barbados. It is particularly necessary that the study solicits views and observations of farmers and other stakeholders in agriculture on the severity and trend of some key events of importance to the sector. In our investigation, drought is considered to be the most increasing climate related threat to agriculture (21%), whereas theft is reported to be the most increasing non-climate related threat affecting agriculture in the Food Zone (Table 42).

Table 42: Severity of climate related events and perceived trend of threats to agriculture in the last 10 years by percentage of respondents.

Perceived trend of threats directly or indirectly related to climate change					**Perceived severity of climate related events (% of respondents)**			**Praedial larceny is:**		
	Drought	Flood	Storm	Theft	Low	Medium	High	A major problem	A minor problem	Not a problem
Increasing	21%	7%	4%	23%						
Decreasing	0%	3%	4%	1%	29%	45%	25%	65%	18%	18%
Same	5%	14%	15%	3%						

Furthermore, praedial larceny is cited as one of the major challenges impacting the growth of the agricultural sector in Barbados, including the Food Zone. Over the years, praedial larceny has evolved from petty theft of agricultural products, to real organized crime. Often, it is an entire harvest that is vandalized. Praedial larceny has thus become a whole industry of crime that further accentuates the vulnerability of agriculture in Barbados. In fact, it constitutes a loss of livelihood and income to farmers and those losses threaten the viability and profitability of farming enterprises. It also hinders the development of the sector as the farming community becomes discouraged on account of economic losses. As such, praedial larceny is considered as major problem that could increase vulnerability and compromise the viability of agriculture if appropriate measures are not taken to contain it (Table 42).

5.4 Assessment of the Determinants of Adaptive Capacity of Agriculture in the Food Zone

Our study also focused on the assessment of the determinants of adaptive capacity of agriculture in the Food Zone to climate change and socio-economic stressors. In fact, there is a convergence on the effectiveness and efficiency of policy interventions in order to improve communities' ability to adapt to changing conditions (their "adaptive capacity"). As such, there is urgency to find ways and means to increase the adaptive capacity of these communities, and to learn more about how this can be done (Adger et al, 2007). From this perspective, a detailed literature review regarding the socio-economic context of the Food Zone of Barbados has identified factors/criteria that may influence the adaptive capacity of agriculture (Appendix 2, Table 3). Then, we use a bottom-up approach through a questionnaire-based survey (Appendix 2), to identify relevant determinants of adaptive capacity for the actors involved in agriculture in the Food Zone.

The survey focused on the identification of the key determinants of adaptive capacity to climate and socio-economic stressors in the past decade, considered as reference period (2004-2014). However, the reference period depended on the kind of question put forward. The World Bank (2014) recommends the use of an approach that combines both quantitative and qualitative tools like a multi criteria analysis (MCA) in prioritizing adaptation measures. Thus, an Analytic Hierarchy Process (AHP), which is a multicriteria analysis technique, is used to prioritize the determinants of adaptive capacity. AHP is one of the more recognized methods of multi-criteria decision making. It aims to refine a decision making process by examining the coherence and consistency of the decision maker preferences. It is a qualitative technique that is based on the judgment, knowledge and experience of stakeholders to prioritize valuable information for many purposes, including improved decision making (Saaty, 1984). It is systematic, flexible and simple, and it is frequently used by researchers and practitioners to compare several objectives or alternatives.

The hierarchical analysis consisted of two levels: the first level corresponded to the purpose of the analysis, (in the framework of this study, it was to identify the key determinants of adaptive capacity of agriculture in the Food Zone of Barbados), while the second consisted of criteria (specifically the factors identified in the literature as those that may affect the ability of Barbadian agriculture to adapt to climate change and socioeconomic stressors). These criteria, namely factors that may influence the adaptive capacity are provided in Appendix 2, Table3.

Based on the rating scale (Appendix-2, Table 1), a pairwise comparison of these nine criteria (Appendix-2, Table 2) is made by farmers from a wide range of production sectors as well as by other stakeholders involved in agriculture either as support (Ministries or other public and international agencies) or as research centers, or as NGOs.

The result of this process of multi-criteria analysis is the establishment of a priority (order) on the basis of a weight allocation to the different criteria (Appendix-3). Figure 52 shows the results in order of priority or importance for the nine determinants of adaptive capacity. The x- axis represents the main determinants of adaptive capacity of agriculture in the Food Zone of Barbados, while the y-axis represents the weighting values issued (the weighted value of each determinant of adaptive capacity is placed at the top of each bar/determinant) (Figure 52). The inconsistency value (an indicator providing information on the level of consistency of judgements) is 0.0154. This average value is below the threshold of acceptability of 0.10 recommended by the AHP. This indicates that the judgments were consistent regarding priority or importance of the key determinants of adaptive capacity.

These results indicate that, for the key stakeholders involved in agriculture in the Food Zone, the crucial determinants of adaptive capacity in order of priority are: Financial resources, Market conditions, policies and programs. Thus, financial resources, market conditions and policies and programs rank first among the determinants of adaptive capacity of the agricultural sector of the Food Zone. This means that for farmers and other stakeholders, agriculture in the Food Zone of Barbados, potential damages associated with climate change (including socio economic stressors) can be alleviated by taking advantage of opportunities arising from such events/criteria by adopting an approach that will further take into account these three determinants of adaptive capacity (financial resources, market conditions and policies and programs).

On the other hand, despite the fact that a large majority (90 per cent of respondents) had estimated that recent fluctuations in weather had affected agriculture in the Food Zone (Table 5.6), they do not seem to consider the changing weather conditions as an obstacle that could impede a better adaptation of agriculture to climate change. This probably justifies the low weight given to adverse weather conditions (Figure 52).

When the results of this multi criteria analysis are compared separately by category of respondents, i.e. the farmers on the one hand and stakeholders on the other, we notice some consistency in the results regarding the weights accorded to the various criteria. Thus, adaptive capacity priorities remain the same (financial resources, market conditions and policies and programs) both for the farmers and stakeholders. Only the order of weighted values varies. Thus, for farmers, financial resources represented the main determinant of their ability to adapt. They are prioritized far ahead of the market conditions and policies and programs, respectively (Figure

53 and Figure 54). In all cases, the inconsistency value is less than 0.1, thereby denoting a high degree of consistency.

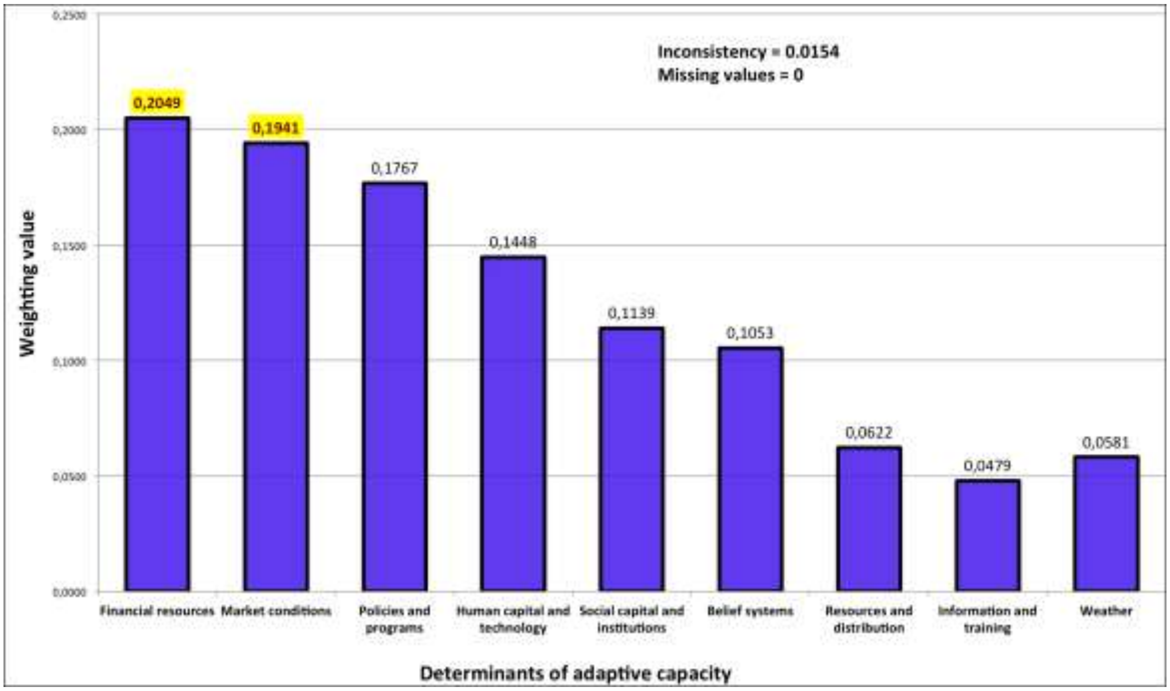


Figure 52: Key determinants of adaptive capacity of agriculture in the Food Zone of Barbados and their relative weighting value during the reference period 2004-2014

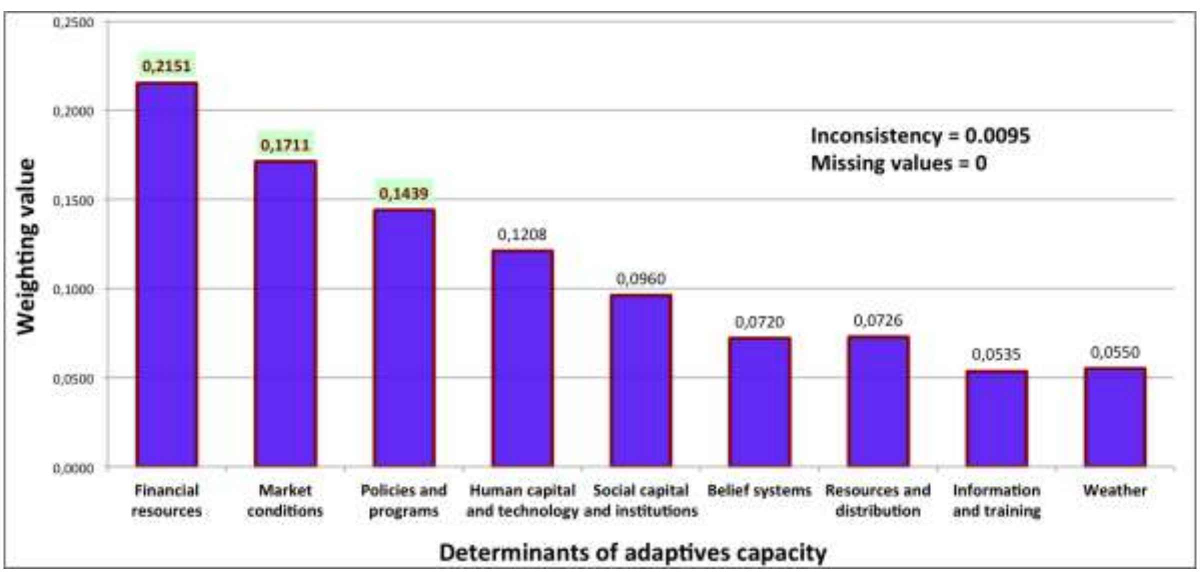


Figure 53: Key determinants of adaptive capacity of agriculture in the Food Zone of Barbados and their weighting value in the food zone for farmers during the reference period, 2004-2014

On the other hand, stakeholders see market conditions and policies and programs to be the major determinants of adaptive capacity of agriculture in the Food Zone of Barbados, followed by financial resources. They consider that policies and programs as well as market conditions are intrinsically linked to the extent that policies influence market conditions (Figure 54).

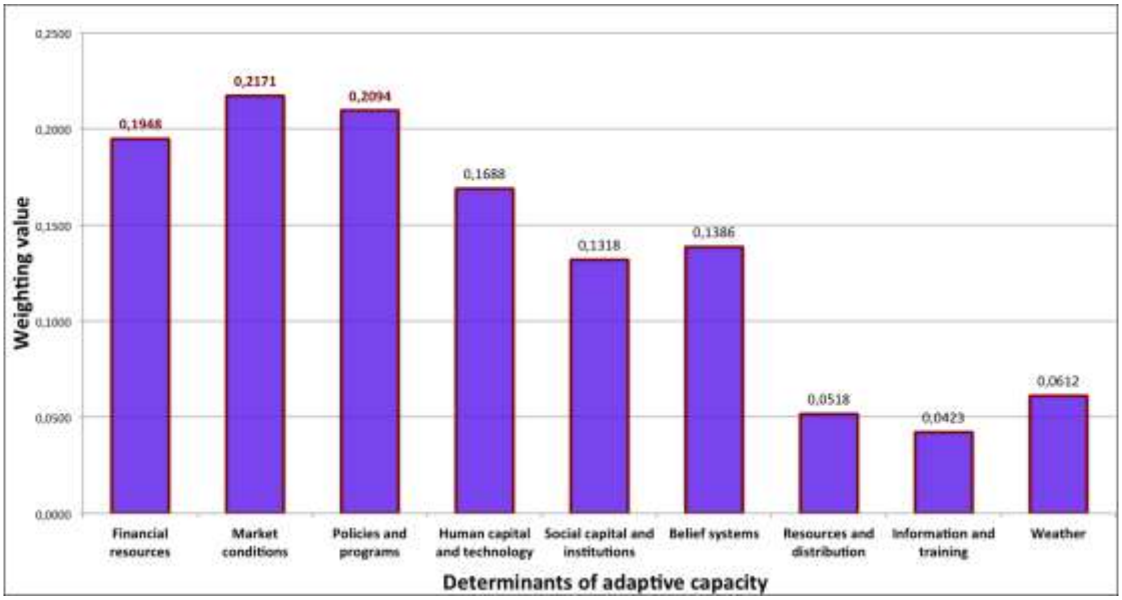


Figure 54: Key determinants of adaptive capacity of agriculture in the Food Zone of Barbados and their weighting value in the food zone for stakeholders during the reference period, 2004-2014

Economic assets such as financial resources, capital means, wealth, or poverty of a nation, or a group, such as is the case here, have been found to be determinants of adaptive capacity (Burton *et al.*, 1998; Kates, 2000). Wealthy nations, groups or communities are widely recognized as being better prepared to bear the costs associated with climate change and risks than poorer peoples and countries (Goklany, 1995; Burton, 1996). In fact, some authors find a direct link between poverty and vulnerability (Chan and Parker, 1996; Fankhauser and Tol, 1997; Rayner and Malone, 1998).

In this case, the prominence of economic and financial considerations as key determinants of adaptive capacity of agriculture in the Food Zone of Barbados responds more to the need to enhance financial strength to cope with multiple challenges, including access to efficient technologies that could improve crop yields, reduce production costs and enhance the competitiveness of local agricultural businesses. Other studies conducted in comparable circumstances derived similar results. For example, Délusca (2010) found that market conditions, financial resources, as well as the policies and programs were the most important determinants of adaptive capacity of agriculture in the municipality of Sainte-Martine in Quebec, Canada.

5.5 Projected socioeconomic impacts of climate change on agriculture in the Food Zone

Moreover, in the event of projected changes in climate variables in the next 20 to 40 years (i.e., an increase in temperature and a decrease in rainfall), a large majority of respondents (58%) believe that farmers will try to apply new production techniques, or they may switch to part-time farming, while only 8% of respondents believe that farmers will abandon agriculture (Table 43).

Table 43: Projected adaptation measures and decision making in the face of climate change

Potential responses in case of increase in climate variables in the next 20 to 40 years (increased temperature & decreased rainfall)				People's consideration towards agriculture in the Food Zone			Feeling about being farmer today	
Quit farming	Trying to apply new production techniques	Switch to part time farming	Other	High esteem	Moderate esteem	Low esteem	Proud	Frustrated
8%	58%	31%	3%	18%	18%	65%	70%	30%

Adverse weather conditions do not seem to discourage farmers in their vocation and their commitment to agriculture in the Food Zone. As a result, adverse climate conditions therefore are not an obstacle to the adaptation of agriculture to climate change. Despite the fact that a fairly high percentage (65 %) of people holds agriculture in low esteem, a large majority of respondents (70%) considered themselves to feel proud to be a farmer today. This finding is very positive from the perspective of future adaptation of agriculture to multiple stressors, including climate change, as it has a positive influence on their ability to adapt, especially since almost all respondents believed in the reality climate change (Table 44).

Table 44: Perception of respondents of the Food Zone towards climate change

Believing Climate Change is real	Do not believe in Climate Change	Weather fluctuations have impacts on agriculture	No impact of weather fluctuations on agriculture
90%	10%	90%	10%

The significance of financial resources, market conditions and policies as key determinants of adaptive capacity of agriculture in the Food Zone of Barbados is also justified by macroeconomic changes that have occurred in agriculture over the past 20 years that is reflected, according to the respondents, by lack of Government support and also by competition from imported food (Figure 55).

A careful analysis of these results shows that it is not so much the lack of support from the Government that is criticized by respondents. Indeed, according to the Ministry of the Environment, Water resources and Drainage (2010), the Government of Barbados has provided in the past some packages of incentives to the agricultural sector in order to stimulate local food production. These government interventions were probably positive because, given the results in Figure 5.1, criteria such as « human capital and technology » and « information and training » are not considered as being of primary importance in the context of enhancing the adaptive capacity of agriculture to multiple stressors in the Food Zone of Barbados. Probably, because these are already a fact on the ground, indicating that incentives such as provision of grants, concessions, and rebates on agricultural machinery and other equipment to farmers appear to have reaped some success, as growth has been experienced for most commodities notably by encouraging involvement in new technologies and processes. For instance, only a few respondents are questioning the lack of support from the Government (Figure 55).

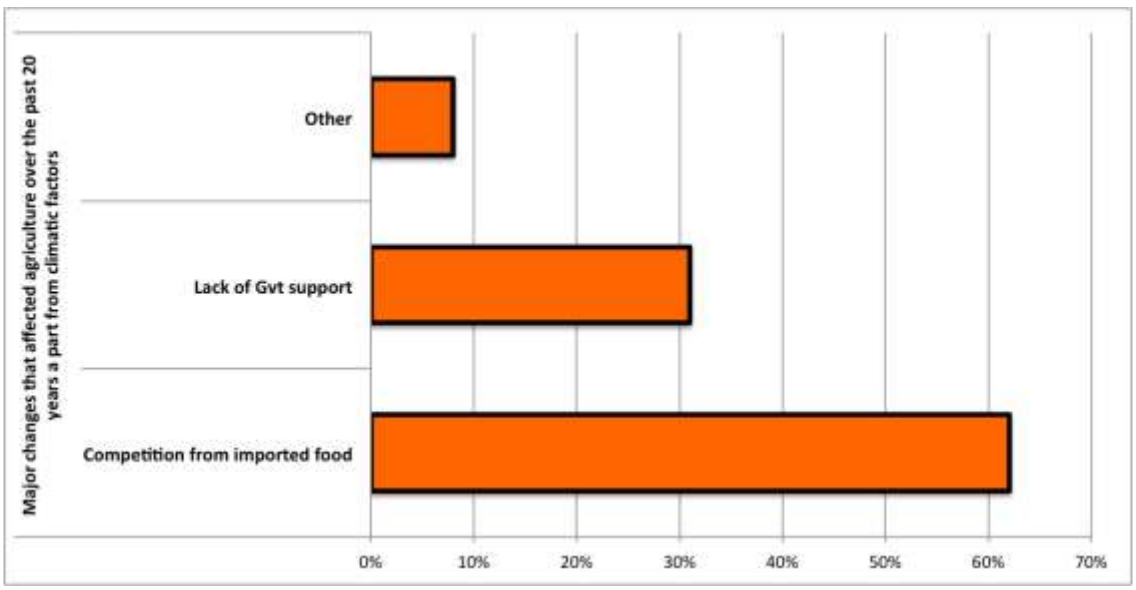


Figure 55: Major changes that have affected agriculture over the past 20 years in the Food Zone of Barbados

5.6 Conclusion and Recommendations

The most plausible interpretation of these results is probably the effective implementation of existing policies, particularly with regard to legislation to protect markets for primary agricultural products. Indeed, even if the government of Barbados has recognised the vulnerability of the agricultural sector especially in relation to new trade arrangements in the face of its contribution to commercial activity and the social and environmental fabric of Barbados (Ministry of Environment, Water Resources and Drainage 2010), the point is that agriculture continues to face competition from imported agricultural products, which explains the country's high dependence on food imports. However, with a high cost of production, local agricultural products cannot compete with imported products. Nevertheless, the overall policy goals for agriculture (CARICOM, 2005) in Barbados include the transformation and repositioning of the sector to increase its contribution to GDP as well as to enhance domestic food security and reduce the food import bill. Instruments such as programmes of income transfers to the farming community, or the provision of targeted incentives to exploit local and export markets are advocated to achieve these objectives.

Furthermore, lowly-ranked criteria such as “social capital and institutions” and “belief systems” illustrate their low performance in strengthening the adaptive capacity of agriculture. For example, although the phenomenon of praedial larceny is known to be a major problem for agriculture as it has experienced a significant increase over the past years, it is not in itself a barrier that can prevent farmers to adapt. Moreover, the respondents believe that the effective implementation of more enforcement legislations could ultimately help stem this phenomenon.

The highly-weighted of criteria such as « financial resources », « market conditions », or « policies and programs » as key determinant of adaptive capacity of agriculture to multiple stressors, sends two signals to decision makers. At first, it shows that although climate change and its potential negative impacts are acknowledged, agriculture in the Food Zone of Barbados is more sensitive to current and future socio-economic stressors rather than climate change, in particular with regard to challenges related to liberalization and globalization. On the other hand, lessons from these results are that the policies to address the vulnerability of agriculture already exist and it only remains to implement them. What is being challenged is the enforcement of these policies. It seems that there is lack of legal authority and institutional capacity needed for the implementation and enforcement of policies such as:

- Establishment of bounded tariff rates for:
    - *All agricultural products except fish and fish products;*
    - *Manufactured goods;*
- Border protection measures for domestic production (agri-food sector, notably for meat, dairy and vegetables);
- Waivers and exemptions for imports of selected inputs and
- Drafting and special safeguard legislation.

For example, through the implementation of the Mauritius Strategy for the implementation of the programme of action for the sustainable development of Small Island Developing States (SIDS), the government of Barbados has adopted various trade policy measures, including the use of a licensing system with the intent to reserve a share of its market for domestic producers (CARICOM, 2005).

Nevertheless, it should be noted that the Government alone cannot solve all the problems. Hence the need to establish partnerships with other actors, including banks and other financial institutions whose financial support (such as credit allocation for agriculture) can contribute significantly to enhance the adaptive capacity of agriculture in the Food Zone of Barbados.

6 Assessment of the Social Construction of Risk and Mapping decision making processes: Cross-cutting issues and responsibilities

This section examines the over-all socio-economic factors as they relate to agriculture in Barbados, bearing in mind the Food Zone located in the Parishes of Saint Michael and Saint George. The analyses also focus on the influence that society, state, corporate, and transnational corporations and policies have on agricultural services and their influence on agricultural policy.

The section also examines the cross linkages between sectors, namely linking agriculture to water resources and availability, tourism and even the coastal zone and cross-linking agriculture to non-climate factors such as the state of the Barbados economy, demographic groups. An assessment is also made of the factors that contribute to vulnerability in the agriculture sector, especially the Food Zone. A brief discussion of adaptation options, in view of present capacity, is also provided.

In the assessment of the socio-economic trends, these are placed in the context of proximate causes, for example, the link between individual behaviour and perception of the agriculture and the political ecology of the agricultural system of Barbados, including the Food Zone. For, instance, an attempt is made to show how international and regional situations or conditions (non-climate factors) can have important influences on the vulnerability of the agriculture sector and the community of the Food Zone, especially in regards SIDS such as Barbados, with small, open economies. It is shown how trade agreements and other world market forces can all have a major impact on the developmental choices that are made as well as influence the markets within Barbados, including the Food Zone.

Furthermore, within the social capitals context, some indicators to test climate sensitivity from a social vulnerability perspective are described for a number of categories: social class, gender, ethnicity and age; technical ability and scientific knowledge and availability of protective measure and insurance protection.

6.1 The context

In 2010, the population of Barbados was estimated around 277,821 peoples. Over the last decade (2000-2010), the population has grown at an average rate of 0.3% (BSS 2010). The population is unequally distributed over the country. For example St. Michael which is the more densely populated parish, the population is estimated at 69,604 whereas in St George it is recorded at 18,203 (BSS, 2010).

The majority of the population, ~ 95% is of African Descent; the remainder consisting of European Descent (2.71%) and persons of mixed (African and European), oriental, east Indian and Middle Eastern (2.3%).

English is the official language, but majority of the population do speak the Bajan dialect which is a form of 'Africanised' English.
The estimated population by Age group and Sex in the year 2010 is given in the following Table (Table 45).

Table 45: Estimated population by age-group and sex 2010

5 Year Age-Group	**Sex**		
	Both sexes	**Males**	**Females**
All Ages	277,821	133,018	144,803
0-4	17,352	8,873	8,479
5-9	18,838	9,683	9,155
10-14	18,567	9,445	9,122
15-19	18,870	9,452	9,418
20-24	18,169	9,061	9,108
25-29	19,088	9,313	9,775
30-34	18,785	9,150	9,635
35-39	20,516	9,884	10,632
40-44	20,113	9,663	10,450
45-49	21,365	10,062	11,303
50-54	20,050	9,411	10,639
55-59	16,653	7,871	8,782
60-64	13,486	6,326	7,160
65-69	10,151	4,511	5,640
70-74	8,680	3,804	4,876
75-79	6,937	2,863	4,074
80-84	5,153	1,986	3,167
85 & over	5,048	1,660	3,388

Source: Barbados Statistical Service (BSS) 2010

The gender distribution reflects a slight female majority 52%, versus 48% for males. At the same time, the age categories comprising the 20 to 50 years old which correspond to the income generating group, notably the age-group most involved in agricultural activities, are actually the largest proportion of the population (49%).

The smaller proportion of younger age group (Table 6.1) denotes a declining population associated with a decreased birth rate that is the result of efforts at family planning and mass education undertaken in the 1950s. This suggests that in the future, as is occurring in developed countries, Barbados, including the Parishes of Saint Michael and Saint George, where the Food Zone is located, will experience an aging population (see Table 6.2), with a relatively small income generating group to support the retired and elderly, which will translate into increased strain on the national insurance and pension scheme.

6.2 The development of macroeconomic trends in Barbados

At the macroeconomic level, Barbados's economy as that of other Small Island States (SIDS) has six common keys characteristics: (1) small population, market and geographical size, (2) limited resource-based, (3) narrowness of output and exports, (4) openness to trade, (5) vulnerability to natural disasters and external economic shock, (6) social homogeneity. Indeed, Barbados is one of the smallest states in the world (431km^2) and one of the highest income non-OECD countries in the UNDP's Human Development Index (HDI). Furthermore, the most recent (2013) estimate of the country's Gross National Income (GNI) per capita was \$13,604. The country has also one of the highest literacy rates (99%) due to significant public investment in education (Moore et al, 2012) and a mean years of schooling of 9.2 years[1] (UNESCO, 2013), (See Table 46).

Table 46: Some socio-economic indicators for Barbados

Surface area (Km2)	Population (2010)	HDI rank (2013)	Life expectancy at birth (2013)		Expected years of schooling (years) (2000-2012)		Mean years of schooling (years)		Expected GNI per capita ($, 2013)	
			Females	Males	Females	Males	Females (2002-2012)	Males (2000-2012)	Females	Males
431	277,821	59	73.8	73.0	17.2	13.8	9.5	9.2	11,165	16,054

Sources: (UNDESA, 2013a); (UNESCO Institute for Statistics 2013); (World Bank, 2014)

The country has experienced the negative effects associated with the recent economic crises which lead to a 3% decrease in the 2010 nominal Gross Domestic Product (GDP) compared to that of 2009. This economic slowdown has exacerbated the country's fiscal imbalance whose deficit was estimated at 8.8% of the GDP for the fiscal year 2010/11 (Moore et al. 2012). Similarly, most of the country's natural resources experienced stress from economic activities mainly because of its relatively small size.

[1] Average number of years of education received by people ages 25 and older, converted from educational attainment levels using official durations of each level

However, the country has experienced some degree of economic development over the past four decades. Indeed, Barbados continues to have the highest Human Development Index of any Caribbean country according to the to UNDP's 2013 report. Given such growth performance, a key issue is what factors have accounted for this economic success despite its small size (in terms of population and surface area), little or no natural resources, and openness to international trade and investment. According to Andrew (2002) and UNDP (2013), the success of Barbados over the four decades is a result of (i) investment in human capital (education and training, health and nutrition), (ii) a well-developed social infrastructure (roads, ports, telephones and telecommunication) (iii) political stability and the rule of law (i.e. good governance), (iv) good social capital (trust and social network) ; (v) sound political and economic management ; (vi) sheer 'economic luck' with respect to the trading arrangement for sugar and the ability of its people to migrate to more developed states and the lack of social disharmony and conflict.

In the coming sections we will examine the contribution of these variables to determine how they affect the vulnerability and adaptive capacity of the Barbados's agricultural sector.

In 2012, four (4) sectors of the economy of Barbados contributed to the bulk of the GDP including finance and business services which is the main contributor ($2,233.1 millions), followed by hotel restaurant ($965.9 millions), government services and transport, storage and communication. Sugar contribution over the same period estimated at $10.8 million remained unchanged whereas the non-sugar agricultural contribution to GDP decreased to record $92.9 million (Ministry of Finance and Economic Affairs, 2012). The balance of payment experienced a decrease mainly because of the influence of the international oil and commodities price combined with a fall-off in the import of consumer goods namely food and beverage, clothing and tobacco as well as machinery imports. As such, at the end of 2012, the external current account experienced a deficit estimated at 4.6% of the GDP. The domestic export had an increase estimated at 11%.

The primary market of Barbados's domestic export continues to be the CARICOM with a market share of 47% or an increase of 16.5% compared to that recorded for 2011. The US and UK are the second and third largest market respectively for Barbados's domestic export. In the same vein, the total import decreased of $30.5 million or 0.9% over the same period. Again, the CARICOM remains the primary supplier and largest trading partner overall, accounting for 37.1% of imports, followed by the USA (30.8%). However, Barbados's import from the USA decreased by 2.9% in 2012 (Ministry of Finance and Economic Affairs, 2012).

As such, the country's economy is highly dependent on foreign market for its main source of income.

6.3 Tourism

Barbados is now considered as a major tourism destination, although the sector experienced an uneven growth. In its process of economic diversification, the Government of Barbados has placed an emphasis on marketing the island beaches and coastal resources through an aggressive advertising and targeting of masses of 'high end' tourists. However tourism's contribution to real GDP has decreased over the past decade from 15.5% in year 2000 to 11.17% in 2013 (see Table 47) (Bank of Barbados 2013). The persistent decline in stay-over and cruise passengers expenditures can be attributed to the continuing global recession (Ministry of Finance and Economic Affairs, 2012).

With regard to its strategy of economic diversification, the Government of Barbados is promoting agro-tourism and eco-tourism as a means of diversifying farm operations, contributing to agricultural stability of the agricultural industry as well as supporting rural communities and businesses. There are five dimension of agro-ecotourism namely (1) agro heritage tourism, (2) farm-based ecotourism; (3) community tourism; (4) health and wellness tourism; (5) culinary tourism. These dimensions are of high importance with regard to VCA analysis as they may provide a means to empower marginalized youth and women in rural and urban areas to earn decent income, as well as allowing visitors to fully experience Barbados' natural assets and promoting the island's heritage like the Barbados Black Belly sheep.

This also points out the need to strengthen the linkages between agriculture and other sectors of the Barbados's economy where tourism not only contributes to a high portion of the GDP, but also accounts for over 70% of the island's foreign exchange earnings. As such, it represents a significant sector with potential for linkages with other sectors particularly in manufacturing and agriculture. In 2012 Barbados attracted more than 536,303 persons to its shores (Ministry of Finance and Economic Affairs, 2012). The characteristic of Barbados as a Caribbean country offer unique opportunities for the linkage of agriculture to both tourism and manufacturing. This aspect should be given consideration since it is a means of strengthening the sectoral adaptive capacity to stressors such as socio-economic and climatic factors.

Table 47: Some sectoral distributions of real GDP (%) of Barbados -1990-2012

Sector	1990	1995	2000	2013
Financial & Business	17.19	17.16	16.8	20.3
Agriculture	5.35	4.29	3.7	3.1
Tourism	14.42	15.19	15.5	11.17
Government general service	13.67	13.18	12.2	16.2

(Source: Bank of Barbados 2013)

6.4 Importance of the agricultural sector for the Barbados economy

The contribution of agricultural sector to the Gross Domestic Product (GDP) have been declining over the past years (Table 48)

Table 48: Trends in the agricultural sector contribution to Barbados's economy

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2012
Share of total GDP (%)	5.7	6.5	5.7	5.3	4.6	5.7	5.3	4.3	4.3	3.9	1.5

Sources: (BES, 2001) ; (UNSD, 2013a)

In 2012, the agricultural sector contribution to GDP is estimated at 5% (Brathwaite, 2013). The sugar and non-sugar agriculture contribution is recorded at $10.5 million (Ministry of Finance and Economic Affairs, 2012). The contribution of sugar reflected an increase of 4%, while for non-sugar agriculture it decreased by 3.8%. This lower contribution is attributed to an improper statistic which did not compute all the backward and forward linkages in the agricultural commodity chains (i.e. the expanded agricultural sector should include input supplies, transport, storage, agribusiness, contribution to export, agro-industry, the food-industry and financial services for agriculture).

However, according to the same Brathwaite (2013), the Barbadian people and decision makers are not convinced by the fact that the agricultural sector can contribute significantly to economic development. In support of this challenging statement, he highlights the general perception that the agricultural sector has many negatives such as:

1. the relationship to slavery and exploitation of labor;
2. uncompetitive and unproductive enterprise e.g. sugar production;
3. low wages and
4. low esteem in a modern society.

These negative perceptions are also justified by the rather small portion of the national budget that is allocated to the Ministry of Agriculture. For example only 1.5% of the Government expenditure is allocated to agriculture in 2012. When compared to other countries of the developing world, this percentage is negligible (e.g. Sub Saharan Africa 6.3%, Asia 6.5%) (Brathwaite, 2013). The agriculture sector continues to be plagued by factors such as adverse weather conditions, labour shortages and low labour productivity, decreased acreage under cultivation, declining yields, larceny and the high cost of inputs (Rawlins, 2003).

As a result, the 2011/12 sugar cane crop experienced a decline in yield of 9.4% compared to 2010/11 crop. Despite this decline, Barbados shipment of raw bulk sugar to the European Union amounted to 23.2 tonnes or an increase of 3.4% over the 2010/11 crop. Foreign exchange earnings from the sale of raw bulk sugar were estimated at $23.6 million or an increase of 1% (Ministry of Finance and Economic Affairs, 2012).

Non-sugar agriculture followed the same trend as sugar production with a decline of 11.9% for the year 2012 compared to 2011, despite an increase in the production of many vegetable crops such as carrot, cabbages, melon and tomatoes. The main reason justifying this reduction in vegetable production is explained by the occurrence of praedial larceny which has become a deterrent for local farmers to engage in vegetable production (Ministry of Finance and Economic Affairs, 2012).

As for the sugar and non-sugar agriculture, the Barbados's cotton production experienced a decline of 14.7% in 2012 as a result of less acreage planted and fewer harvesters for the crop. On the other hand, the credit bank allocation to the agricultural sector decreased by $6.1 million. The sugar cane sub-sector recorded a credit of $8 million (or a decrease of about $1 million from $ 8.9 million recorded in 2011), whereas other agricultural production received $ 6.2 million (a decrease of $4.4 million from $10.6 million recorded in 2011) (Ministry of Finance and Economic Affairs, 2012).

6.5 Sugar sector

Sugar was the largest contributor to the GDP and trade sector in past years. However, with the diversification of the economy, its production and contribution to the GDP fell. In fact, contributions of sugar to GDP fell from 9.2% in 1971 to only 1.9% in 1995. In 2012, sugar production accounted only for 1% of total GDP (Bank of Barbados 2013).

This decline is partly justified by biophysical constraints including a decline in soil fertility, and increase in the frequency of agricultural drought such that it is difficult to make the export quota for international partners such as European Union, or the USA. In addition, the majority of the lands formerly under sugar cultivation were taken out of cultivation during the period of economic diversification and this lead to significant growth of residential areas and other infrastructures. Compounding this is the fact that the sugar's price is no more guaranteed by the European partners. Barbados like most of the Caribbean sugar producing countries would not be operating without preferential access to United States (USA) and European Union (EU) sugar markets that pay two or three times world market prices for imports from quota holders. These preferences have eroded over time as the quantities of import have declined as the EU and USA face internal and external pressure for reform of their sugar programs. Furthermore, Barbados has had its EU quotas reduced and assigned to other countries because it did not meet them. In addition fluctuations in international currencies exchange on which Barbados sugar export is dependent negatively affect the role of sugar production as a support for Barbados's economy.

From the early 1990s, in response to the erosion of preferences in the EU sugar market, the Government's strategic planning within the agricultural sector are based on the restructuring of the sugar industry and the accelerated diversification into other agricultural based activities. These strategies were centered on increasing productivity and efficiency in growing and milling sugarcane, and improving management structure and institutional strengthening such as reorganizing the Ministry of Agriculture, the Rural Development Commission, the Barbados Agricultural Development and Marketing Corporation (BADMC), as well as producers groups and farmers organizations. Also, the strategy focuses on electricity generation and fuel production. As a result, the sugar industry is expected to supply 10% of the country's annual electrical energy requirement.

6.6 Non sugar agriculture

As the production and profitability of sugar is declining, there is an increasing interest and export drive for other agricultural products of greatest export value including cotton, breadfruit, hot peppers, sweet potatoes and cut flowers and foliage. Nevertheless, the country is highly dependent on food imports and is becoming even more, and imported food continues to displace domestic production, which is characterized by high production cost and lack of competitiveness. As a consequence, food security becomes a major concern.

Given the highly open nature of the economy, its heavy dependence on its natural resources to attract visitors, and the linkage between agriculture and other economic sectors such as tourism, Barbados has identified a number of non-trade factors such as food security, farm income and poverty alleviation, rural development, and environmental protection. Also, several products have been identified as sensitive within the agricultural sector in Barbados in term of domestic market. Thus, products such as poultry, eggs, milks, tomatoes, cabbages, pork, lettuces, okras, etc. are of strategic importance and benefited from targeted policies. However, data limitations have proven to be a major challenge to Ministry of Agriculture in the formulation and implementation of policy. As a result, collection and analysis of statistical data relating to agricultural production in Barbados need to be strengthened.

In preparation of its 2002-2012 strategic plan the Ministry of Agriculture undertook a SWOT (Strength Weakness, Opportunity and Threat) analysis for the agricultural sector. The SWOT highlights the challenges and trends of the sector (The Barbados National Agriculture Survey 2007).

The identified strengths of the Barbados agriculture's sector include:

- Strong demand for fresh local produces;
- Ability to collaborate with various local, regional, and international agricultural organizations on research and development projects and for the provision of resources;

- Farmers knowledgeable in production techniques;
- Well-developed transport network to majors markets;
- Climate favorable for year round production;
- Presence of internationally renowned, superior quality products such as Barbados Black Belly Sheep, Barbados cherry, or West Indian Sea Island cotton;
- Well-developed institutional infrastructure for R & D and support service;
- Demonstrated capability to manage harmful pest diseases;
- Experience in agricultural production especially with plantation;

The identified weaknesses of the agriculture sector on the other hand include:

- High cost of production due to costly inputs, leading to relatively high prices;
- Generally low productivity in main sub-sectors;
- Lack of accurate and reliable information for decision making and planning at all levels;
- Weak farmers' organisations and lack of coordination among farmers;
- Inconsistency in quality and supply of produce;
- Seasonality of production which leads to wide price and income fluctuations for farmers;
- Inadequate post-harvest handling and processing systems/mechanisms;
- Marketing systems are underdeveloped, i.e. farmers have limited capability in effective marketing of produce; low number of farmers' markets with weak infrastructure;
- Small size of average farm precludes exploitation of economies of scale in most instances;
- Limited value added capability given insufficient infrastructure for processing;
- General aversion to basic agricultural work;
- Loss of arable lands to more lucrative non- agricultural activities;
- Competition for limited resources (physical, technical, financial);
- Absence of a cohesive regional fisheries agreement.

However, the SWOT identified several opportunities for the agriculture sector, including:

- Initiatives such as the Agribusiness Desk and a revamped R&D programme enable farmers to become more efficient and business like, leading to enhanced competitiveness and sustainability in the agriculture sector;
- Linkages with other sectors, other agricultural organisations highlight the critical role of the agriculture sector in the overall economy;
- Strong niche market potential for commodities like Sea - Island cotton, Barbados Black Belly Sheep, Barbados cherry and value added products;
- Significant amount of idle, arable land can be brought into production, through initiatives such as the 'Land for Landless Programme';
- Enhanced contribution towards domestic consumption and possibility for decreases in foreign exchange outflows and the food import bill;

- Knowledge base on island can be harnessed, exploited for improved productivity and reduced costs;
- Ability, under international trading arrangements, to capitalize on Special and Differential Treatment provisions, such as technical assistance from developed countries, for the modernization of the sector;
- Opportunities for increased exports through trade liberalization;
- Proximity to markets and existence of regular sea/air transport.

On the other hand, the SWOT identified several threats to the agriculture sector, including:

- Competition from cheap subsidized imports;
- Inadequate legislation to meet export requirements and for the protection of intellectual property and genetic resources;
- Business potential of farming not being capitalized on by farmers;
- Use of TBTs, SPS, to restrict the export of goods of interest to Barbados;
- Increased possibility of the introduction of new and exotic pests and diseases;
- Inherent bias of distributors towards imported products;
- High freight cost;
- Limited capacity to effectively participate in international negotiation bodies such as WTO;
- Environmental degradation.

6.7 Employment and vulnerability

According to the International Labour Organisation (ILO, 2014) the unemployment rate in Barbados is estimated at 11.6% of the population aged 15 years and older for the years 2004 to 2013. Over the same period of time, the vulnerable employment (i.e. percentage of employed people engaged as unpaid family workers and own-account workers) accounted for 14% out of the total employment to population ratio which is estimated at 67.5% (ILO 2014b). According to Brathwaite (2013) employment opportunities in Barbados are constrained by many factors such as:

- Structural adjustment programmes which have reduced the size of the public service;
- New immigration policies in the developed economies which will limit the opportunities for emigration to traditionally developed economies such as the United Kingdom, United States and Canada;
- The absence of protected markets for primary agricultural products in traditional markets;
- New technologies which reduce the need for manual labour and manpower in many industries.

However, the major critical issues are the youth unemployment and the lack of skilled labour. These are of great importance in the future development of the agricultural sector of the Food Zone of Barbados as the current farmers are aging: 29% of the farm holders are over 65 years old (NAS, 2007) (see Table 49 and Figure 56).

Table 49: Number of holders (individuals, household and Partnership holding only) by age-group and sex

Number of Holders (Individual, Household and Partnership Holdings only) by Age Group and Sex

		<25	25- <35	35- <45	45- <55	55- <65	65+
	Age Group	**1**	**2**	**3**	**4**	**5**	**6**
1989	16584	238	1863	3250	3018	3065	5150
2007 - Total	13406	121	884	2044	3118	3125	3848
1989 (%)	100	1	11	20	18	18	31
2007 - Total (%)	100	1	7	15	23	23	29
2007 - Male	8102	86	662	1298	2002	1908	2006
2007 - Female	5304	35	222	746	1116	1217	1842

**37 holders, Sex NS

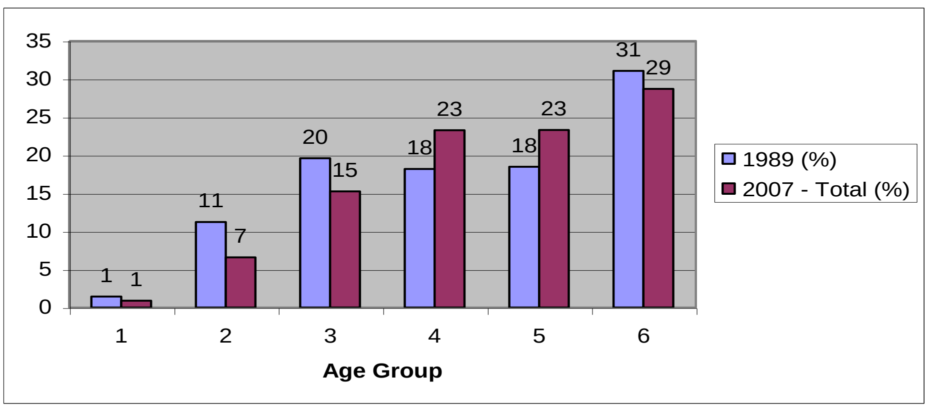


Figure 56: Number of holders (individuals, household and Partnership holding only) by age-group and sex (Source: The Barbados National Agriculture Survey 2007)

In addition, the farmers lack technical and financial resources as well as infrastructures to withstand stressors such as the adverse effects of climate change and variability. For example the trust in food and agriculture implied the need for skilled human resources in different areas of agriculture and food processing such as the production, marketing and consumption, food processing, biotechnology, and agro-energy among others. However, according to FAO (2014), during more than a decade (from 1998 to 2013), the rural population has decreased to -1% of the total population, while over the same period, the labour force in agriculture experienced a decrease of -5% out of the total labour force in the country (FAO, 2014).

Surprisingly, the female representation in agricultural labour force has increased significantly to reach 50% of the labour force in agriculture (Table 50). This may have significant implication in terms of vulnerability and adaptive capacity as women are listed among the most vulnerable group to the effects of climate change and variability. There will also be the need for scientific expertise such as agronomists, plant pathologists, entomologists, soil scientists, food scientists, etc. (Table 51).

Table 50: Evolution of population and labour force composition of Barbados

	Share [%]				Annual growth rate [%]		
	1998	**2003**	**2008**	**2013**	**1998-2003**	**2003-2008**	**2008-2013**
Rural population [% of total population]	63.02	59.78	57.19	54.39	-1.05	-0.88	-1
Labour force in agriculture [% of total labour force]	4.67	3.82	3.01	2.33	-3.94	-4.65	-4.99
Females [% of labour force in agriculture]	42.86	33.33	40.00	50.00	-4.91	3.72	4.56
Source: FAOSTAT, FAO of the UN, Accessed on January 24, 2014. http://faostat.fao.org/site/550/default.aspx#ancor							

Table 51: Population aged 15 years and over who were trained or are being trained as market-oriented skilled agricultural workers (Source: Barbados Statistical Service, 2010)

	Institutional training														
Occupational group	Total	Agriculture college	Barbados community college	BIMAP	Erdiston Teachers' Training College	Hospitality Institute School	National Vocational Training Board	Samuel Jackman Prescod Polytechnic	Teaching School of Nursing	University	Other Institution	On the Job	Private Study	Other Non-Institutional Training	Not Stated
Market oriented skilled agricultural workers	181	6	1	3	1	-	14	68	-	9	19	45	2	2	11

The combination of these factors contributed to the high dependency of the country on imported food thus affecting the economy, the cost of living and the welfare of the population. Data from the Central Bank of Barbados (2013) indicate that inflation climbed from 3.7% in 2009 to 9.4% in 2011. The major components of this increase appear to be the increase in the price of energy and food with potential impacts on the poor and other vulnerable groups of the society. Increases in food prices not only impact negatively on the health and nutrition of the poor, but it contributes to poverty, and increased criminal activities in society. The increase in crime and praedial larceny may be related to limited job opportunities and the high cost of food.

6.8 Praedial Larceny

Praedial larceny, the theft of agriculture produce is widely acknowledged in the Caribbean region as a practice that is negatively impacting the development of the agricultural sector. Agricultural producers (crop, livestock, marine fishers and aqua culturists) suffer heavy losses and are hesitant to invest and expand their enterprise. It is the most extensive among all crimes committed in the Caribbean sub region in terms of the number of persons and families affected. A comprehensive study conducted by the Food and Agriculture Organization (FAO) reveals that 98% of all producers surveyed have experienced loss of produce from theft: more than 332 000 fisher folk families, and well over 1, 000, 000 crops and livestock farm families. Even, the poor and vulnerable farming populations are not spared by the phenomenon. Praedial larceny is considered as a crime that has potentially high, though undetermined, social costs to welfare in farming communities, livelihoods and household food security. A large majority of farmers (i.e. 90%) regionally recognized that it is the single greatest disincentive to investment in the sector (FAO, 2013).

Praedial larceny has moved from the theft of small amounts to large amounts of produce involving in some instances truckloads of bananas, an entire field of pineapples or the harvest of a freshwater fish pond with a determination among the thieves that poses serious dangers to farm families and farm workers. Some aquaculture farmers have abandoned their entire enterprise due to heavy losses and the high cost paid for security. The praedial larceny practice is part of a complex socioeconomic environment encompassing wide ranging group of individuals who have developed a real crime business and industry of agricultural produce, equipment and materials.

Most of the time, the crime enters undetected into the normal process of the legal industry. Domestic fresh food distribution is the area of preferred choice by the offenders. Conservative estimates from FAO (2013) are that 18% of farm value output at the regional level is taken by thieves. As a consequence, millions of dollars (US) are lost each year in the Caribbean region (FAO, 2013). In fact, the impact of praedial larceny in the region is great and has become a major risk to security and sustainability of the gains in primary agricultural activities in member states of CARICOM. The region is losing over US $321 million annually to praedial larceny and it has now become one of the most pervasive and entrenched crimes in business and livelihoods.

Regarding Barbados, despite the lack of reliable statistics on the phenomenon, the scourge of praedial larceny remains a serious and never ending problem whose scope continues to increase exponentially contrary to statistics (Stabroek News, 2013). The journal reported, based on interviews with farmers and activists, that praedial larceny is one of the major, if not the major constraint to agriculture in Barbados. The authorities have legislated on the matter. The Praedial Larceny Prevention Act CAP 142A which was proclaimed in 1992 with the aim of being deterrent to thieves. However the agricultural community and professional stakeholders doubted efficiency of such response. They rely on the fact that judicial decisions are usually unsuitable in terms of the extent of the crime. This is justified by the fact that major players involved in praedial larceny prevention and risk reduction, including the police and judiciary are unaware of the changed nature of praedial larceny from petty crime to the serious offence that it is today. Farmers even think that the police do not treat crimes in the agricultural sector with the same seriousness that they do those in the tourism and business sectors. As a result, farmers have become frustrated with by long delays in the court cases and consequently, they no longer show an interest in reporting incidences. According to Vincent (2011) only an estimated 45% of incidences are reported to the police.

Despite the aforementioned measures including the Praedial Larceny Prevention Act and the proposal to amend it to bring greater enforcement of the law, the challenges remain and it is obvious that agricultural stakeholders may not be able to sustain or improve their operation at the current level of risk associated with praedial larceny and that stronger measures must be taken urgently to prevent or reduce this scourge.

6.9 Policy and Tools for the Agricultural and Food Sectors and Adaptation Strategies

Agricultural policies in Barbados have been articulated within the framework of National Policy. They are mainly directed toward improving exports by promoting and maintaining agricultural production in the country for economic diversification, food security and environmental considerations. As such, the Government of Barbados (GoB) has adopted a global approach including tax concessions and implemented incentives schemes and rebates through various agencies, including the Ministry of Agriculture and Rural Development, the Ministry of Commerce, Consumer Affairs and Business Development, amongst other Ministries and Government agencies.

The specific policy instruments used to achieve these goals include:

- Definition of a green belt for agriculture;
- Development of a programme of income transfers to the farming community;
- Provision of targeted incentives to exploit local and export markets;
- Upgrade technology to attract new investments in non-traditional agriculture;
- Major institutional reforms: Ministry of Agricultural and Rural Development, Barbados Agricultural Development and Marketing Company (BADMC);
- Improvement in quality assurance and standards.

With respect to export facilitation, the GoB has provided agricultural exporters and exporters of food products with various incentives, including export credit schemes.

At the production level, incentives and rebates through the Agricultural Incentives Programme have been introduced to increase production, lower costs of production and improve quality of produce. To enhance the production of value added and niche market products, incentives have been introduced for initiatives such as the creation of an organic market. Such an initiative has been coupled with other incentives for items such as approved farm management computer programs and rebates on the adoption of new technologies with the aim of reducing the overall production cost as well as production of items for which there is a growing demand. Farmers are also being educated about sanitary and phytosanitary measures and Hazard Analysis Critical Control Points (HACCP), and other standards which have an impact on the quality of produce and thus on its exports performance.

Concerning marketing and export promotion, a rebate of 30% up to a maximum of BDS $10,000 has been introduced to defray the cost of international transport and freight for exporters of fresh produce. Exporters can also benefit from a technical assistance fund of BDS $ 25,000 to assist producers and marketers in the conduct of feasibility studies, access new technologies, and implement quality assurance schemes related to the export of fresh agricultural produce. Assistance is also being sought for enhancing Barbados' regulatory system with respect to conduct and certification regarding risk analysis, minimum residue limit, Hazard Analysis and Critical Control Point (HACCP) and international standards organization requirements.

The export market for agricultural products has traditionally been developed for sugar. Despite the declining fortunes of the sugar industry in Barbados, preferential market access arrangements continue to be extremely important and relevant. Without these trade preferences, given the state of the world market for sugar, the sugar industry would have collapsed years ago, with serious consequences for the agricultural sector and the Barbados economy as a whole. Policy measures for the sugar sector from the 2003's medium term strategic and macroeconomic framework highlighted the importance of certain policies (Singh et al. 2005) such as:

- Transformation of the sugar industry to take advantage of value added activities in pharmaceuticals, energy, alcohol, rum, board, wax and sweeteners;
- Continue to meet EU obligations and that of the domestic market by producing 40,000 tonnes of sugar annually;
- Maintain technological and fiscal support to the industry as well as annual assistance to BAMC (Barbados Agricultural Marketing Company) in 'out-of-crop' financing;
- Introduce sugarcane replanting incentive scheme to encourage producers to maintain and return lands to cane cultivation;
- Price support to the independent plantations as an incentive to continue production;
- Continue government support to meet part of the wage bill of independent growers as well as meeting the cost of new diversification activities.

Despite the implementation of these policies, sugar production contribution to the GDP continues to be on a downward slope. This shows the limitations of these policies to meet the stated objectives, probably because of the high dependency of sugar production on preference markets. In fact, many Caribbean sugar producers are not profitable even at current preferential prices and would become even more unprofitable if preference prices eroded as it is the case presently. An alternative may be to shift from a production strategy to a more conservative strategy by converting the sugar lands into pasture lands for sheep and cattle. According to Mitchell (2005), this would require much less intensive farming practices and labor than sugar and it would still provide both environmental protection for the land and attractive vistas for tourists. Sugar production could still be maintained on some lands, but another portion of the lands could be shifted to permanent pasture which could be devoted to grazing of cattle or the Barbados black belly sheep which is well adapted to the island environment and has superior meat qualities that make it very marketable to the large tourist industry or for export. In adopting such a strategy, the GoB could curtail the losses currently incurred in supporting the sugar industry as the cost of maintaining permanent pasture would be small compared to the cost of growing sugar cane. Accordingly, the Government lands actually devoted to sugar production could be leased to local livestock producers in much the same way that government-owned lands in the western United States have been leased to livestock producers. Then, the government lease regulations could limit the number of animals per acre in order to prevent overgrazing. Such lands could be leased on a competitive bid basis or directed to small farmers as part of an income support program (Mitchell, 2005).

With regard to other non-sugar agriculture, the policies are aimed at increasing domestic production for satisfying local market requirements as well as satisfying certain developmental objectives such as employment creation and generating higher levels of farm income. In this perspective, and as stated before, Barbados has employed an import substitution strategy for promoting economic development. To this end, the country has used special differential treatment mechanisms and presenting a new mechanism called 'small developing economies' as a basis for further diversification.

According to Brathwaite (2013), the specific trade policy measures implemented with respect to agriculture include:

- Establishment of bounded tariff rates for:
    - *All agricultural products except fish and fish products*
    - *Manufactured goods*
- Border protection measures for domestic production (agri-food sector, notably for meat, dairy and vegetables);
- Waivers and exemptions for imports of selected inputs and
- Drafting and special safeguard legislation (2002)'

It should be noted that these policies make provisions for appropriate safeguards of certain food products and aerated beverages. For example, poultry are imported only by BADMC, a state run organization.

Adaptation strategies to uncertainties such as climate change or socio-economic development also required capacity building, promotion of best practices and technology transfer. To this end, the GoB has adopted policies aimed at promoting the best practices and modernizing and improving the competitive edge of the agricultural sector of Barbados, including the Food Zone. These policies/strategies are summarizes in Table 52

Table 52: Summary of policies/strategies for technology transfer in the Agriculture Sector of Barbados

Items	Policies/Strategies
Extension services specific to the Commodity	Institutional reforms of MARD[2], BADMC[3], RDC[4] and farmers organizations
Technological Packages	To encourage farmers to invest in proven technology and good agricultural practices. Introduction of new crop technology
Training in Management	To accelerate the programme of improving access to technology and retooling to enhance competitiveness
Training in Marketing	Implementation of a farm attachment mentorship programme for youths
Training in Value Added	Special incentives to be introduced to invest in marketing and processing facilities in the Scotland District
Promotion of Best Practices	To be monitored and accelerated: implement a technical assistance programme

From this review of the tools and policies to support the agricultural sector of Barbados, it is obvious that these are commendable policies to support agriculture in the island. However, from our point of view, the legislation has to be updated and effectively implemented so as to build adaptive capacity of Barbados's agriculture in today's challenges including climate change as well as the global trading regime. To illustrate the need for updating and implementing policies and measures, one must consider that despite all these policies, the food import bill continues to increase (Table 53). Accordingly, Williams (2014) reported that for the professionals of the agricultural sector, the duty-free concession given to agricultural entities are no longer enough as the agricultural input cost has increased significantly. On the other hand, the pressure on scarce agricultural land is increasingly growing; consequently the Government need to step in and take some form of action.

[2] Ministry of Agriculture and Rural Development
[3] Barbados Agricultural Development and Marketing Corporation
[4] Rural Development Commission

Table 53: Evolution of trade values for selected commodities

	Value [Millions of USD]				**Annual growth rate [%]**		
	1996	**2001**	**2006**	**2011**	**1996-2001**	**2001-2006**	**2006-2011**
Total merchandise imports	833.6	1068.6	1629.0	1804.9	5.09	8.8	2.07
Total merchandise exports	280.6	259.3	441.2	475.1	-1.57	11.22	1.49
Food (excluding fish) imports	115.4	131.9	173.2	244.0	2.71	5.6	7.09
Food (excluding fish) exports	86.6	52.6	46.8	43.3	-9.49	-2.31	-1.54
Source: FAOSTAT, FAO of the UN, Accessed on September 18, 2014. http://faostat.fao.org/site/535/default.aspx#ancor							

6.10 Water constraints

Barbados is classified as a water-scarce country as ground water is the main source of potable water on the island. Furthermore, the country depends heavily on imported fossil fuel as 1/5 of the country's import is devoted to energy requirements, a good portion of which is used for pumping and distribution activities in the water sector.

Both ground and surface water are used for agriculture. For instance, the agricultural sector currently utilizes an estimated 6 million gallons of water per day mainly for the irrigation of vegetable crops (Singh, 2005) (Figure 57). According to the current green economy scoping, with exception of sugar cane, most crops in Barbados require some form of irrigation. The country does have a strong policy and institutional commitment to sustainable development. In this respect, the island water policy statement includes development of a code of agricultural practices to address water pollution and conservation measures. Some of these measures consist of restricting water use for non-essential purposes in the dry season, constructing a desalinisation plant to augment supplies as well as developing water resources in the Scotland district.

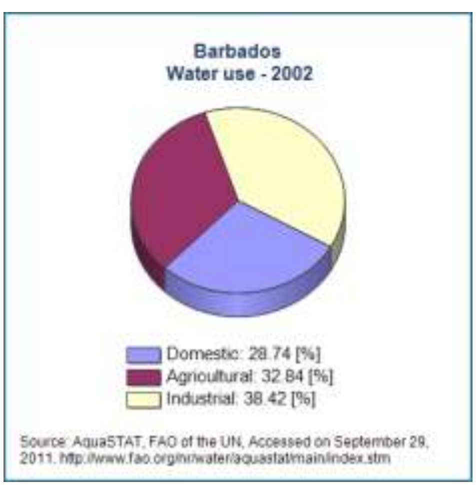


Figure 57: Water use by Sectors in Barbados (2002)

As such, despite the Government supported irrigation projects, irrigated land remains only a very small fraction of the total agricultural land and the area equipped for irrigation on the island, including the Food Zone. Over the past decade, there has been a slight change in land suitable for irrigation, ranging from 36.6% in 2002 to 44.1% in 2012 (FAO, 2014). According to Singh (2005) while improved irrigation systems are being used by farmers (mostly drip irrigation), there is a need to upgrade and expand the efficiency and management of these systems. In addition, most of the techniques and technologies required to support irrigated agriculture and its water efficiency are relatively well-known and freely available. The hurdle is the potential to make a sound economic case to farmers and to diffuse the knowledge and information to the sector as well as to ensure that the relevant support services are at farmer's disposal (Singh, 2005)

Furthermore, freshwater is also being contaminated with salt water and waste water, thereby affecting agricultural land with a resulting effect on productivity. Managing scarce resource such as freshwater in a country like Barbados with increased population pressure, increased water demand due to urbanization and expanding tourism, is a big challenge because of the increasing sectoral competition for water and land resources. This challenge is made more difficult to meet, because of phenomena such as increased climate variability and change with associated frequency of natural disasters, as well as reduced water quality due to pollution from industrial, agricultural and municipal wastes among others. For example according to FAO (2013b), freshwater withdrawals accounts for 108% of the total renewable water resources in Barbados between years 2007 and 2011. Industry and agricultural activities being the most water consuming sector (see Figure 6.2). From this perspective, access to water may be a limiting factor for agriculture in Barbados, including the Food Zone and may increase its vulnerability to climate change. To this end, consideration of issues related to water is crucial in any analysis of the vulnerability of agriculture as well as strengthening the adaptive capacity of farmers involved in production.

6.11 Non-climate Determinants of Adaptive Capacity

A part from climatic variables, non-climatic factors should also be considered in the analysis of agricultural vulnerability and adaptation to climate change and variability. The latter consists mainly of economic, political and social conditions that affect stakeholders' vulnerability and adaptive capacity (Daouda *et al*. 2014). Thus, governmental (or public) policies, market conditions and technological assets are determinants that can exacerbate or reduce climate risks. Some observers even believe that the threat associated with uncertainties posed by climate change and variability is much smaller than those related to changes in technology, competitive markets, trade regulation, or consumers' demands (Burton and Lim 2005).

From this perspective, the analysis of the Barbados's socio-economic context provides an overview of factors that may influence the adaptive capacity of farmers to climate change and socio-economic conditions. These factors will be fully investigated using individual questionnaires and focus groups (Appendix 2). The results will be analyzed using a multi-criteria method to determine the most important determinants of adaptive capacity to climate change and socioeconomic conditions for agricultural stakeholders in Barbados, including the Food Zone. The rationale associated with each determinant will then provide guidance for the development of indicators

6.12 Economic Loss Estimates: impacts and sensitivity

Disasters such as climate change and variability can result in significant economic damage through the immediate loss of assets as well as the longer term impacts on the prices of goods and services. In recent years, both economic and insured losses globally show an increasing trend as a result of population growth and increased levels of property at risk especially in the coastal zone where rising sea levels and storm surges are not only destroying coastal infrastructure such as roads, bridges and buildings, but also causing inundation, erosion and salinization of agricultural lands.

It is expected that the Advisory Committee would be employed to assist in choosing weights to be placed on the policy alternatives, including monetary and non-monetary impacts, such as to the natural environment in which agriculture is practised, in this case the Food Zone of Barbados. Questions that will need to be answered would include: what are the benefits and costs of various adaptation programs over time, and who gains or losses from these adaptation measures.

The CCCCC/VCA methodology (Pulwarty and Hutchinson, 2008) recommends that an estimate of economic losses due to climate change and variability be attempted. One way to assess recovery from an event such as climate change is to lump its economic quantity of interest and compare it to the equivalent value of the period (years) preceding the event.

Among the multiple methods that exist, Economic Loss Potential (ELP) under present and future conditions of populations and property, is a common indicator widely used to benchmark complex proxies for which comprehensive data may not exist (CCCCC, 2008).

ELP = Change in wealth per capita x Inflation factor x Population change

In regards to the Food Zone of Barbados, our survey reveals that drought is the most important disaster resulting from climate change affecting agriculture in the last 10 years. This is also confirmed by Farrell et al (2010), who reveal that the last major climatic event occurring within the Caribbean region in recent years is the drought of 2009-2010. Therefore, 2009 will serve as the baseline year for this exercise.

According to World Population Review (2014), population change in Barbados between 2009 and 2013 is estimated at 2.51 %. Also, according to the IMF (2014a) the variation in GDP per capita in Barbados for the 2009-2013 period is estimated at -7.9 %. Furthermore, the inflation rate in Barbados was recorded at 1.69 % percent in August of 2014 (Trading Economy and Barbados Statistic Service, 2014).

Thus, the ELP of the drought that impacted Barbados in 2009-2010 is calculated as follow:

Barbados ELP for 2014 compared to 2009 = -7.9 x 1.69 x 2.51 = -33.51%

This means that if a drought of similar magnitude as that of 2009-2010 occurred in 2014, its damages may be 33.5 times less than in 2009 in term of economic loss. This is probably due to the fact that since 2009 the economic situation on the island has deteriorated significantly with several macroeconomic indicators flashing red. The observed variation of GDP between 2009 and 2013 (-7.9) has greatly influenced this result. This is confirmed by a recent report by the International Monetary Fund (IMF 2014b). Consequently climatic event has more damaging impact on a healthy economy than depressed economic as is the case currently with Barbados.

7 Development of Integrated Vulnerability Indicators

This section focuses on integrated indicators that would further lead to the development of community risk profiles of the Food Zone and adaptation recommendations that need to be mainstreamed into government policy. These integrated indicators will also provide an improved understanding of the relationship between the physical availability of the resource of concern, namely, food from agriculture, its accessibility, crop production indices, capacity of the agriculture sector and the level of welfare of farmers in the Food Zone.

These integrated indicators are developed from the preceding biophysical and socio-economic scenarios of climate change developed and described in preceding sections. The major biophysical indicators are temperature rise, lesser and more variable rainfall, increasing doughtiness and marginally, sea level rise and storm surges. On the other hand, the major socio-economic indicators include, but not restricted to, financial resources, market conditions, government policies and programs, human capital, technology and access to information and the problem of praedial larceny (Table 54).

The trends and tendencies of the integrated indicators are then linked to ensuing impacts and vulnerabilities and then finally the risks to which farmers in the Food Zone are exposed are summarized in Table 54

Table 54: Integrated Vulnerability Indicators for the Food Zone of Barbados

Biophysical	**Trend/Tendency**	**Impacts/Vulnerabilities**	**Integrated Risks**
1.Air Temperature	-Increasing: max., min. mean	-Agricultural production -Irrigation requirements -Greenhouses	- Reduced yields - Change crops and varieties; - Food security - Cost of production and farm profitability - Discouragement/loos of farmers - Need for energy-cooling of greenhouses and chicken farms - Need for energy-pumps/distribution of irrigation water - Increasing competition for scarcer water supplies - Greater need for Government support: subsidies and insurance schemes -Greater reliance on imported food - Spillover effect on other critical sectors such as tourism
2. Rainfall	-More variable and more intense	-Agricultural Production -Increased Irrigation Requirements	
3.Drought (P-E)	-Increasing and longer dry season	-Variable and non-guaranteed agricultural Production -Increased Irrigation Requirements	
4.Sea Levels and Storm Surges	-Rising sea levels and more intense storm surges	Of little consequence to the Food Zone. But indirect impacts such as salinization of coastal aquifers that are sources of irrigation water	
Socio-Economic	**Trend/Tendency**	**Impacts/Vulnerabilities/ Adaptive Capacity**	**Integrated Risks**
1.Financial Resources	Greater demand	-Modernization and efficiency of agricultural production	-Farmers lacking the necessary access to credits for purchasing machinery, seeds, fertilizers and other inputs for agricultural production - Lack of guaranteed markets for produce and lack of more attractive quotas for sugar - Lack of agro-processing industries - Insufficient involvement of the Ministry of Agricultures and lack of provision of greater and more timely support for farmers -Farming becoming unprofitable if irrigation water costs are too high -Agricultural practices remain traditional and lack of modernization - Farmers lacking information to new technologies, planting methods, control of pests and diseases - Farmers become adverse to taking risks with new technologies, crops and varieties -Lack of control of praedial larceny with subsequent loss of profitability and abandonment of agriculture -Marginalization of vulnerable groups: women and children
2. Market conditions	More difficult	-Competition from imports -Restriction of quotas for sugar	
3. Policies and Programs	Greater need	-Farmers cannot compete with imported food -Use of irrigation increases cost of production	
4.Human Capital, Technology and Access to Information	Greater need	-Farmers not abreast with new technologies, new crops or varieties, cultivation methods, early warning weather systems -	
5.Praedial Larceny	Increasing	-Loss of profitability -Discouragement of farmers to continue to practise agriculture	

However, stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested the following adaptation strategies in response to changing climatic conditions (Table 55):

Table 55: Further adaptation strategies in response to changing climatic conditions: National Consultation Workshop (December 08, 2014)

	Impact area / Component	Impacts and Responses
		Crops /Livestock
	Temperature Rise	1. Introduction of Tolerant / plant varieties / forage varieties 2. Widening of forage nutrition bases 3. Protected agricultural / livestock systems 4. Improved weather forecasting 5. Introduction of mulches 6. Introduction of staggered production systems 7. Temperature control systems for livestock and greenhouses 8. Training of farmers to use climate modification systems 9. Incentives for introduction and improvement of technologies 10. Temperature control / tunnel ventilation systems /houses for crops and livestock 11. Introduction of irrigation /hydroponic systems
	Rainfall: Slight decrease and variability	1. Water harvesting 2. Crop insurance 3. Introduction of protected agriculture systems 4. Prevention off soil erosion 5. Design of appropriate drainage systems 6. Introduction of varieties resistant to diseases and pests 7. Crop forecasting to inform of times of planting, land preparation, spraying etc. 8. Improvement of electronic communication systems 9. Email blast
	Drought	1. Water harvesting 2. Drought tolerant species/ varieties 3. Combinations of mulching with drip irrigation 4. Forecasting 5. Water harvesting
	Governmental Programmes and Insurance	1. Incentives 2. Crop insurance 3. Capacity building and training programmes 4. Development of cooperatives
	Farm Production practices	1. Mulching 2. Shade covers /Protective Agriculture 3. Introduction of mulches 4. Introduction of staggered production systems 5. Introduction of crop and livestock shelter and protection systems 6. Use of tolerant/ adaptive productive varieties 7. Improved farm production practices
	Farm Financial Management	1. Improved record keeping a. Fixed and variable costs b. Yields c. Production Volumes etc.

8 Uncertainty Characterization

Climate variability and change are bringing new and increasing risks and uncertainty about the future. A major challenge for assessing climate risks, opportunities and impacts is the poor or lack of access to and understanding of climate information and climate scenarios. Climate information from meteorological services is often viewed as overly scientific and uncertain, whereas information from local knowledge is not widely appreciated. While uncertainty of the future will always exist, and is recognized and worked with in sectors such as business and insurance, uncertainty in climate information is not well understood and as such people tend to be sceptical about climate science. Yet uncertainty is not a problem to be solved; it can be understood, managed and used to inform decisions and plans. CARE, (2014).

The indicators used and reported in the above all are plagued by some measure or uncertainty. Various IPCC reports (2001; 2007; 2014) all allude to the cascade of uncertainties in vulnerability assessments: uncertainties regarding future world population growth and our dependence on fossil fuels and consequently the level of GHG emissions. Given these gaps in technical knowledge and the inability to provide accurate projections of GHG emissions and radiative forcing upon which global climate models are based, uncertainty becomes a key component in the development of scenarios of alternative futures and consequently climate scenarios. As such, the degree of uncertainty for climate projections remains somewhat hypothetical.

In regards to the socio-economic aspect, our evaluation of adaptive capacity also contains some degree of uncertainty: the questions posed to farmers and stakeholders may not have been clear and this may have solicited subjective and ambiguous responses.

8.1 Development of National and Community-level Risk Profiles of the Food Zone

It is understandable from the foregoing sections that the farming community of the Food Zone would be at risk to climate change and variability well into the future (2030s and 2060s). Furthermore, the adaptive capacity of the farmers of the Food Zone can be considered as generally low. As such strengthening of their adaptive capacity, especially in regards to financial resources, market conditions, government policies and programmes and human capital and technology would go a long way towards alleviating these risks.

Furthermore, the sensitivity and vulnerability assessments carried out in the preceding sections, allows us to develop the vulnerability and capacities profile using the indicators developed and assessed previously (Table 56).

The vulnerability checklist (Table 56), based on the climate scenarios presented and the assessment of adaptive capacity of farmers and stakeholders of the Food Zone also allows us to identify the potential impacts of those events on other cross- cutting sectors, namely water resources and tourism, in particular.

It is our hope that the checklist in Table 56 will also help systematise what is already known about climate change impacts on the agriculture sector of the Food Zone from past experience and how this and additional information can assist planners in the appropriate government ministries and agencies to anticipate problems that might arise in the future as the climate changes.

Finally, it is our expectation that the Advisory Council together with the VCA team of Consultants (CCSI) would then be able, to identify priority areas for adaptation measures in the Food Zone.

Table 56: Sensitivity Matrix: Level of Risk Profiles for the Food Zone

Vulnerable Sector: agriculture and farmers in the Food Zone	**Magnitude of Vulnerability and Rates of Change**	**Persistence and reversibility**	**Likelihood and confidence**	**Distribution of Impacts**	**Potential for adaptation**
-Economic Sector: agriculture - Community at risk Food Zone.	-Temperature rise of ~ 1^{0}C by 2030s and of ~ 2^{0}C by 2036s and of -Generally lower and more variable rainfall -Increasing drought especially in the dry season	-Changes in climate variables are likely to be persistent and irreversible	Overall high confidence and likelihood of occurrence	-Impacts on feasibility and costs of agricultural production -Low adaptive capacity may hinder adaptation -Vulnerable groups (poor, women and children) at risk	-Adaptive Capacity is low and may be insufficient to delay or prevent the adverse impacts of climate change -Cost will likely be high for agriculture in the Food Zone

8.2 Further Mapping Decision-making Processes: Entry Points for Mainstreaming

There is a growing body of literature that discusses the benefits and possibilities of mainstreaming or integrating climate change policies in development plans. Various mechanisms through which development agencies as well as donor and recipient countries can seek to capitalize on the opportunities to mainstream are beginning to emerge (Klein et al., 2007; Mertz et al., 2009). Studies from Fiji and elsewhere, provide examples (and trade-offs) of where synergies can be found in integrating adaptation to climate change into development cooperation activities, notably in the areas of disaster risk reduction, community-based approaches to development, and building adaptive capacity Agrawala and van Aalst (2008).

Other studies also support the need for more rapid integration of adaptation into development planning, to ensure that adaptation is not side-lined, or treated separately from sectoral policies. Although there are synergies and benefits to be derived from the integration of climate change and development policies, care is needed to avoid institutional overlaps, and differences in language and approach— which can give rise to conflict (Schipper and Pelling, 2006; Boyd et al. 2009)

Overall, there appears to be an emerging consensus around the views expressed by that climate change and development strategies should be considered as complementary, and that some elements such as land and water management and urban, peri-urban, and rural planning provide important adaptation, development, and mitigation opportunities. The potential to mainstream climate change adaptation and deliver an integrated approach may be reasonably strong in small islands as Barbados, there appears to be limited capacity to (Nunn et al., 2013; Swart and Raes (2007).

In our assessment of the adaptive capacity of farmers and stakeholders of the Food Zone we were able to gather invaluable insights regarding the issues and challenges that confront the agricultural community of the Food Zone from narratives and particularly, illustrative stories from both technical and non-technical stakeholders in relation to different adaptation options that are already being used to adapt to climate change and variability: use of alternative energies (solar and wind); use of ventilated greenhouses (shade houses) for growing vegetables (ex. Mr. Junior Phillips) and raising chickens (Chickmont Foods).

In the next section we will explore how farmers and stakeholders affected by on-going and future climate change and variability might respond to different scenarios of climate change and adaptation by developing criteria for ongoing effectiveness of adaptation and improvements in adaptive capacity, for instance foster co-production of decision calendars with advisory groups from impacted communities relating to choice of crops and cultivars and planting cycles;
One feasible way for mapping entry points into mainstreaming is to use the phenological stages of a typical crop (Table 57) Jones et al., 2003.

Table 57: Typical phenological stages of most crops

Stages	Phases
Preparatory 1	Idle uncultivated land
Preparatory 2	Germination of seeds
Preparatory 3	Germination to emergence
Phenology 1	Emergence to the end of the juvenile phase
Phenology 2	End of the juvenile phase to initiation of flowering
Phenology 3	Initiation of flowering to the end of leaf development
Phenology 4	End of leaf development to the beginning of grain filling
Phenology 5	Beginning of grain filling to physiological maturity
Phenology 6	Physiological maturity to harvest
Post-Harvest	Marketing, processing, export…

The length of each preparatory and phenological stage, namely growing season will of course depend on the crop type. For instance, taking into account the three crops selected for in-depth study in this report: sugarcane, depending on variety typically takes 12 to 15 months from planting to harvest; cassava, depending on variety, typically takes 10 to 14 months from planting to harvest and tomatoes depending on variety, typically 40 to more than 100 days from transplanting to harvest, with an added 4 to 6 weeks longer from seed to transplanting (Jones et al., 2003).

8.3 Evaluate Scenarios in the context of Mainstreaming

The various components (physical, social, economic, environmental) of the scenarios developed in previous Sections is drawn together (Draft VCA Report) at this stage and will be evaluated by eliciting input from the stakeholder Advisory Council and other stakeholders at the upcoming validation workshop (December 08, 2014).

The data gathered and analyzed thus far essentially forms the baseline, or the situation that will exist in the future taking into account population growth and other socio-economic changes but assuming no policy interventions to reduce vulnerability at this point.

The baseline will therefore provide a reference for assessing the future under new policy interventions. At the Advisory Final Workshop and during the period of Evaluation of the Draft Final Report, it is expected that the Advisory Panel and other stakeholders can determine what policies could be implemented and use the scenarios to assess the impact of those policies.

The economic impacts of the different paths should be considered as well as the uncertainties of future climatic conditions and societal driving forces. One aspect of development that cannot be predicted is the invention of new technologies that may address certain issues and significantly affect the suggested outcome. The Advisory Panel is expected to assess the various scenarios for plausibility, likely development of the scenarios and management of the scenario information, namely archiving and opportunities for updating as physical, environmental and social situations change into the future.

Based on these discussions final scenarios are selected for wider stakeholder dialogue during the evaluation of the Draft Final Report. The narrative used for the scenarios would take the form of critical issues, community or national goals, trends, physical, social and institutional factors that condition or are responsible for the observed trends, projections and alternatives.

The existing knowledge, identified uncertainties and knowledge gaps are to be be developed into a framework for incorporation into existing or planned adaptation programs in agriculture: by working with the stakeholders, one is defining the pathways for implementation that will work in the given situation.

For the final selected scenarios, policy or gaming exercises will be carried out among key stakeholders using key entry points in their decision calendars and criteria for information relevance. The critical question to be asked is: how might we respond individually, institutionally, and in an integrated way to climate change and its biophysical and socio-economic impacts on agriculture on the Food Zone of Barbados.

The development of mainstreaming scenarios is an iterative process and in this integrated assessment should involve relevant stakeholders at key stages. The stakeholder discussions should lead to a preliminary range of adaptations that are then considered further to identify the potential barriers to adaptation and opportunities for effective decision-making.

It is possible to initially identify small adaptation steps that carry the VCA towards a long-term goal, but which allow for new knowledge to be incorporated as it becomes available.

8.4 Specific Recommendations in the context of Mainstreaming

The following is a preliminary and suggestive list of actions and policies (CCSI) with support from current literature (Smit and Skinner, 2002; Bárcena et al. 2013; Ramirez et al. 2013) that can be mainstreamed into GoB plans for addressing climate change vulnerabilities and adaptive capacity for the Food Zone of Barbados:

It is expected that the agricultural sector of the Food Zone of Barbados will be seriously affected by future climate change. This creates the need to carry out adaptations in the sector, industry and markets, in producer strategies and in rural development strategies, with the objective of reducing social and economic costs. Policies focussing on sensitization of the farming community to the risks associated with climate change will therefore be of great benefit. Stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that the addition of communication and information strategies should be given serious consideration and added to this list of adaptation recommendations.

However, stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that:

- Rebates encouraging the use of renewable energy production and technology in farming operations should be promoted in order to offset operations. In particular, there should be assistance with offsetting the cost of using batteries to store energy generated from alternative sources.
- Development of more water catchment areas managed by the Government to assist with storage and distribution of water.
- The use of renewable energy technologies should be encouraged for pumping and distributing water and cooling systems.

Furthermore, adaptation to climate change needs to be seen as an iterative process, where the likely state of the climate will not be at a stable equilibrium, rather an ongoing transient process (Stafford Smith et al. 2011). Therefore adaptation responses need to be viewed and shaped appropriately. At the centre of climate change adaptation efforts are interventions aimed at enhancing adaptive capacity and stimulating adaptive actions. But, stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that:

- Currently farmers do not keep adequate records. Record keeping and sharing by registered farmers should be encouraged so that it can be monitored and used by the MAFFWRM. Records are useful to assist with crop production and livestock quality assessment. Keeping of records becomes vital for purposes of traceability when external trading and selling products are considered and this should be promoted.

Agricultural adaptation options can be grouped according to four main categories that are not mutually exclusive: (1) technological developments, (2) government programs and insurance, (3) farm production practices, and (4) farm financial management:

1. **Technological** adaptations can be developed through research programs undertaken by central, parish and district governments, and through research and development programs of private sector industries. The development of new crop varieties including types, cultivars and hybrids, has the potential to provide crop choices better suited to temperature, moisture and other conditions associated with climate change. This involves the development of plant varieties that are more tolerant to such climatic conditions as heat or drought through

conventional breeding, cloning and genetic engineering. Technological adaptation options have been proposed in crop development, to increase their tolerance to climate change and variability; weather and climate information systems, to provide future seasonal weather forecasts; and resource management to deal with of climate-related risks. Weather predictions over days or weeks have relevance to the timing of operations such as planting, spraying or harvesting. Farmers may use this information with respect to the timing of operations such as planting and harvesting, the choice of production activities such as crop varieties and the type of production, such as irrigation or dry-land agriculture. Resource management adaptation policies such as water management innovations, including more efficient irrigation use, to address the risk of moisture deficiencies and increasing frequency of droughts.

However, stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that these needs to be broken down into separate focus areas such as.

- Climate-smart commercial crops and livestock research needs to be led by government with support from non-governmental agencies;
- A need for increased support for plant protection research and monitoring in relation to pest and disease;
- Sharing of information using the MAFFWRM website and that web based applications be further encouraged. Currently more human resources that are needed to maintain the website should be provided.

2. **Government Programs** involve financial management activities such as the use of use of agricultural support programs and agricultural subsidies. Agricultural subsidy and support programs may include:

- Introduce or change investment in established income stabilization programs to influence farm-level risk management strategies with respect to climate-related income loss;
- Modify subsidy, support and incentive programs to influence farm-level production practices and financial management;
- Change ad hoc compensation and assistance programs to share publicly the risk of farm level income loss associated with disasters and extreme events related to climate change;
- Promote and develop private insurance to reduce climate-related risks to farm-level production, infrastructure and income;
- Introduce resource management programs and develop and implement policies and programs to influence farm-level land and water resource use and management practices in light of changing climate conditions.

Stakeholders who attended the National Consultation Workshop (December 08, 2014), however suggested that:

- The terms domestic support or incentives should be preferably used rather than the term subsidies;
- Crop insurance is a difficult topic to implement because of the unwillingness of insurance companies to get on board;
- Record keeping is very important and currently farmers are reluctant to keep and share records.

3. **Farm production** practices involve changes in farm operational practices, which may be stimulated or informed by government programs or industry initiatives. Farm production adaptations include farm-level decisions with respect to farm production, land use, land topography, irrigation, and the timing of operations. Land use changes may involve changing the location of crop and livestock production to address the environmental variations and economic risks associated with climate change and the use alternative fallow and tillage practices, such as mulching, to address climate change-related moisture and nutrient deficiencies. Changing farm production activities have the potential to reduce exposure to climate-related risks and increase the flexibility of farm production to changing climatic conditions. Production adaptations could include the diversification of crop varieties, including the substitution of plant types, cultivars and hybrids, designed for higher drought or heat tolerance and that have the potential to increase farm efficiency in light of changing temperature and moisture stresses. Altering the intensity of chemical fertilizers and pesticides, capital and labour inputs has the potential to reduce the risks in farm production to climate change, but may increase the cost of production.

   Again, stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that:

   - Incentives for organic farming exist but they need to be better promoted;
   - Urban farming / peri-urban farming and the creation of green spaces should be more widely encouraged;
   - These are initiatives that can be readily supported by international funding agencies.

4. **Farm financial management** adaptation options are farm-level responses using farm income strategies, both government supported and private, to reduce the risk of climate-related income loss. Government agricultural support and incentive programs greatly influence farm financial management decisions. Farm financial adaptations involve decisions with respect to crop insurance and income stabilization programs and include:

- Introduction or modification of crop insurance programs to influence farm-level risk management strategies with respect to climate-related loss of crop yields;
- Invest in crop shares and futures to reduce the risks of climate-related income loss;
- Participate in income stabilization programs to reduce the risk of income loss due to changing climate conditions and variability;
- Diversify source of household income in order to address the risk of climate-related income loss.

5. Furthermore, the problem of Praedial Larceny needs to be addressed in Barbados. One suggestion is to have all farmers registered at a central registry and they should be given identification badges that they must produce when selling their produce to the various markets: grocery chains, restaurants and hotels, local and even export.

   However, stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that:

   - Registration of farmers is encouraged but it is not compulsory. Identification Cards are issued on registration with the MAFFW and the issuance of registration certificates when produce is purchased is mandated by law. However, this is not enforced because there is no established inspectorate to enforce it. The police can enforce it but don't because of inadequate sensitization. There is ongoing sensitization on the matter so that it can be enforced. These initiatives should be continued.

   Stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that:

   - Focus should be placed on greater inclusion of youth and women in issues related to agriculture;
   - Family / community farming should be further investigated and encouraged.

However these adaptation options may face a variety of challenges and barriers in Barbados. These barriers to adaptation to climate change will include: economic resources, technical knowledge, and adaptive capacity in the agriculture sector. Climate change may therefore present possible opportunities and priorities for the modernization of agriculture in Barbados by enabling effective and proactive adaptation to climate change.

Other stakeholders who attended the National Consultation Workshop (December 08, 2014), further suggested that:

- Adaptation through education and training: CAMI Farmers' Forum started the awareness;
- Need for removal of barriers.

- Mode of transferring information/demonstrations on farms: highlight successes, failures.
- Use of media/GIS etc. :training seminars to be recorded and placed on websites;
- Disseminate of information: this is already being done but need for further enhancement;
- General information about crops to correlate with weather/simulations is possible;
- CBC weather news/make comparisons with historical data/farmers corner radio program;
- CIMH is already producing Precipitation Outlook, Temperature Outlook and Drought Monitoring;
- Based on the micro-scale spatial variability of weather conditions, especially rainfall, within the Food Zone, there is the need to install a modern automatic weather station, possibly in the vicinity of the Saint George Parrish Church;
- Lack of data on soils, temperature etc. is prohibiting use of models: need for centralization of critical data;
- Mainstreaming of data is2014 compliant: Ministry needs to be more aggressive in collection of data;
- Subsidies for weather related equipment/production information is needed: farm records needed;
- Crop insurance may be possible through Group insurance;
- Harvesting of rainwater, use of drip-lines, storage ponds;
- Project to source tanks in bulk can be done through BADMC;
- Diversification of crops being done.

9 Prepare and Develop Final VCA Report

The final step was to prepare the report on the VCA process for the agriculture sector with the focus on the Food Zone located in the Parishes of Saint Michael and Saint George and include all the findings. The suggested contents of the Final VCA Report are follows very closely the VCA methodology suggested by the 5s and includes the following:

1. Objectives of the joint vulnerability and capacity analysis;
2. Data sources and variables;
3. Partners and stakeholders: characteristics and problem framing;
4. Conceptual models;
5. Methodologies (selection of indicators, including rationale, data preparation, clustering, and analyses);
6. Results (baseline and current vulnerability, system thresholds, buffers, analysis of risk and coping, risk perception, capacity, area profiles, preparedness and decision making);

7. Interpretation and application of results and discussion of linkages to programming and targeting; barriers and opportunities to mainstreaming adaptation (indicators, sensitivity matrices, plausible responses);
8. Future directions;
9. Tables and maps (embedded in text).

This VCA Report has drawn on the risks and adaptive management experiences related to climate change and has identified several initiatives that should contribute to the long-term goal of reducing the impacts of climate change on the Food Zone of Barbados.

It is expected that these initiatives will contribute to and inform:

- A coordinated effort to improve the assessment of risk of the agriculture sector of the Food Zone;
- Multi-way information exchange systems;
- Informed action at the local level including capacity building;
- Decision processes for disaster mitigation, preparedness, response and recovery;
- Empowerment of affected populations.

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11 Annexes

11.1 Appendix - 1

The following is a list of participants in the Focus Group discussion, following the presentations of Professor Singh and Dr. Délusca on August 25, 2014 at the Ministry of Agriculture:

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11.2 Appendix -2 Questionnaire Used

<u>VCA Adaptive Capacity: Farmers' Focus Group Survey form</u>

Agriculture –: Food Zone

Name: Location:
Sex: M F Age:
Occupation:
Level of education:

<u>Vulnerability assessment</u>

1- Livelihood strategies
Q1: What is the primary source of income/livelihood of your household? (*Tick the appropriate ones- can be more than one*)
Agriculture
☐ Livestock
☐ Fishery
☐ Business
☐ Non-farm income (sale of labour, skills)
☐ Other (specify): --

2- Social networks
Q2: In the past how many types of help did you provide or receive from others? (*Tick the appropriate box)*

Land preparation	☐ Help given	☐ Help received
Planting crops	☐ Help given	☐ Help received
Harvesting	☐ Help given	☐ Help received

Other (specify):---

3- Sensitivity Food
Q3.1: How do you irrigate your land? (Tick the appropriate box)
☐ Rain-fed
☐ Drip irrigation
☐ Other: specify---

Q3.2: Are you using farm machineries?
☐ Yes
☐ No
☐ More or less
☐ Other (specify) ---
Q3.3: What are the major foods that you produce?

☐ Main food crop (specify) --
☐ Main cash crop (specify) --
☐ Other (specify) ---

4- Sensitivity exposure

Q4.1: How can your farm withstand extreme event (such as storm, strong winds, severe rain…) without significant damage?

☐ Yes, with minor damage
☐ Perhaps, but with significant damage likely
☐ Other (specify) ---

Q4.2: During the last 5 years, has your farm experienced damage/loss related to praedial larceny?

☐ Yes
☐ No
☐ Other (specify) ---

Q4.3: What kind of climate event do you experience most in your farm?

☐ Drought
☐ Flood
☐ Storm
☐ Other (specify) ---

Q4.4: Did you receive early warning of such incidents?

☐ Yes
☐ No
☐ Other (specify) ---

Q4.5: How severe are the shocks?

☐ Low
☐ Medium
☐ High

Q4.6: Which of the following assisted you to deal with the events you just mentioned?

☐ National Government
☐ Insurance company
☐ NGO
☐ Family members/neighbours
☐ Other (specify) ---

Q4.7: What is your understanding on the occurrence of calamities in the past 10 years?

Drought	☐ Increasing	☐ Decreasing	☐ Same
Flood	☐ Increasing	☐ Decreasing	☐ Same
Storm	☐ Increasing	☐ Decreasing	☐ Same
Theft	☐ Increasing	☐ Decreasing	☐ Same

Other (specify) ---

5- Water scarcity

Q5.1: How often are the conflicts over the use of water in your community for agriculture, irrigation, etc.?

☐ Never
☐ Rarely
☐ Sometimes
☐ Often
☐ Always
☐ Other (specify) --

<u>Criteria (factors that may influence Adaptive Capacity: Current Situation)</u>

1- Financial resources (high production cost, decreased credit bank allocation to agriculture, savings, land tenure, investments, government incentives – rebates (irrigation water use…)

Q1: In your estimation do you think that you have the required financial assets or support to be a successful/profitable farmer and earn a decent livelihood?

☐ Yes
☐ No
☐ More or less
☐ Other: Specify---

2- Market conditions (economic dependency on foreign markets; dependency on food imports; dependency of sugar production on preferential access to foreign markets; low wages; underdeveloped marketing systems; lack of competitiveness)

- Profitable crop yields, access to water and irrigation systems, ability to purchase fertilizers, greenhouse production…

Q2-1: In your estimation do you think that you have a guaranteed market for your produce:

☐ Yes
☐ No
☐ More or less
☐ Other: Specify---

Q2-2: In your estimation do you think that you can compete with imported food products taking into account quality and price of product:

☐ Yes
☐ No
☐ More or less

☐ Other: Specify---

Q2-3: In your estimation do you think that agro processing and packaging industries would make your enterprise more reliable and profitable:

☐ Yes
☐ No
☐ More or less
☐ Other: Specify---

Q2-4: In your estimation do you think that access to labour and wages are critical in determining the survivability and profitability of your enterprise:

☐ Yes
☐ No
☐ More or less
☐ Other: Specify---

3- Policies and programs (inadequate legislation to protect markets for primary agricultural products; inadequate land use legislation; inadequate water use regulation…

Q3-1: In your estimation do you think that the government (GOB) provides the sufficient and necessary policy and monetary incentives to agriculture/farmers:

☐ Yes
☐ No
☐ More or less
☐ Other: Specify---

Q3-2: In your estimation do you think that the government (GOB) provides the sufficient and necessary policy and monetary incentives to agriculture/farmers:

☐ Yes
☐ No
☐ More or less
☐ Other: Specify---

Q3-3: In your estimation do you think that the government (GOB) can do more (policy measures not in contravention to WTO rules) to promote and protect local agricultural production:

☐ Yes
☐ No
☐ More or less
☐ Other: Specify---

Q3-4: In your estimation, in view of the fact that sugarcane production is declining (markets, access to labour, profitability) do you think that the government (GOB) should introduce land use zoning changes to allow for the production of agricultural produce (instead of sugar) as opposed to urban development…:

- ☐ Yes
- ☐ No
- ☐ More or less
- ☐ Other: Specify---

Q3-5: In your estimation do you think that the government (GOB) can do more (policy measures) to further subsidize efficient (dript) irrigation technologies for agricultural production?

- ☐ Yes
- ☐ No
- ☐ More or less
- ☐ Other: Specify---

4- Human Capital and Technology (increased women representation in agricultural labour force; lack of skilled labour; lack of technical resources; inappropriate agricultural practices; lack of machinery)

Q4-1: In your estimation do you think that Barbadian farmers (including women) are:

- ☐ Highly skilled
- ☐ Moderately skilled
- ☐ Unskilled
- ☐ Other: Specify---

Q4-2: In your estimation do you think that quality labour is easy to access:

- ☐ Yes
- ☐ No
- ☐ More or less
- ☐ Other: Specify---

Q4-3: In your estimation do you think that you have access to the technical resources and best agricultural practice methods (including machinery):

- ☐ Yes
- ☐ No
- ☐ More or less
- ☐ Other: Specify---

5- Social capital and institutions (praedial larceny; weak farmers' organisations, lack of coordination among farmers)

Q5-1: In your estimation, is praedial larceny:

- ☐ A major problem
- ☐ A minor problem
- ☐ Not a problem
- ☐ Other: Specify---

Q5-2: In your estimation do you think that more vibrant farmer organisations and a greater coordination between farmers would be:

- ☐ Highly beneficial
- ☐ Moderately beneficial
- ☐ Of little or no benefit
- ☐ Other: Specify---

6- Belief systems (low esteem in a modern society; negative perception of agriculture (the relationship to slavery and exploitation of labor)

Q6-1: In your estimation do you think that people hold agriculture in:

- ☐ High esteem
- ☐ Moderate esteem
- ☐ Low esteem
- ☐ Other: Specify---

7- Resources and distribution (loss of arable lands; small size of average farm; labour shortages and low labour productivity; decreased acreage under cultivation; upsurge in the acreage of idle land; competing uses for lands; water constraints; lack of infrastructures)

Q7-1: Do you think that access to more land, more affordable water and proper infrastructure (roads, storage facilities…) to practice agriculture would be:

- ☐ Highly beneficial
- ☐ Moderately beneficial
- ☐ Of little or no benefit
- ☐ Other: Specify---

8- Information and training (lack of accurate and reliable information for decision making and planning; lack of training for capacity building)

Q8-1: Do you think that access to information (types of cultivars, irrigation scheduling and technology) and training in best agricultural practices would benefit you:

- ☐ Yes
- ☐ No
- ☐ More or less
- ☐ Other: Specify---

9- Weather (Adverse weather conditions)

Q8-1: Have recent fluctuations in weather (drought, intense rainfalls, storminess…) affected agricultural production and profitability:

☐ Yes
☐ No
☐ More or less
☐ Other: Specify--

Q8-2: If in the next 20 to 40 years temperature was to increase (on average by about 1^0C) and rainfall was to decrease and become more variable, how would you respond as a farmer:

☐ I will probably quit farming altogether and find alternative employment
☐ I will try to apply new production techniques (drought resistant crop varieties, new types of crops) and continue farming
☐ I will switch to part-time farming and do other jobs as well
☐ Other: Specify--

Adaptation process and decision making

a. What does it feel like to be a farmer today?

☐ Proud to be a farmer
☐ Frustrated and neglected
☐ Other: Specify--

b. How long have you practiced agriculture?

☐ Less than 10 years
☐ Over 20 years
☐ Other: Specify--

c. What do you think of climate change and variability (CCV)? How do you rate it?

☐ I think climate change is real and it is already happening
☐ I do not believe in climate change
☐ Other: Specify--

d. Do you think that climate change is important to you?

☐ Yes
☐ No
☐ Other: Specify--

e. When did you become aware of it?

☐ Recently (less than 10 years)
☐ Quite a while now (more than 10 years)
☐ Other: Specify---

f. In your opinion, apart from climatic factors, what are the major changes in agriculture over the past 20 years that have affected agriculture?

☐ Competition from imported foods
☐ Lack of government support
☐ Other: Specify---

g. Is there anything else you want to add?

☐ Yes
☐ No
☐ Other: Specify---

Appendix-2, Table 1: Rating scale for criteria assessment

Verbal judgement	**Numerical rating**
Extremely more important	9 8
Very strongly more important	7 6
Strongly higher	5 4
Moderately higher	3 2
Equal importance	1

Now, based on the nine criteria identified in Table 3 (see Table 3), what criteria do you think are most important to deal with climate change? Please make a pairwise comparison of the nine criteria in the Table 3 below, based on the above rating scale.

Appendix -2 Table 2: Determinants of adaptive capacity

Criteria	1	2	3	4	5	6	7	8	9
1	**1**								
2		**1**							
3			**1**						
4				**1**					
5					**1**				
6						**1**			
7							**1**		
8								**1**	
9									**1**

Appendix 2 -Table 3: Criteria used for Questionnaire

1- Financial resources High production cost Decreased credit bank allocation to agriculture
2- Market conditions Economic dependency on foreign market Dependency on food import Dependency of sugar production on preferential access to foreign market Low wages Underdeveloped Marketing systems Lack of competitiveness
3- Policies and programs Inadequate legislation (absence of protected markets for primary agricultural products) Inadequate land use legislation Inadequate water use regulation
4- Human capital and technology Increased women representation in agricultural labour force Lack of skilled labour Lack of technical resources Inappropriate agricultural practices Lack of machinery
5- Social capital and institutions Praedial larceny Weak farmers' organisations Lack of coordination among farmers

6- Belief systems Low esteem in a modern society Negative perception of agriculture (the relationship to slavery and exploitation of labor)
7- Resources and distribution Loss of arable lands Small size of average farm Labour shortages and low labour productivity, Decreased acreage under cultivation Upsurge in the acreage of idle land Competing uses for lands Water constraints Lack of infrastructures
8- Information and training Lack of accurate and reliable information for decision making and planning Lack of training for capacity building
9- Weather Adverse weather conditions

Appendix 2 – Table 4: List of Farmers and Stakeholders who participated in Survey

List of respondents

Farmers

Name	Sex	Level of education	Farming produce
Unknown	M	Secondary	Potato
Glenn Clark	M	University	Cucumber
Arthur Phillips	M	Secondary	Beans, pepper, lettuce, cucumber
Dorma Williams	F	Secondary	Vegetable
Trevor Farnum	M	Secondary	Sugarcane
Calvin Vaughn	M	Secondary	Livestock
Dindial Moutram	M	Secondary	Water melon, pumpkin, Squash, tomato, cucumber
Nicole Blackman	F	Secondary	Water melon, Okras, Tomato
Raquel Cozier	F	University	Livestock, Dairy, Hay
Rodjeneet Young	M	Secondary	Livestock poultry
Junior Phillips	M	University	Cassava, melon lettuce, seedlings
Clive Browne	M	Some college	Pumpkins, Thyme, Fruits
Orville Downes	M	High school	Melon, squash, tomatoes, pumpkin
Shawn Smith	M	Secondary	Fisherman
Sylvester Mason	M	Secondary	Fisherman
Roger Greaves	M	Secondary	Fisherman
Hugh Andrew	M	A level	Vegetable, root crop
David Archer	M	University	Sugarcane
Unknown	M	College	Vegetable
Colin Wiltshire	M	University	

Other stakeholders

Name	Affiliation
Sandra Bellamy	Barbados Agricultural Management Company (BAMC)
Katrina	Ministry of agriculture
Israel K	Market division, Ministry of Agriculture
Kenny Ward	Soil conservation unit, Ministry of Agriculture
Theodore Fraser	Barbados agricultural society (BAS)
Lystra Fletcher-Paul	Food and agriculture organisation (FAO)
E. Worrell	Barbados Agricultural Development and Marketing Corporation (BADMC)
Glendene Bartlett	Barbados Agricultural Development and Marketing Corporation (BADMC)
Mickael James	Plant pathology unit, Ministry of agriculture
Jamekal Andwele	Extension service, BADMC
Dr. Anthony Kennedy	West Indies Central Sugarcane breeding research centre
Rickardo Ward	Ministry of Environment and drainage

Appendix-2, Table 5: Profile of Respondents

Farmer's (production sector)	Other stakeholders
Sugarcane Livestock and poultry Fishery Vegetable Dairy Cassava, tomato, lettuce Cucumber, Pumpkin, Melon Beans, okra, pepper Thyme, Hay	Ministry of agriculture • Market division • Soil conservation Unit • Plant pathology West Indies Central Sugarcane breeding research centre Barbados Agricultural Development Management Company (BADMC) Barbados agricultural society (BAS) Food and Agriculture Organization (FAO) Ministry of environment and drainage Barbados Agricultural Management Company (BAMC)
Total: 20	Total: 12

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