A NATIONAL ADAPTATION STRATEGY TO ADDRESS CLIMATE CHANGE IN THE AGRICULTURE SECTOR IN BELIZE

Prepared for

The Caribbean Community Climate Change Centre

Belmopan, Belize

and

The National Climate Change Office

Ministry of Forestry, Fisheries and Sustainable Development

Belmopan, Belize

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A National Adaptation Strategy (and Action Plan) to Address Climate Change in the Agriculture Sector in Belize.

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FOREWORD

The continued success of the Agricultural Sector is of critical importance to the social, economic and environmental sustainability of the Belizean nation. Agriculture is the second most important sector in the provision of employment and is the key contributor to Belize's food and nutrition security. Since 2006, with the establishment of cogeneration facilities in the northern sugar cane region, this sector has also become a key contributor to Belize's energy security and its gradual transition towards a green economy.

Like many Small Island Developing States, Belize is very vulnerable to the adverse effects of climate change and climate variability. Belize's main export commodities are all vulnerable to the impacts of climate change and, therefore, the development of the **"National Adaptation Strategy to Address Climate Change in the Agriculture Sector"** is an important addition to the nation's set of appropriate responses.

The Ministry of Natural Resources and Agriculture is the Government of Belize's agency responsible for the planning, regulation and implementation of the national policies and programs which will enable the country to maintain effective its responses to climate change in this sector, over time. It is in that context, that I commend the European Union Global Climate Change Alliance, the Caribbean Community Climate Change Centre and all the stakeholders who contributed to the development of this Strategy and Action Plan. Belize now has a clearly articulated framework to guide the development of the agriculture sector forward.

Looking to the future, there is one certainty which is that there will be climate change and climate variability impacts over the foreseeable future. However, the work contained in this document will ensure that Belize has a set of viable responses to address these challenges.

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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 website: http://www.climatechange.ict.gov.bz

Table of Contents

Page Nos.

Page Nos.

Page Nos.

Page Nos.

List of Annexes

List of Tables and Figures

Page Nos.

Page Nos.

Abbreviations and Acronyms

AED	Agriculture Enterprise Development
AMS	Accompanying Measures for Sugar
BAHA	Belize Agricultural Health Authority
BAMS	Banana Accompanying Measures
BCA	Biological Control Agents
BCM	Belize Citrus Mutual
BEL	Belize Electricity Limited
BEST	Belize Enterprise for Sustainable Technology
BGA	Banana Growers Association
BLPA	Belize Livestock Producers Association
BMDC	Belize Marketing Development Corporation
BRDP	Belize Rural Development Programme
BSCFA	Belize Sugar Cane Farmers Association
BSGA	Belize Shrimp Growers Association
BSI	Belize Sugar Industry
CARDI	Caribbean Agriculture Research and Development Institute
CC	Climate Change
CCCCC	Caribbean Community Climate Change Centre
CDB	Caribbean Development Bank
CGA	Citrus Growers Association
CIMH	Caribbean Institute of Meteorology and Hydrology
CMIP	Climate Modelling Inter-comparison Project
CPBL	Citrus Products of Belize Limited
CREI	Citrus Research and Education Institute
DRR	Disaster Risk Reduction
DOE	Department of Environment
DRM	Disaster Risk Management
EU	European Union
FAO	Food and Agriculture Organization
GCM	Global Climate Models
GHG	Greenhouse Gas
GMO	Genetically Modified Organism
GOB	Government of Belize
ICB	Insurance Corporation of Belize
IICA	Inter-American Institute for Cooperation on Agriculture
IPCC	Inter-Governmental Panel on Climate Change
IPM	Integrated Pest Management
MoA	Ministry of Agriculture
MFFSD	Ministry of Forestry, Fisheries and Sustainable Development
MNRA	Ministry of Natural Resources and Agriculture
MSL	Mean Sea Level
NAO	National Authorizing Office
NAS	National Adaptation Strategy
NCCARD	National Coordinating Committee for Research and Development
NCCC	National Climate Change Committee

NGO	Non-governmental Organization
NIWRA	National Integrated Water Resource Authority
OIRSA	International Regional Organization for Agricultural Health
PCB	Pesticides Control Board
PCS	Protective Cropping Structures
PRECIS	Providing Regional Climate for Impact Studies
PSWGIA	Philip S.W. Goldson International Airport
RCP	Regional Climate Pathway
SRES	Special Report on Emission Scenarios
SST	Sea Surface Temperature
SICB	Sugar Industry Control Board
SIRDI	Sugar Industry Research and Development Institute
UB	University of Belize
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme

A. Executive Summary

Agriculture is critical to Belize's development for foreign exchange earnings and savings, employment, and food and nutrition security. Belize is considered food secure in basic grains, livestock and seasonally available vegetables and fruits from a production standpoint. Food production and security should not be taken for granted since threats exist as evidenced during the recent bouts of excessive rainfall and flooding in late 2013 and early 2014.

Like other developing countries, particularly Small Island Developing States, Belize is very vulnerable to the adverse effects and the impacts of climate change and climate variability. The main export commodities, bananas, citrus, sugar and aquaculture, plus commodities accessing emerging markets and the local food crops are all vulnerable to the vagaries of the climate.

In this context support was provided to the Government of Belize (GOB) through the Caribbean Community Climate Change Centre (CCCCC), with the Ministry of Forestry, Fisheries and Sustainable Development (MFFSD) as the implementing agency, to prepare a National Adaptation Strategy (NAS) and Action Plan to address the current and projected impacts of climate change on the agriculture sector in Belize. Belize Enterprise for Sustainable Technology (BEST) consultants were tasked to prepare this strategy with specific adaptation measures to reduce the impacts of climate change and climate variability on agriculture in Belize. This required an assessment of the agriculture sector including its vulnerability and adaptation to climate variability and climate change; a review of the pertinent policies, legislation, institutions, organizations and resources directly or indirectly involved with agriculture, taking into consideration the views, concerns and recommendations of the key stakeholders; and the financial, institutional, human and other resource requirements to implement the strategic options proposed.

The technical assessment was informed by a comprehensive literature review of the Belizean agriculture sector including its institutional, policy and ecological environment, climate change model projections for Belize from recently conducted climate modelling experiments using the Hadley Centre Regional Climate Model (RCM), Providing Regional Climate for Impact Studies (PRECIS) (- Echam4, - Echam5 and - HADCM3) under the A2 and B2 scenarios of the Inter-Governmental Panel on Climate Change (IPCC) scenarios (SRES), and recent regional and national crop modelling studies.

Climate Change Projections

The results of the analysis on climatic trends and future climate model projections for the western Caribbean region, including Belize, indicated that over the past 50 years temperatures have been rising steadily and are projected to continue along this trend. Rainfall variability has increased, and will likely become more pronounced in the future. Increases in seasonal evapotranspiration rates have been noted over the recent past, while significant decrease in wet season moisture surpluses is foreseen. Global sea levels have risen over the past 130 years and are forecast to continue rising during the 21st century.

The review of meteorological data for the period 1961-2013, shows the annual *average minimum* temperature at the Philip S.W. Goldson International Airport (PSWGIA) has been increasing at the rate of 0.028 °C per annum or has risen by 1.4 °C over the past 52 years. The analysis indicates that, for the same period, the annual *average maximum* temperature has been rising at the rate of 0.0133 °C per annum or about 0.6 °C in the past 45 years. The *annual average* temperature at the PSWGIA has increased by 0.5 °C since 1961. The studies show that the nights are warming up faster than the days, but in general the temperatures in Belize are rising.

A trend analysis of the historic rainfall for Belize City since 1887 to the present showed a 4.6 mm per annum decrease in rainfall or 46 mm decrease per decade, which translates to 480 mm decrease in annual rainfall over the past 126 years. However, the review and analysis of rainfall records from 1960-2013 for PSWGIA, shows a slight increasing trend of 1.4 mm per annum or 14 mm per decade. The historic rainfall record 1901-2013 for central Belize (Mitchell, 2013) revealed an increasing trend of 7.6 mm per decade or 82 mm increase over the 108 years record. Meanwhile, for northern Belize rainfall trend analysis for the period 1992 to 2013 at Towerhill indicates a rise of about 275 mm over the twenty-three years. In short, the trend analysis indicates that wet years have been more frequent at the end of the 20th century and the first decade of the 21st century, with higher frequency of short, but intense rainfall events as was experienced with the upsurge of tropical cyclone activity in the western Caribbean during the 1990-2010 decades.

A trend analysis for seasonal evapotranspiration rates (E) for central Belize indicates that the greatest increase occurred during June–July–August (JJA) at the rate of 3.4 mm per season over the 30 year period 1980-2010. Meanwhile, global sea levels have been rising at the rate of 0.0162 cm per annum, a rise of near 21 cm for the period 1880-2010 (CISRO, 2012).

Analysis of Climate Change projections suggested that, under the A2 scenario (worst case) Belize will experience temperature increases of near 2 °C by the 2050s and almost 4 °C by the 2080s, relative to the baseline period 1961-1990. RCM projections for the 2050s show percent change in rainfall in the order of -20 % to – 30 % from the reference period 1961-1990 under the A2 scenario, and around -50 % to -60 % change from normal by the 2080s.

Projections of atmospheric moisture deficit/surplus (P-E) show that by the 2080s, dry months deficits will decrease slightly, but the wet season months (JJA & SON) will see a decrease in moisture surpluses. This means that the dry seasons will be slightly less intense around the 2080s, but the wet seasons will become drier.

Sea surface temperatures are projected to rise at an average of 0.7 °C to 2.7 °C in the Caribbean. (CaribSave, 2009)

The coastal lowlands in northern Belize will be vulnerable to sea-level rise according to the global climate model projections. Between 2046 and 2065 the mean increase in sea levels for the different scenarios will range from 0.17 m to 0.3 m with 0.38 m being at the extreme value. For the period 2081 to 2100 this average increases and ranges between 0.4 m and 0.63 m with 0.82 m as the extreme.

Climate Change Impacts on the Agriculture Sector

Climate Change and climate variability will impact agriculture systems and practices such as soil fertility and land preparation; pest and disease control; and water requirements (excess and deficits). Higher temperatures will cause increased stress on current livestock breeds, and crop types and varieties. Climate Change and climate variability will very likely result in less rainfall overall, but the most detrimental effect is likely to come from the variation in the seasonal distribution of rainfall, leading to more periodic droughts and floods.

Development of the Strategy

With a focus on foreign exchange and food and nutrition security, nine commodities, sugarcane, citrus, bananas, shrimp, rice, corn, beans, livestock and vegetables were identified as the most important for review and analysis during the preparation of the NAS. Extensive consultations including the use of structured questionnaires were held with three categories of stakeholders (1) policy makers; (2) agriculture producers; and, (3) support entities to identify vulnerabilities, gaps, needs, policies and strategies necessary to adapt to the challenges of climate change and climate variability; to design appropriate interventions; to assess technical, institutional and educational needs for implementation; and to indicate consensus views on the roles, responsibilities and capabilities of the various entities which must partner in the implementation of the recommended strategies.

Two of the salient issues emerging from the extensive consultation process were: (1) that most stakeholders have observed climate change and climate variability effects on agricultural systems, and (2) that pests/diseases and soil nutrition management were considered the most critical adaptation needs. Whereas some farmers use chemical pesticides as the primary method of pest control, most are environmentally conscious and believe that integrated crop and pest management are better alternatives. Vegetable farmers recommended protective cropping structures as an important adaptation measure. Commodity tolerance for climate change and climate variability effects is considered a priority adaptation measure, including adjustment of commodity types and varieties and production systems to minimize need for extraneous interventions. Stakeholders in general considered organic production an economic opportunity as well as an adaptation measure in response to climate change and climate variability. It was noted that most farmers are business oriented, and expressed a strong desire for a commodity insurance plan that will provide effective coverage. An area of concern is that only half of the government policy makers are knowledgeable about Belize's national biosafety policy and most producers are unaware of the policy.

Based on current information regarding possible adaptation measures, the status of the agricultural sector including its policy and institutional framework, the consultations with stakeholder groups and analysis of responses, a draft strategy was prepared including recommendations for specific technical and cross-cutting adaptation measures, policy, legal and institutional strengthening and stakeholder education, early warning and awareness programmes.

During and following the staging of three regional consultative workshops the draft strategy was supplemented, re-defined and refined with comments and suggestions received from key stakeholders including producer groups and support agencies. A revised draft strategy and action plan was subsequently presented to policy makers and other key stakeholders in a national workshop for further inputs leading to the preparation of the final draft of the synthesis report.

Draft Strategy and Action Plan

Technical adaptation measures are recommended to combat the following four detrimental effects of Climate Change and Climate variability:

i. Direct effects - rainfall changes: excess, shortage and variability

ii. Direct effects - temperature increase

iii. Indirect effects of rainfall and temperature changes – *greater than* changes in pests and diseases status

iv. Indirect effects of rainfall and temperature changes – *greater than* changes in soil fertility

The recommended measures for each of the direct and indirect effects are as follows:

(a) Rainfall excesses and flooding

- Properly designed drainage infrastructure, systems and mechanisms to alleviate waterlogging stress on crops and pastures.

- Well designed and drained road infrastructure to ensure access to farms and transport of farm produce post rainfall event.

- Relocation of annual crops within a farmed area during an annual production cycle based on seasonal rainfall forecast.

(b) Rainfall deficit and drought

- Irrigation, including drip irrigation to conserve scarce water resources, to supply the water needs of priority crops. Use of renewable energy sources to reduce cost of pumping water for irrigation.

- Watershed management to maintain the country's water resources in the long term.

- Water harvesting during periods of rainfall for use under conditions of water shortage.

(c) Rainfall variability

- Seasonal production to adjust to the different crop water requirements at critical phases of the production cycle.

- Timely and localized weather forecast specifically for agriculture purposes to enable farmers to time their activities in relation to forecasted weather events/conditions.

(d) Temperature increase

- Selection for heat-tolerant crop and pasture varieties and livestock breeds that are better adapted to the increased temperatures regimes brought about under Climate Change, with emphasis on indigenous genetic diversity. Preservation of selected indigenous crop and livestock in germplasm banks.

- Alleviation of heat stress on plants through irrigation to supply sufficient water to allow the cooling effect of evapotranspiration,

- Silvopastoral systems which utilize shade trees of economic value to alleviate heat stress on range livestock.

- Heat alleviating infrastructure or appropriately ventilated housing designs especially for poultry, pigs, sheep and goats.

(e) Changes in pests and diseases

- Integrated Pest Management (IPM) practices to keep pests below economic threshold levels in order to minimize risks to human health, beneficial and non-target organisms, and the environment.

- Protective cropping structures (PCS) to physically exclude arthropod pests, and minimize disease incidence by excluding rainfall disseminated fungal and bacterial pathogens. Protective cropping structures can also be utilized for the production of vegetables on coastal areas vulnerable to salt water intrusion when combined with the use of harvested water for irrigation and decreased water use for pest management.

- Use of models developed for Climate Change scenarios to forecast potential pest outbreaks based on meteorological data.

- The use of appropriate indigenous or, if necessary, imported Biological Control Agents (BCA) for the most expedient, cost effective and environmentally sustainable option for management of crop pests and disease vectors.

- Improved biodiversity for the agro-ecological balance needed for economic sustainability of agriculture production systems.

- Research into new pest and disease interactions that will evolve as a result of Climate Change.

(f) Changes in soil fertility

- Soil and nutrition management to implement measures to preserve and improve the physical, chemical and nutritional properties of soils affected by increased temperatures and variation in water regime resulting from Climate Change. Selection of nutritious pasture grasses that can tolerate soils affected by both drought and excessive water, along with grazing management practices to maintain longevity and fertility of pastures.

- Selection of nutritious pasture grasses that can tolerate soils affected by both drought and excessive water.
- Use of grazing management practices to maintain longevity and fertility of pastures.
- Improvement of soil fertility through the use of organic matter such as compost, vermiculture and bokashi.
- Use of physical and chemical amendments, and beneficial micro organisms.
- Vegetation management (crop cover) to prevent exposure of bare soils and its subsequent erosion, including maintenance of live vegetative cover during fallow periods.

(g) Aquaculture adaptation measures

- Improved brood stock (resistance to disease and tolerance to environmental change i.e., control of temperature and salinity).
- Access to clean water sources (to facilitate rapid water exchange regularly).
- Water Storage.
- Reduced energy cost including the use of renewable and / alternative sources of energy i.e., solar, wind, etc.
- Research (resistant varieties, improved management systems; improved shrimp growing techniques)
- Information and technology transfer
- Improvement in regulatory services (Belize Agricultural Health Authority (BAHA) & the Department of the Environment (DOE)

(h) Cross-cutting measures

(a) Commodity Insurance

Commodity insurance is considered critical to maintain levels of production under the predicted Climate Change scenarios. The current need for insurance services to farmers and producers in the sector will be substantially increased as some of the impacts that are expected with Climate Change become increasingly evident.

(b) Group resilience

It is recognized that the people factor is always the most important element for successful implementation. Suggestion is made to achieve the effective engagement of the primary stakeholders, the farming community, and to promote group resiliency for responding to the challenges of Climate Change.

(c) Monitoring and documentation

Effective adaptation to the effects of Climate Change will require continuous monitoring and documentation of crop and livestock responses to the meteorological, agro-ecological and environmental changes experienced over time. Actions will include the provision of monitoring/documentation software and materials, along with training and education of stakeholders.

Strategy implementation

The agriculture sector is fairly well poised to implement the proposed adaptation measures in terms of technical capacity, institutional and policy environment and stakeholder attitude, but with some failings or shortfalls for which recommendations for rectification are indicated. Commitment of top level decision makers will be the key determining factor for implementation.

Implementation of the strategy will require investments in infrastructure and equipment, research and training, education and early warning systems and matching funds for a public/private sector partnership commodity insurance scheme.

Infrastructure development and procurement of equipment needed to effect improvements in the agriculture sector in drainage, irrigation, feeder roads network, pest/disease management, crop nutrition, agro-meteorology forecasting, monitoring and documentation detailed in table 6(a) amount to approximately BZ$ 26.15 million.

A further BZ$ 720,000 will be required for the necessary research and training needs as indicated in table 6(b). Training includes both in-service training and formal education to equip the national agriculture institution with the necessary subject matter expertise for effective and efficient implementation of the technical adaptation measures.

An annual budget of BZ$ 50,000 is recommended for education programmes for all stakeholders and early warning systems for the agriculture sector as shown in table 6(c).

Finally it is recommended that GOB allocate annual funding of BZ$ 5.0 million as matching funds for an agriculture commodity insurance scheme (table 6(d)) in partnership with a designated private entity which has indicated an interest in this area.

B. INTRODUCTION – CONTEXT OF ASSIGNMENT

The Caribbean Community Climate Change Centre (CCCCC) has secured resources to execute a regional project designed to assist sixteen (16) CARIFORUM[1] member states to develop the capacity to design and implement Climate Change adaptation policies and measures. Through this "European Union Global Climate Change Alliance Caribbean Support Project', funded from the 10th European Development Fund-Intra African Caribbean Pacific financial framework , the CCCCC has embarked on a series of initiatives to incorporate and mainstream climate change adaptation into the national development planning processes and mechanisms of participating countries. The end result is an expectation that the economic and social development of these countries and the region will be enhanced.

Over the recent past, the Government of Belize (GOB) has taken several initiatives to mainstream Climate Change into its national development planning processes. One major activity in this vein has been the establishment of a National Climate Change Office in the Ministry of Forestry, Fisheries and Sustainable Development (MFFSD), which serves as the National Focal Point for Climate Change issues and is the body responsible for overseeing the GOB's international climate change obligations particularly those under the United Nations Framework Convention on Climate Change (UNFCCC).

Vulnerability studies and assessments on the impacts of Climate Change on agriculture and food security in the sub-regions of Central America and the Caribbean, indicate a reduction in yields for several key crops (Ramirez, et al. 2013, Eitzinger, 2012), increasing stress and reduction in livestock production, increased crop pests and animal diseases, continued degradation of recharged areas and scarcity of water, and a threat to the livelihood security of thousands of persons and their families who depend directly or indirectly on agriculture for their survival.

Specific adaptation responses now, rather than later, could reduce the vulnerability of farmers and agriculture sector-dependent communities. Adaptation is aimed at developing strategies and actions to diminish the vulnerability to climate change, so that the expected negative impacts may be smaller or eliminated.

In Belize, the Ministry of Natural Resources and Agriculture (MNRA) and MFFSD have been selected as the implementing bodies for a national Global Climate Change Alliance Project aimed at addressing issues of coastal flooding and the modelling of impacts in these areas where agriculture is the main economic activity. Also, there have been projects to prepare a national energy policy, a renewable energy policy and other initiatives which help to provide a sound basis for building an adaptation strategy for the agricultural sector in Belize.

It is in this context that support was provided to the GOB through the CCCCC, with the MFFSD as the implementing agency, to prepare a National Adaptation Strategy and Action Plan (NASAP) for the agriculture sector to address the current and projected impacts of Climate Change on the agriculture

[1] The Caribbean Forum (CARIFORUM) is a subgroup of African, Caribbean and Pacific (ACP) Group of States and serves as a base for economic dialogue with the European Union. It was established in 1992 and is comprised of the 15 Caribbean Community member states and the Dominican Republic.

sector. The Belize Enterprise for Sustainable Technology (BEST) was contracted to undertake this task.

The Climate Change and Agriculture assessment endeavours to highlight the technical, agronomic and economic impacts of Climate Change (CC) on the agricultural sector. The intent is to identify practical and cost-effective adaptation measures that will help inform an agricultural strategy which can be mainstreamed into the planning cycle of present and future development plans, programmes and projects in the various subsectors in agriculture. The strategic plan will put the agriculture sector in a better state of preparedness to face the continued challenges posed by increasing climate variability and Climate Change impacts. It should improve the capacity of the sector to become more resilient, competitive and diversified to enable the sector to grasp any opportunities arising with warmer climate, and reduce its vulnerability to increasing future extreme climatic events.

The specific objectives to be fulfilled are:

- An impact assessment of the vulnerability and adaptation of the agriculture sector to climate variability and Climate Change and its predicted adverse effects in the medium and long term;
- An assessment of the agricultural sector and pertinent legislation, institutions, organizations and resources that are directly or indirectly involved with agriculture related activities;
- An assessment of the financial, institutional, human and other resource requirements to implement the strategic options proposed ;
- A national agriculture sector adaptation strategy with specific adaptation measures to reduce the impacts of Climate Change on agriculture;
- An action plan with recommendations on the possible mechanisms and resources required for implementation.

C. STRUCTURE OF THE NATIONAL ADAPTATION STRATEGY FOR THE AGRICULTURE SECTOR

The National Adaptation Strategy (NAS) for the Agriculture Sector will be governed by the following guiding principles listed below:

- Climate Change and Disaster Risk Management (DRM) in agriculture are inter-related and have some mutual adaptation needs. A comprehensive DRM strategy has been prepared and will be referred to but not repeated in the Climate Change strategy;

- Agriculture is primarily for food and nutrition security, revenue and foreign exchange generation and employment. All agriculture industries are important and all producers must co-exist;

- The Climate Change adaptation strategy must fit into the overall strategy for agriculture advancement for it to be meaningful. Similarly the agriculture policy and strategy must ally with the country's national development policy to elicit commitment from relevant policy makers;

- All the nation's populace are stakeholders in a CC strategy for agriculture. However appropriate action and subsequent implementation will depend on the collective wisdom and buy in of the key stakeholders which are the policy makers and the farming population at all levels;

- Adaptation measures have to increase or maintain competitiveness in agriculture, which could mean the need to change selection of crops in a globally competitive scenario;

- Agriculture systems need to improve technical efficiency of production to offset losses caused by unfavorable climatic factors. Improved efficiency should be a consistent objective but it becomes more critical when dealing with exogenous factors we cannot control; and

- The CC adaptation strategy should be revisited or updated periodically as new technologies and agriculture opportunities become available and critical needs emerge due to human and technological factors.

In the preparation of the NAS, the following issues will be assessed sequentially and pragmatically:

1. Belize's current agricultural status, framework and environment;
2. Projected Climate Change impacts on agricultural activities and development;
3. Possible adaptation strategies to address the adverse effects of climate change on agriculture;
4. How well the sector is poised to adopt the proposed measures; and
5. Action Plan – including the adaptation measures, costs, funding mechanisms, timeframes, and implementing agencies.

D. METHODOLOGY

The development of the National Adaptation Strategy to address Climate Change the Agricultural Sector in Belize could be a very exhaustive process since farmers produce a wide array of commodities for export, the domestic market or subsistence. These commodities include sugarcane, citrus, bananas, papaya, cacao, cowpea, hot pepper, rice, corn, beans, sorghum, soybean, pineapple, peanuts, cassava, cocoyam, other root crops, coconuts, onions, potatoes, carrots, tomatoes, cabbage, sweet pepper, a wide variety of fruits and other vegetables, aquaculture and livestock.

With a focus on foreign exchange and food and nutrition security, nine commodities were selected as the most important for the preparation of the NAS.

The traditional export commodities sugarcane, citrus and bananas, along with the more recently developed aquaculture industry (shrimp) are the most significant for foreign exchange earnings. Rice, corn, beans and livestock (primarily poultry and cattle) are considered the staples of the Belizean diet and critical to food security. Vegetables are produced mainly by small farmers scattered throughout the country and stakeholders at large fully recognize the important health benefits afforded by the consumption of more vegetables in the Belizean diet, and the necessity of providing a wholesome product.

After selection of the commodities of emphasis for the development of the adaptation strategy three major categories of stakeholders were identified for the consultative process: (1) policy makers, (2) agriculture producers and (3) support entities. Policy makers included the various departments of the ministries of Natural Resources and Agriculture, Forestry, Fisheries and Sustainable Development, Economic Development, Science, Technology and Public Utilities, and statutory regulatory bodies such as the Belize Agricultural Health Authority (BAHA), Pesticides Control Board (PCB) and the Belize Livestock Producers Association (BLPA), Support agencies included research, education, funding and partnering organizations, agriculture affiliated regional and international organizations, non-governmental organizations (NGO's) and agriculture services providers.

The technical assessment was informed by several methodologies that provided quantitative as well as qualitative data and information to fulfil the objectives. These included:

i. A comprehensive literature review of (a) the agriculture sector including its institutional, policy and ecological environment, (b) regional and national past studies on CC, its impacts on agriculture and possible adaptation strategies and (c) climate projections under two IPCC climate change SRES Scenarios downscaled regional Models, namely the PRECIS-Echam4 A2 and B2 and PRECIS-HadCM3.

ii. An analysis of historical rainfall, temperature and evapotranspiration for Belize to evaluate climate trends and warming.

iii. An evaluation of the IPCC AR-5 Global Climate Model (GCMs-RCM).

iv. Analyses of regional climate change model data in relation to plant growth and development and livestock comfort and production.

The preliminary assessment of climate projections for Belize was used to inform the drafting of a survey instrument to gauge stakeholder's perception and interest on the effects of climate change on agriculture, to meaningfully engage stakeholders in a participatory approach to identify vulnerabilities, gaps, needs, policies and strategies necessary to adapt to the challenges of climate change, to design appropriate interventions, assess technical, institutional and educational needs for implementation, and indicate consensus views on the roles, responsibilities and capabilities of the various entities which must partner in the implementation of any recommended strategies. Three questionnaires, one for each stakeholder category, were used to assist the consultation process with stakeholders in all six districts. Initial consultations with producers, policy makers and support agencies were carried out mainly by individual, group and electronic interviews. Questionnaire responses from all the stakeholders were documented, analysed and used to assist the preparation of a draft adaptation strategy and action plan. This draft strategy was used as the basis to conduct three regional consultative workshops, with a stakeholder mix of producers and support agencies, in the Orange Walk, Stann Creek and Cayo Districts.

The draft strategy was augmented and refined with the comments and suggestions received from the three regional workshops. The adjusted draft strategy and action plan was then presented to policy makers at a national workshop for comments and further inputs for the preparation of the final draft synthesis report.

1. OVERVIEW OF THE AGRICULTURE SECTOR

1.1 Economic Framework

1.1.1 Government

Belize, a full member of the Caribbean Common Market, is an independent Parliamentary democracy which uses the Westminster model of government. There are two independent houses that form the legislature, a 31 member elected House of Representatives and a 13 member appointed Senate. As a member of the British Commonwealth, the country retains the Queen of England as its head of State represented in Belize by an appointed Governor General. Members of the House of Representatives hold office for five years, but elections can be called at any point by the Prime Minister, who is the head of the Executive Branch of government. There are two major political parties, the Peoples United Party and the United Democratic Party, which have held national office since political independence in September 1981.

1.1.2 Geography and Climate

Located in northern Central America, Belize is nestled on the south-eastern corner of the Yucatan Peninsula, bounded in the north by Mexico, in the south and west by Guatemala, and to the east by the Caribbean Sea. It has a total land area of 8,867 square miles or 22,967 square kilometers. The mainland makes up 95% per cent of the territory and five per cent is represented by more than 1,060 small islands or cayes. The country boasts the longest living barrier reef in the Western Hemisphere.

With its territorial waters included, Belize’s coordinates extend from 15° 53′ and 18° 30′ N latitude and 87° 15′ and 89° 15′ W longitude. Using an offshore territorial limit of 12 miles or 20 km, the national territory including the cayes and territorial sea is 18,000 sq. miles or 46, 620 sq. km. There are about 595 sq. miles or 1,540 sq. km of lagoons on the mainland, reducing the actual landmass to some 8,263 sq. miles or 21,400 sq. km. From north to south Belize has a length of about 161 mi or 260 km, and from east to west from about 111 to about 180 km. The coastline extends a little farther to about 173 m or about 280 km. The country is comprised of 6 districts, nine municipalities, and more than two hundred and forty villages.

1.1.3 Population

The population estimates for 2013 place Belize population at 349,728 persons residing in the six districts. The demographic profile from Census 2010 was about 51 percent males and 49 percent females. The urban population was 44 percent of the total and while the rural population stood at 56 percent. According to the 2010 census, the population density was 15 persons per square kilometer, the lowest population density in Central America, with an annual population growth rate of 2.56%.

Table 1 (a): Belize Census 2010 Provisional Population and Household (Source: SIB, 2010)

	Total	Males	Females	No. of Households	Average Household Size	% Total	% Males	% Females
Country Total	***312,668***	***157,923***	***154,745***	***79,245***	***3.9***		***50.5***	***49.5***
Urban	**138,766**	**67,884**	**70,882**	**39,104**	**3.6**	**44.4**	**43.0**	**44.9**
Rural	**171,827**	**88,261**	**83,566**	**40,141**	**4.2**	**55.0**	**55.9**	**52.9**
Homeless Population	118	113	5					
Institutional Population	1,957	1,665	292					
Pop Density persons/km2	14							
Pop Growth Rate % per yr	2.1							

1.1. 4 The Belizean Economy

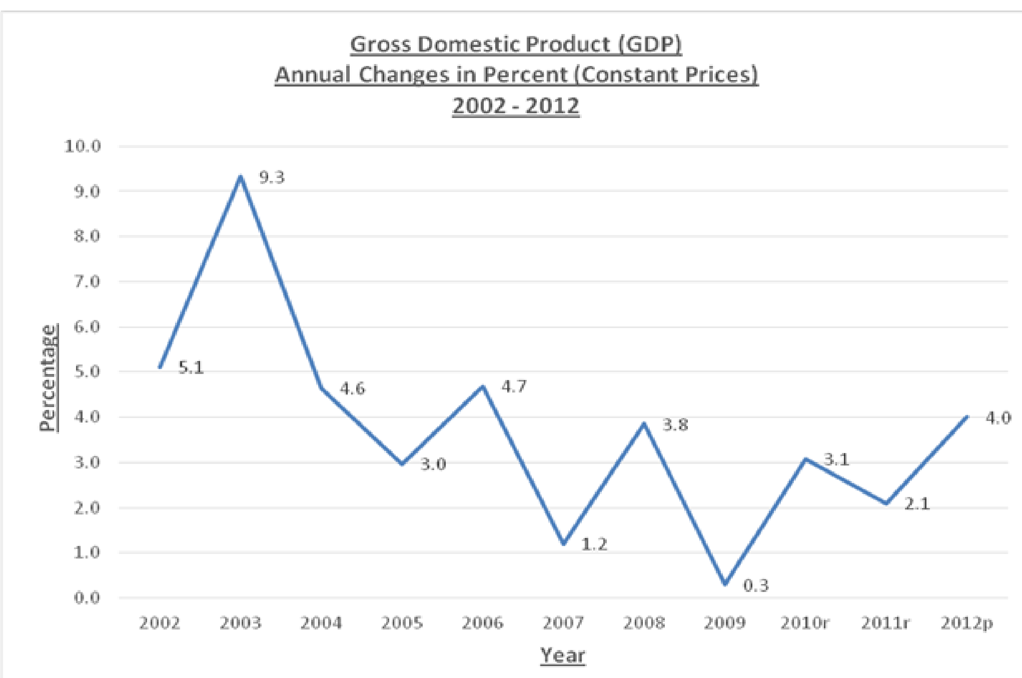
The Belizean economy is a small open economic system in which international trade is a large component of the country's transactions. Trade in real goods in a significant part of the earnings of foreign exchange and as a consequence, the economy is more subject to shocks from external activities. The critical sectors of the economy are mostly natural resources based, including the Tourism sector which is dependent on maintaining the pristine state of the rivers, coastal waters and cayes and the health of the forests and watersheds which is what most visitors come to enjoy.

Table 1 (b): Belize GDP Market Prices 2002 – 2012

Gross Domestic Product by Activity *Constant Prices - BZ$ Million*											
Industry	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010r***	***2011r***	***2012p***
Agriculture and forestry	183.9	212.1	237.2	235.4	233.4	230.4	222.4	210.2	237.9	226.6	249.8
Growing of crops; horticulture	136.4	163.8	184.3	181.0	186.5	180.8	173.2	162.9	193.7	177.7	202.0
Livestock farming	36.7	38.1	41.9	42.1	34.6	37.1	36.5	37.1	38.4	43.0	42.6
Forestry and logging	10.8	10.2	11.0	12.3	12.3	12.5	12.7	10.2	5.8	5.9	5.3
Fishing	60.3	126.8	133.8	147.2	124.4	53.5	89.6	109.5	103.7	100.2	99.3
Mining and quarrying	8.8	8.8	9.3	8.7	9.0	10.4	12.4	11.0	11.5	11.9	13.0
Primary Industries	***252.9***	***347.8***	***380.3***	***391.3***	***366.9***	***294.3***	***324.4***	***330.7***	***353.2***	***338.7***	***362.1***
Manufacturing	160.9	160.4	180.3	181.1	236.2	243.9	254.5	326.0	299.3	291.6	269.5
Manuf. of food products and beverages	121.0	120.3	134.4	136.0	127.3	118.9	124.9	126.2	118.1	121.1	139.6
Man. of textiles, clothing and footwear	17.7	18.0	22.1	19.6	20.2	9.6	0.2	0.0	0.0	0.0	0.0
Other manufacturing (incl. petroleum)	22.2	22.2	23.8	25.4	88.7	115.4	129.5	199.8	181.2	170.5	129.9
Electricity and water supply	60.2	65.3	64.3	64.0	90.4	92.5	96.3	106.1	128.9	124.4	115.8
Construction	87.0	71.5	74.7	72.0	70.6	68.4	79.0	71.1	53.5	52.1	60.0
Secondary Industries	***308.2***	***297.2***	***319.3***	***317.0***	***397.2***	***404.8***	***429.9***	***503.2***	***481.8***	***468.1***	***445.2***
Wholesale and retail trade, repairs	302.4	306.6	306.6	322.7	326.8	332.8	347.1	323.9	357.7	381.9	402.0
Hotels and restaurants	68.0	77.9	84.4	88.1	87.5	91.4	87.2	78.1	81.0	82.4	91.5
Transport, and communication	176.4	191.5	201.1	218.8	226.4	258.2	248.1	245.0	256.7	260.2	273.4
Transport and storage	72.4	73.5	81.3	80.4	78.3	81.4	79.7	71.1	76.6	74.9	78.0
Post and telecommunications	104.0	118.0	119.7	138.5	148.2	176.8	168.4	173.9	180.1	185.3	195.5
Financial intermediation	131.1	172.4	181.8	179.6	194.5	219.4	223.4	273.6	285.7	281.1	273.1
Real estate, renting and business services	121.7	123.1	130.0	143.0	154.8	157.4	160.1	147.9	146.2	149.8	157.6
Community, social and personal services	106.2	111.5	115.3	120.6	124.2	128.3	130.3	130.8	132.7	135.8	139.3
General government services	181.2	192.7	195.3	197.8	189.2	197.3	206.8	221.2	222.5	220.5	234.6
Tertiary Industries	***1,087.0***	***1,175.7***	***1,214.5***	***1,270.7***	***1,303.4***	***1,384.8***	***1,403.0***	***1,420.5***	***1,482.5***	***1,511.8***	***1,571.6***
Less: Financial services indirectly measured	73.4	97.3	101.3	99.7	109.3	129.0	126.6	151.0	166.6	152.0	142.8
All Industries at Basic Prices	***1,574.7***	***1,723.4***	***1,812.7***	***1,879.2***	***1,958.1***	***1,955.0***	***2,030.6***	***2,103.4***	***2,150.8***	***2,166.6***	***2,236.2***
Taxes less subsidies on products	262.4	285.1	289.1	285.0	307.8	338.3	351.0	285.3	311.5	347.4	378.7
GDP at Market Prices	***1,837.1***	***2,008.4***	***2,101.8***	***2,164.3***	***2,265.9***	***2,293.3***	***2,381.6***	***2,388.7***	***2,462.4***	***2,514.0***	***2,614.9***

Source: SIB, 2013

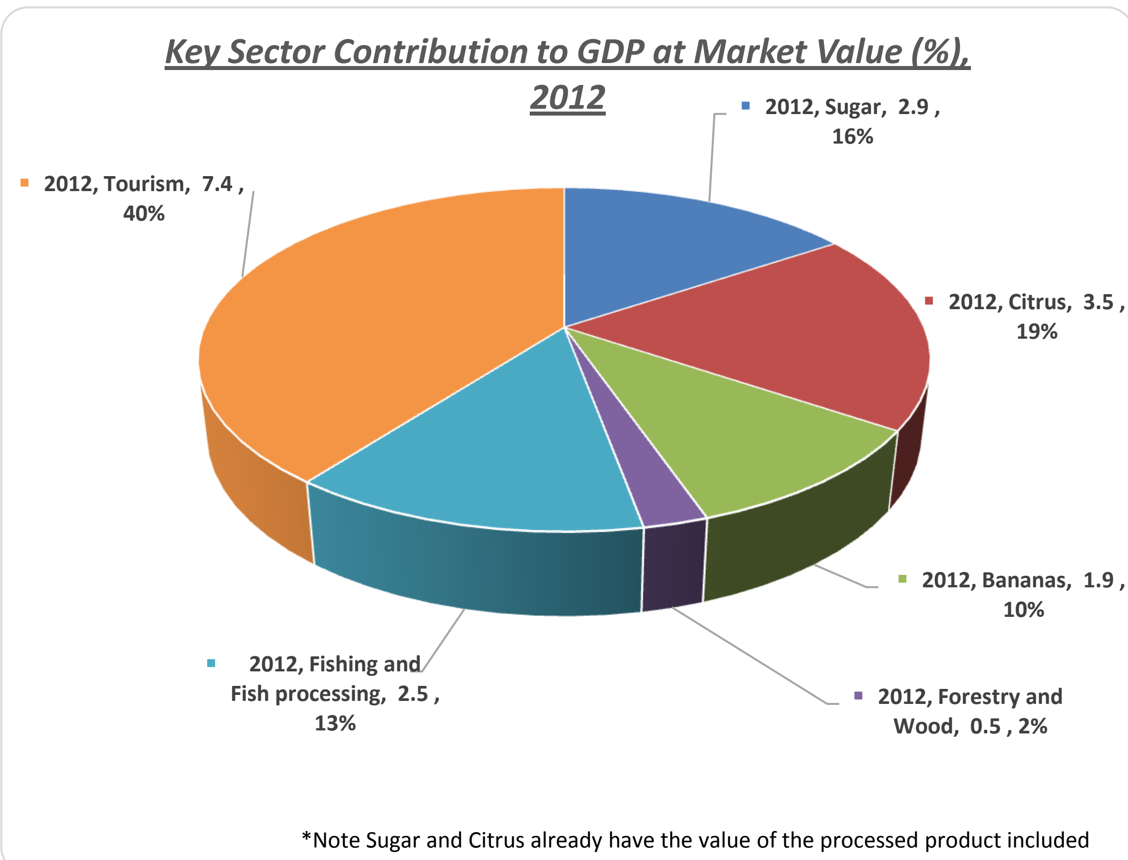
Figure 1 (a): GDP Growths 2002 – 2012 (Source SIB 2013)



During the period from 2002 - 2012, Belize's economy experienced growth ranging from a high of 9.3% in 2003 and a low of 0.3 % in 2009. The average rate of growth over that period was 3.6%. In the latter part of that decade, the most significant growth was contributed by the petroleum industry which began in 2006.

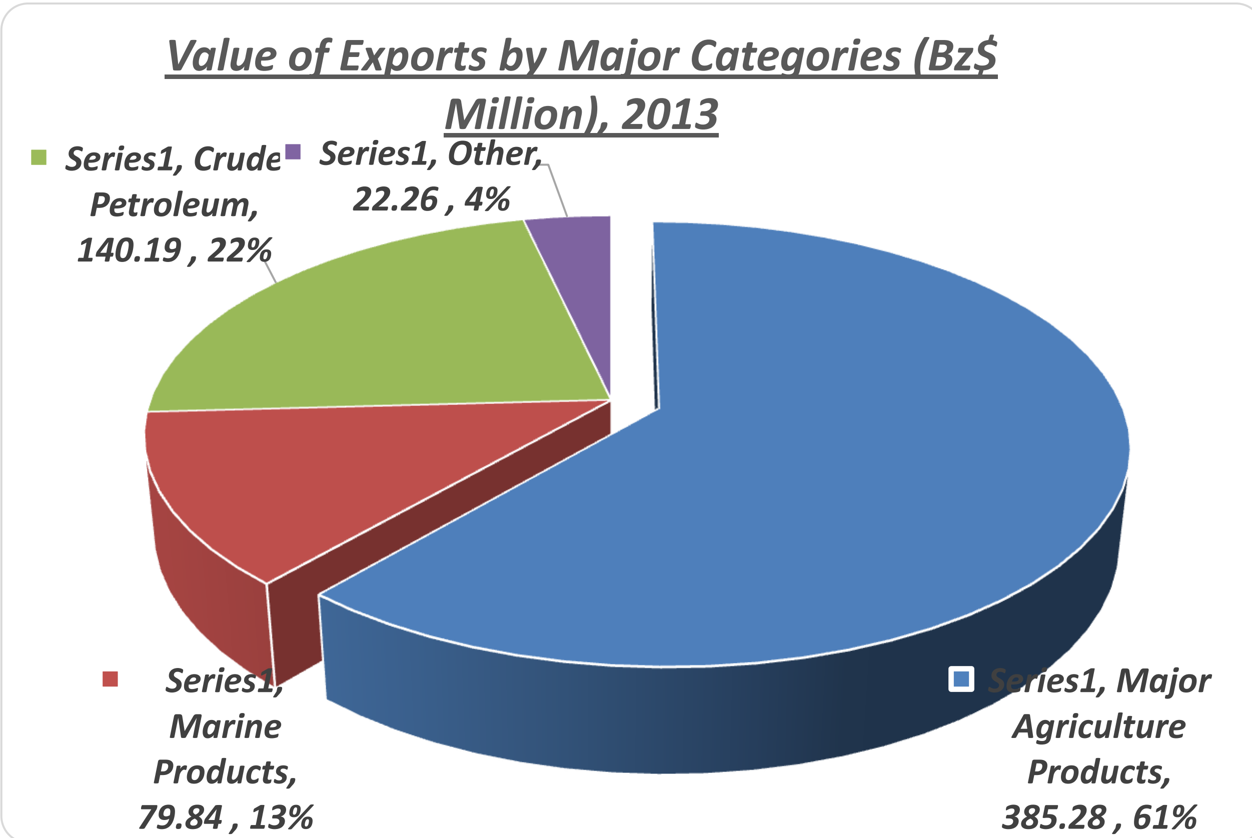
In reality, the Agriculture sector is the most important component of Belize's GDP both from an economic and a social standpoint. In 2012, the production of sugar, citrus and bananas alone contributed 8.3 % of GDP which was more than the 7.4 % contribution made by the Tourism sector. The other significant contributor was the fishing and fish processing sector which added 2.5 % to GDP.

Figure 1 (b): Key Sector Contributions to GDP at Market Value (Source: SIB, 2013)



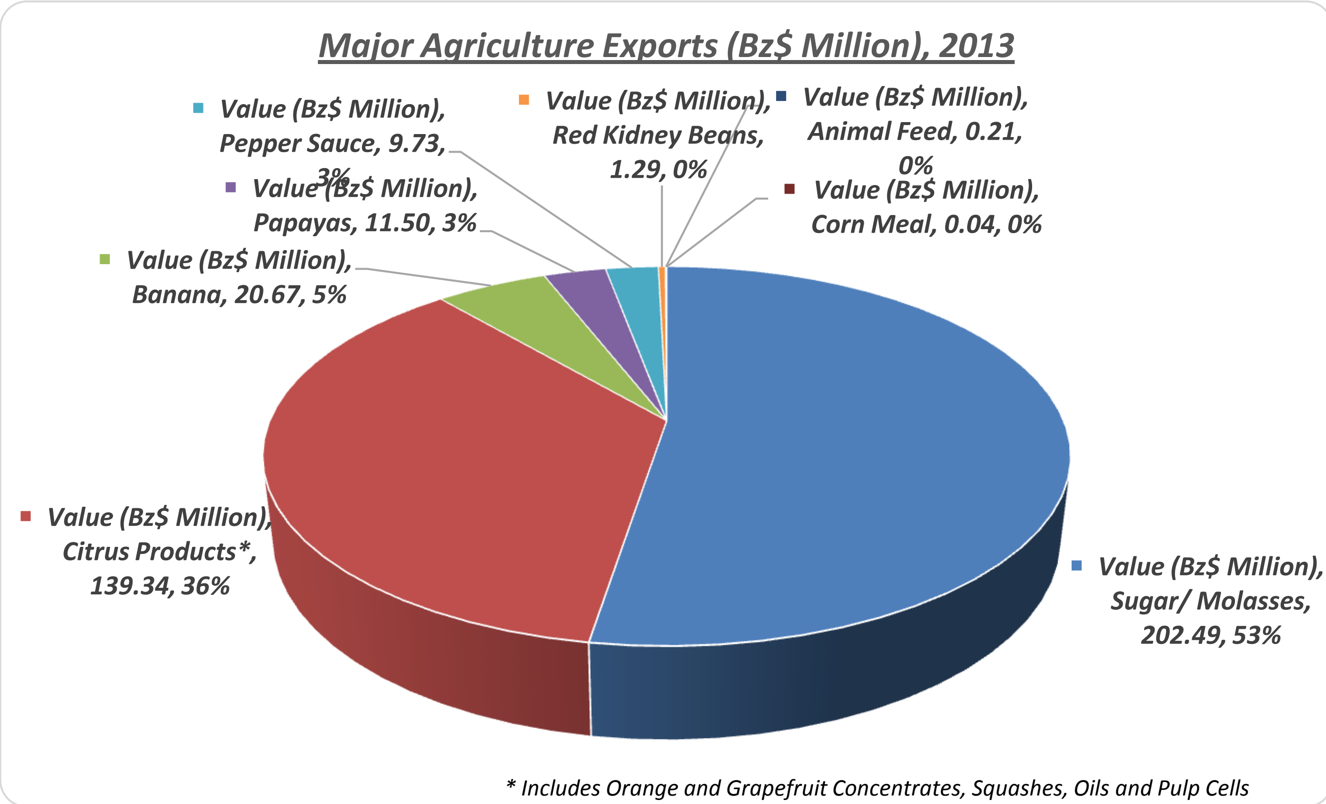
Closer examination provides a clearer appreciation of the importance of agriculture to the Belizean economy. In 2013, the total value of exports was BZ$ 678.61 million. As Figure 1 (b) below shows, agriculture accounted for 385.28 million or 61% of all exports. Exports of crude petroleum at BZ$ 140.19 million or 22% and marine products at BZ$ 79.84 or 13% were a distant second and third place, respectively.

Figure 1 (c): Value of Exports by Major Categories 2013 (Source SIB, 2013)



Further analysis of the performance of the agriculture sector shows the range of products which are exported and their relative importance. Clearly, sugar citrus and bananas are still the most important commodities. Papayas, pepper sauce, beans and animal feed are newer and less significant contributors to agriculture export earnings.

Figure 1 (d): Major Agriculture Exports (BZE$ Million), 2013 (Source: SIB, 2013)



1.1.5 Critical Issues in Agriculture and the Belizean Economy

Structure and Ownership

The structure and ownership patterns in the four major agricultural export subsectors are critical to the growth, development and sustainability of these subsectors themselves and the broader macro economy. A total of 5,444 individual farmers in the Corozal and Orange Walk Districts make up the sugar sub-sector thus the income generated from the sugar industry has broad impact on household incomes and livelihoods in these two districts.

In the citrus sub-sector, a total of 591 farm families in this industry benefit directly from the incomes and dividends generated. The number of farmers indicates a lesser national impact than the sugar industry; however, it has immense importance to the Stann Creek, and Toledo Districts where citrus farms are located and where the combined levels of indigence and poverty are higher than the national average.

The situation is quite the converse in the banana and aquaculture sub-sectors. These two industries comprise eight and nine owners of banana farms and shrimp production units, respectively. The ownership structure indicates that profits and dividends generated by these industries do not have the same broad impact on household and individual incomes as the previous two industries.

Employment

In September 2013 Belize's unemployment rate stood at 14%. One of the important considerations for the national economy is always how well it absorbs its workforce. In examining the composition of the workforce and where they are engaged, the results are interesting. Wholesale and Retail Trade and Repairs at 21,943 employees is the category that absorbs the largest number of workers. This is the followed closely, in second place, by Agriculture, Aquaculture and Related Activities with 21,669 employees and Community, Social and Personal Services in third place with 20,070 workers. An important observation is that though frequently indicated in public statements and notices, Tourism at fourth place employs only 18,850 workers. The fact is that the first three categories of employment absorb one in six workers and the Tourism industry only one in seven. This information further demonstrates the need to closely analyse the performance of these sectors during the decision making process.

Table 1 (c): Employment by Major Industry by Gender

Main Industry Employed by Sex				
	Male	Female	Total	Ratio of Persons Employed by Industry
Wholesale and Retail Trade; Repairs	13,163	8,780	**21,943**	**6**
Agriculture and Related Activities / Aquaculture	19,657	2,012	**21,669**	**6**
Community, Social & Personal Services; Extra Territorial Organisations & Bodies	7,611	12,459	**20,070**	**6**
Tourism	10,660	8,190	**18,850**	**7**
Government Services; Compulsory Social Security	8,389	6,495	**14,884**	**9**
Construction	8,215	395	**8,610**	**15**
Manufacturing	5,603	2,725	**8,328**	**15**
Real Estate, Renting and Business Activities	3,026	1,600	**4,626**	**28**
Financial Intermediation	1,113	1,776	**2,889**	**44**
Transportation Storage and Communication	2,186	372	**2,558**	**50**
Electricity and Gas and Water Supply	1,164	309	**1,473**	**87**
Forestry, Logging and Sawmilling	590	9	**599**	**214**
Mining and Quarrying	522	26	**548**	**234**
DK/NS	800	429	**1,229**	**104**
Total	**82,699**	**45,577**	**128,276**	
Source: SIB (LFS September 2013)				

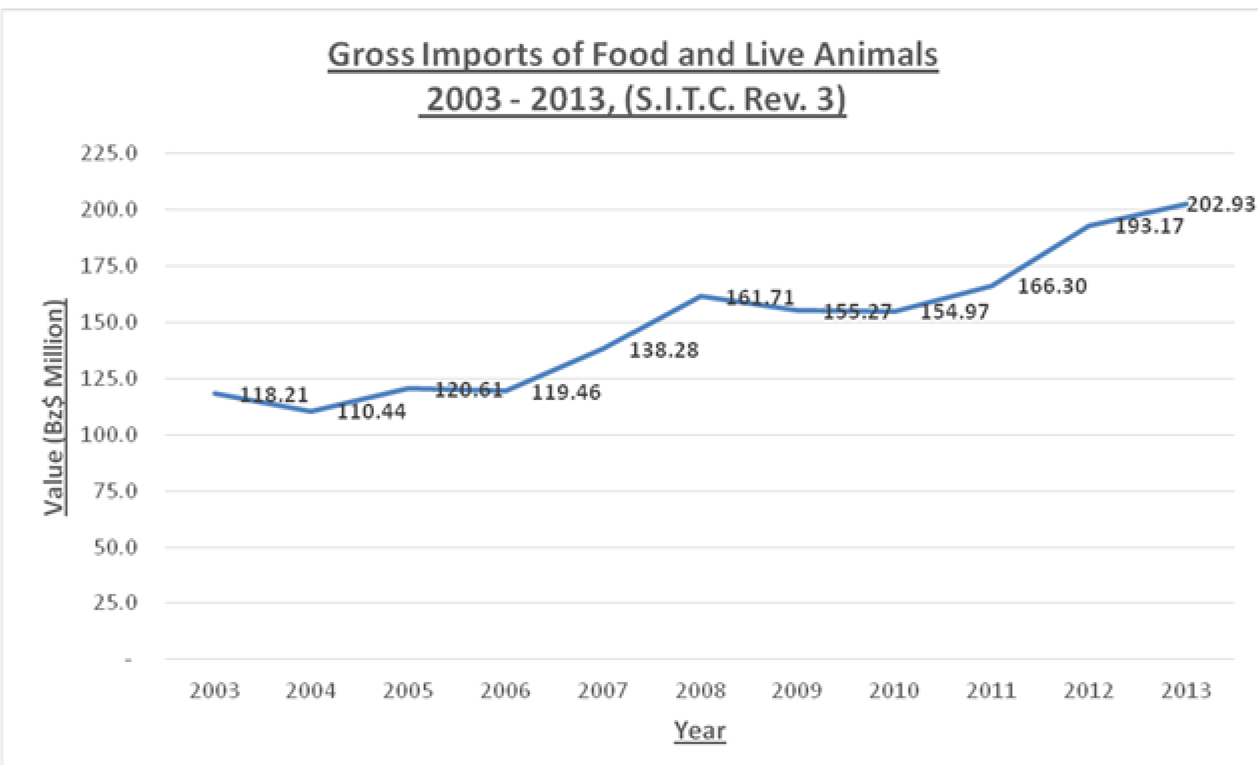
Food and Nutrition Security

Agriculture is critical to Belize's development for foreign exchange earnings and savings, employment, income generation, food and nutrition security. The importance of nutrition security should not be understated as there is a recognized direct correlation with the health of a nation's populace and its consequent productivity and economic development. Belize is considered food secure in basic grains, root crops, livestock, fish and seasonally available vegetables and fruits, from a production standpoint. Socio-politically there are major pockets of food insecurity due to issues of access and distribution. Production food security though long standing, should not be taken for granted since serious threats exist as evidenced by the rising costs of production phenomenon experienced in 2008, and the impacts of the recent bout of excessive rainfall in late 2013 and early 2014. In both cases the nation took note as there was a temporary shortage of some regularly produced commodities, followed by significant increases in consumer prices.

A national food and nutrition security policy was developed in the early 2000's and is supported by a multi-sectoral commission currently chaired by a Ministry of Agriculture appointee. The ministry undertook a primary school vegetable gardens programme with FAO assistance for over a decade and there have been recent attempts at urban gardening to address the critical nutrition insecurity in particularly vulnerable neighbourhoods in the nation's old capital. Both agriculture and education ministries have expressed the desire and intent to institutionalize the school vegetable gardens programme but this has not been brought to fruition.

Food Imports

Figure 1 (e): Gross Imports of Food and Live Animals (Source SIB, 2013)



The value of food imports has grown from 119.21 BZ$ Million to 202.93 BZ$ Million in the 10 year period from 2003 – 2013. This reflects an average annual growth rate of 5.9% over that period. When compared to the growth rate of the population, 2.56%, it clearly shows that the demand for imported food items more than doubled the population growth rate.

Population Growth

Belize's population is growing at an estimated rate of 2.56% per year. If this is maintained, it should double the current population in about forty years. Based on the projections from the Statistical Institute of Belize (SIB), this growth will also be accompanied with decreases in infant mortality and increases in life expectancy. This will translate into a larger, older and more dependent population with greater food and nutrition needs. If Belize's food supply is to remain reasonably secure, then the growth rate of the agriculture sector must match or exceed the rate of population growth.

Table 1 (d): Population Projections 1980- 2050 (Source SIB, 2013)

Constant Variable Projections

Total Population 1980 to 2050			
Year	Total	Male	Female
1980	143,792	72,749	71,043
1985	162,633	82,251	80,382
1990	185,217	93,489	91,728
1995	214,860	108,269	106,591
2000	246,136	123,920	122,215
2005	277,409	139,547	137,862
2010	313,198	157,425	155,773
2015	353,541	177,607	175,934
2020	397,903	199,783	198,120
2025	445,555	223,600	221,955
2030	496,634	249,122	247,512
2035	551,823	276,641	275,182
2040	611,757	306,447	305,310
2045	676,553	338,718	337,835
2050	746,518	373,612	372,906

Infant Mortality				
Year	Infant Mortality Rate (by 1000)	Age 0	Age 0-4	Age 1-4
1980-1985	46.1	1,378	1,564	186
1985-1990	42.1	1,326	1,457	131
1990-1995	28.1	988	1,068	80
1995-2000	22.0	813	857	44
2000-2005	18.0	667	708	40
2005-2010	16.0	674	715	41
2010-2015	14.2	672	714	42
2015-2020	12.8	662	704	41
2020-2025	11.4	641	681	40
2025-2030	10.2	616	655	39
2030-2035	9.2	611	650	40
2035-2040	8.3	604	644	40
2040-2045	7.5	604	644	41
2045-2050	6.8	596	637	41

Life Expectancy at Birth 1980 to 2050			
Life Expectancy			
Year	Total	Male	Female
1980-1985	65.69	63.76	67.67
1985-1990	67.46	65.00	70.00
1990-1995	70.10	68.06	72.21
1995-2000	71.44	69.76	73.18
2000-2005	72.64	70.96	74.38
2005-2010	73.74	71.96	75.58
2010-2015	74.74	72.96	76.58
2015-2020	75.64	73.76	77.58
2020-2025	76.44	74.56	78.38
2025-2030	77.24	75.36	79.18
2030-2035	77.89	75.86	79.98
2035-2040	78.54	76.36	80.78
2040-2045	79.04	76.86	81.28
2045-2050	79.54	77.36	81.78

Conclusion

This review clearly demonstrates the continued importance of the agriculture sector to the Belizean economy. Agriculture makes critical contributions to Belize's national income, foreign exchange earnings, employment and food and nutrition security for the fast growing population.

1.2 Environmental Context of Agriculture

1.2.1 Watersheds and Main Cropping Zones

Belize is uniquely endowed with substantial surface and groundwater resources. A dependable tropical/subtropical rainfall regime in the northwest Caribbean region and Central America replenishes the freshwater resource after extended dry periods, which are often induced by recurrent atmospheric/oceanic phenomena such as El Niño Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), and feedback mechanisms associated with Climate Change. However, increased demands for freshwater resulting from population growth, expanding economic activity, energy production and agricultural production are threatening the quality and availability of the country's freshwater resources. Coupled with these is the added stress on the resource induced by increasing climatic variability and climate change effects witnessed over the past two decades.

Belize has a total of 18 major river catchments with another 16 sub-catchments, which drain the Maya Mountains and the higher elevation of the interior, and discharge into the Caribbean Sea. The Hydrology Unit of the Ministry of Natural Resources and Agriculture divides the country into four water basin regions, namely: Region 7 in the north, Region 9 in the west and central corridor, Region 11 comprising the coastal plain and coastal slopes, and Region 13 in the extreme south.

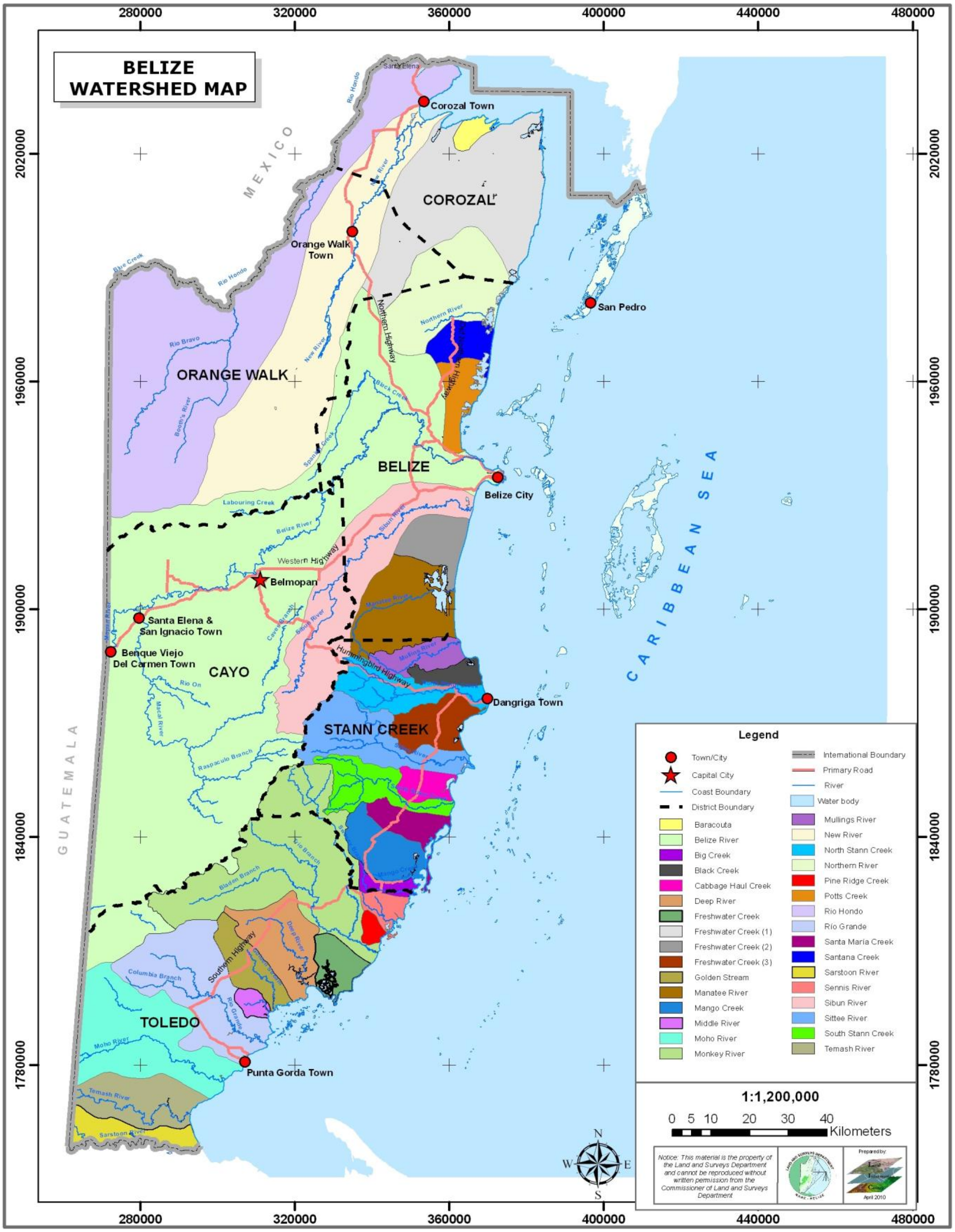
Figure 1 (f) below is a watershed map of Belize, showing the 18 main watersheds and about 16 minor watersheds draining the mainland of Belize.

Groundwater is a vital source of freshwater in rural Belize, where almost 95 % of the freshwater supply comes from groundwater sources. (Rural Water Unit, Ministry of Rural Development). Groundwater is extracted in rural areas through the use of hand pumps and rudimentary water systems, although the former is gradually phasing out. The Rural Water Unit is primarily responsible for drilling wells and installing pumps. It also works closely with communities in the development of rudimentary water systems, which are financed jointly by the Government of Belize through the Social Investment Fund (SIF) and United Nation's agencies such as UNICEF, PAHO, and UNHCR.

The total volume per capita of renewable freshwater in Belize for 2008 was 53.156 thousand cubic meters, one of the highest in Latin America (FAO Aguastat, 1988-2008). In additions, numerous freshwater and brackish water lakes or lagoons are scattered in the central and northern coastal and inland low-lying areas.

Potable water supply for urban communities and some rural settlements, and the provision of sewerage services for Belize City and Belmopan are provided by the Belize Water Services Limited (BWS), a semi- autonomous water company. BWS manages water supply systems for nine urban areas and some fifty-six rudimentary systems.

<u>Figure 1 (f): Watershed map of Belize</u> (Source: LIC, MNRA 2014)



1.2.2 Soils of Belize

The soils of Belize are classified according to the land regions or important groups of land systems they are attributed with as described in the land resource assessments conducted by King et al. (1986, 1989, and 1992). The soils can also be grouped into nine categories as listed in Table 1 (e) (Simpson, 2009). This categorization describes the main soils in their physiographic groups.

Table 1 (e): Soil Categories in Belize

Soil Category	Soil Type/ Groups
1	Soils of the Maya Mountain - Soils of the Mountain Pine Plateau - Soils of the rugged land systems
2	Clays of the limestone uplands and foothills
3	Grey and brown soils of the Toledo Beds
4	Pine ridge soils of the coastal plain
5	Dark limestone clays of the Northern coastal plain
6	Reddish limestone clays of the Northern coastal plain
7	Swamp soils
8	Young soils on river alluvium
9	Young coastal soils

(Source: Simpson, 2009)

The lands of Belize have also been categorized into five agricultural land classes or grades, representing their potential for agricultural use and limitations such as drainage, shallowness, low fertility, lack of moisture in the dry season and steepness. Table 1(f) is a summary of the Agricultural Land Class or Grade.

Approximately 16% of the land in Belize is suitable for mechanized agriculture with income potential and/or good financial success. Of this amount, 4% is Grade 1 land suitable for most crops. The greater portion of this land is under citrus and banana cultivation. Grade 2 land comprises the remainder of the mechanized agriculture lands and includes a large portion of the northern coastal plain under sugarcane production.

Table 1 (f): Agricultural Value of Lands in Belize

Land Category	Land Class/Grade	Area (km^2)	% of Total	Recommended Use
High income potential	1	990	4	Agriculture
Good financial success	2	2,790	12	Agriculture
Success subject to skill management	3	4,480	20	Forestry/Agriculture
Marginal	4	4,470	20	Forestry/Protection
Mostly steep land	5	10,000	44	Protection

(Source: Simpson, 2009)

Grade 3 land makes up about 20 % (4,480 km^2) of Belize's land, similar to the Grade 4 class. Grade 3 land requires skill management and substantial investment for acceptable returns. The Grade 4 land are marginal lands and are best left under forests if demands for additional agricultural land are low. Grade 5 land comprising about 44 % of the total land mass are lands that are very marginal. These are the steep slopes of the Maya Mountain and areas with limestone karst. In summary, Grade 1 and 2 lands are suitable for cultivating food and cash crops, while Grade 3 land may be used for small holder development; Grade 4 land for forest and plantation crops and Grade 5 land is best left under forests. Grade 4 and 5 land under cultivation are prone to erosion, and measures should be enforced to discourage cultivation on these marginal and steep terrain, which may accelerate runoff, reduce ground water replenishment and increase land degradation.

Wetlands such as the Crooked Tree lagoons, the swamp floodplains of the New River, other wetlands of the main river basins and coastal lagoon systems, are natural reservoirs that hold excess floodwaters during the rainy season, and gradually release the water during dry periods. These wetlands should be preserved and agriculture expansion into these sensitive areas should be discouraged. Many of Belize's protected areas and Forest Reserves are recharge areas for groundwater. They also attenuate surface runoff during storm events. De-reservation of sections of these sensitive Forest Reserves for agriculture expansion is unsustainable and should also be discouraged.

1.3 Agriculture Systems and Crops

Approximately, 800,000 hectares or about 38% of Belize's total land area is considered potentially suitable for agriculture, but only 9.7% (about 78,000 hectares) is used for crop and livestock production. About half of this area is under pasture, with the remainder in a variety of permanent and annual crops. The traditional export commodities sugarcane, citrus and bananas, along with the more recently developed aquaculture industry are the most significant for foreign exchange earnings. These commodities are produced in specific zones, and benefit from an organized marketing, and to some extent, production system. Rice, corn, beans and livestock (primarily poultry and cattle) are considered the staples of the Belizean diet and critical to food security. Corn, beans and cattle are also exported. The "staples" are produced throughout the country with varying degrees of sophistication ranging from the "milpa" or subsistence to the fully mechanized operations. According to the Bureau of Western Hemisphere Affairs2, the traditional system of "milpa" (shifting cultivation) involves the annual clearing of new land for crop production; however, increasing numbers of farmers are making permanent use of cleared land by mechanical means.

The current structure of agriculture in Belize is characterized by three main sub-sectors: a) a fairly well organized traditional export sector for sugar, banana, citrus, and marine products which are the principal sources of agricultural employment and foreign exchange earnings. b) a small-scale farm sector, producing food mainly for local consumption, and c) a well-integrated large-scale commercial sector (i.e. Mennonites). The Mennonites do not participate in the traditional export sector, but they do export food products (corn, beans, and cowpea).

A recent agriculture census in Belize shows that there are approximately 12,000 farmers, 24% of farms have less than 5 acres, 33% between 5 and 20 acres, and 74% of farms in the country are below 50 acres. (FAO, 2011) The majority of land used for agriculture (37%) has been classified as shifting cultivation and unimproved pasture, followed closely by mechanized agriculture of corn, beans, and rice (34%) practiced primarily by the Mennonites.

Vegetables are produced mainly by small farmers scattered throughout the country for the domestic market. Vegetable producers are of varied philosophies including the strictly cash crop approach to the recognized health benefits and desire to offer the paying consumer a more wholesome product.

Livestock production includes mainly beef cattle, dairy cattle, poultry, and pigs, although there is growing interest in sheep rearing.

Belize's agriculture policy has emphasized market-led strategies, increasing diversification and achieving self-reliance for food products as main goals. This has resulted in the development of new export commodities (papayas, aquaculture, habanero peppers) and an expansion of the food crop and livestock sub-sector. Hot pepper is grown for processing into hot sauces for both the domestic and export markets, and an increase in the quantity of onions produced mainly in the northern districts has reduced importation of this commodity by almost fifty per cent.

About 10 percent of the agriculture land under production at any given time is irrigated and the remainder is rain fed (Irrigation Unit, MNRA, 2013). Conditions for agriculture vary widely in Belize from the swampy lowlands in the north to very wet, alluvial floodplains in the south (GOB, 2012).

Table 1 (g): Characteristics of Crop Production in Belize

Crops	Production System	Districts	Topography	Type of Soil	Main Pests
1 - Sugarcane	Semi – mechanized	Corozal Orange Walk	Flat	Dark limestone	Froghoppers
2 - Citrus	Semi-mechanized	Stann Creek Cayo	Flat valley, rolling, slope	Red clay	Citrus greening
3 - Banana	Semi-mechanized	Southern Stann Creek	Flat, rolling	Red clay	Black Sigatoka
4 - Corn	Mechanized Milpa	Cayo, Orange Walk, Corozal, Toledo	Flat, rolling	Light clay	Armyworm
5 - Rice	Upland mechanized Irrigated-mechanized Milpa	Orange Walk, Cayo, Toledo	Flat, rolling and Hilly	Light clay	Rice blast Spinki mite
6 - R.K. Beans	Semi-mechanized	Cayo, Orange Walk, Corozal	Flat	Light clay	Web blight
7 - Vegetables	Semi-mechanized non-irrigated Irrigated	Corozal, Orange Walk, Cayo, Belize	Flat	Alluvial and light clay	Fungi & insects

(Source: Trujillo, M., MNRA Central Farm, 2014)

1.3.1 Sugarcane

Sugar cane is cultivated in the Orange Walk and Corozal Districts in northern Belize, mainly in the low lands and flood plains of the New River and the Rio Hondo and its tributaries. The region is prone to floods particularly in the middle and upper reaches of the Rio Hondo. Total acreage under cultivation is about 60,000 acres. The annual production of sugarcane biomass is a little over 1 million tonnes with a conversion rate to sugar of about 9:1.

Figure 1 (g): Sugar production (2000 to 2013)

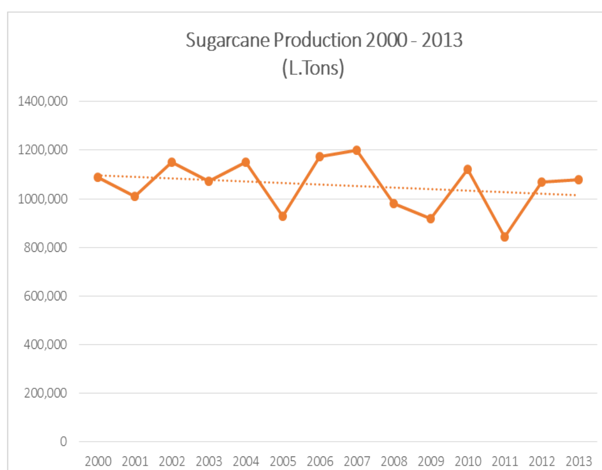
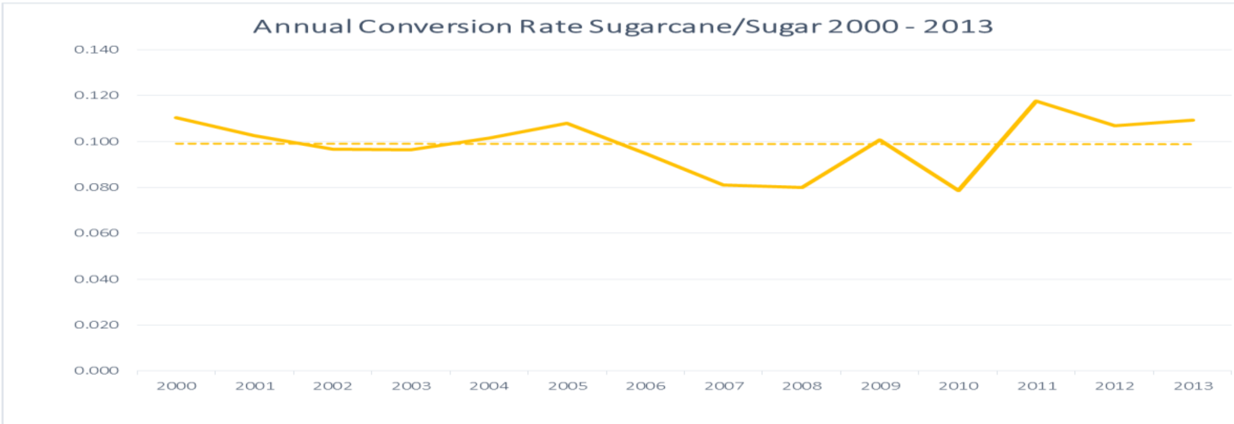


Figure 1 (h): Annual Conversion Rate Sugarcane (2000 – 2013)



(Source: Sugar Industry of Belize, 2014)

The industry consists of 5,444 farmers including the processor, Belize Sugar Industries Limited (BSI) which has the largest holding. Ninety per cent of farmers are small holders with farm sizes less than 20 acres, of which 35% are less than 5 acres.

The industry provides direct employment to about 4,800 workers in addition to the registered sugar cane farmers, and it is estimated that some 40,000 people are dependent on the industry, equivalent to almost 15% of Belize's population.

Production

The production system is rain fed monoculture with use of mineral fertilizers and the deployment of manual and chemical weed control practices. Chemical pesticides are primarily used for control of the major pest, the sugarcane froghopper *Aeneolamia postica*, which can account for 30% reduction in yields. The life cycle of this pest is also affected by the current practice of burning sugarcane fields before manual harvesting. Recently a biological control agent, the entomo-pathogenic fungus *Metarhizium anisopliae* was introduced on a limited scale for control of the froghopper.

The dominant sugarcane variety grown in northern Belize is the Barbados - B79474 variety. Planting is carried out in June-July and the crop is harvested 11 months later. Under the current practice yields are low with this variety and farmers are experimenting with new varieties, changes in planting season and extended harvesting dates to improve yields.

Best practice for high yields requires about 16% or 10,000 acres of cane to be replanted annually, however only 3,000 acres are replanted annually, resulting in over-aged rattoon yielding less sugar content as compared with best practices.

The industry plans to rehabilitate 7,000 acres over the next three years. Under the Accompanying Measures for Sugar (AMS) 2008 and AMS 2010, € 6.5 M or BZ$ 16.00 million has been made available to the Government of Belize through a Contribution Agreement with the CDB to provide loans to sugar cane farmers. The program is managed by the Development Finance Corporation for replanting and rehabilitation of approximately 2,600 acres annually. The Sugar Industry Research and Development Institute (SIRDI) is a co-facilitator of the replanting programme by undertaking the technical evaluation of each financing proposal and advising on best practices for efficient sugar cane production.

Structure of the Sugar Industry

The sugar industry is privately owned but is regulated by the Government of Belize through the Sugar Industry Control Board (SICB) under the provisions of the Sugar Industry Act, Chapter 325 of the Laws of Belize, Revised Edition, 2003. The sector is complex with a heavy institutional, organisational and operational structure. Farmers are organised within the Belize Sugar Cane Farmers Association (BSCFA), which, amongst others responsibilities, negotiates the price of sugar cane delivered to the manufacturer, makes loans to growers, deals with agricultural inputs, and provides agricultural services.

The SICB executes its regulatory functions through the Sugar Cane Production Committee (SCPC), Sugar Cane Quality Control Authority (SCQCA), and the Sugar Industry Research and Development Institute. The SCPC is responsible for the coordination of the harvesting and delivery of sugarcane to BSI’s Tower Hill Factory.

Marketing

All sugar cane produced is sold to the privately owned sugar processing plant of the Belize Sugar Industries Limited (BSI), located in Orange Walk District. It is a subsidiary of American Sugar Refining. The bulk of raw sugar produced is exported to the EU under the current EU-ACP Economic Partnership Agreement (EPA). Under the EU quota a portion of the sugar exports is paid a Fair Trade premium. Earnings from Fair Trade are designated for actions to improve farmers’ production systems and community well-being. In 2011, 67,000 tonnes were exported to the EU, 16,500 tonnes to the US market and approximately 15,000 tonnes of sugar were sold on the local market. In 2013, out of a total production of 118,140 tonnes, 94,541 tonnes were exported to the EU as White Sugar Equivalent and 13,065 tonnes were sold on the local market.

Niche Marketing

In 2013 9,353 tons went to a niche market in Europe as Direct Consumption (DC) sugars at a premium price of €565.00 or BZ$1,249.94 per metric ton. This price consists of a basic price of €335.20 per metric ton plus an additional premium of €229.80 (Personal communication, BSI, 2014)

Prices on the EU market are expected to drop substantially in 2017 with the demise of the sugar quota, and the industry will have to step up its productivity to be able to survive the increased competition from beet sugar production.

BSI has diversified into co-generation of electricity, using bagasse as the fuel source. Belcogen, a wholly owned subsidiary of BSI, installed a 32.5 Mega Watt Hour (MWh) plant which eventually will meet about 20% of Belize's national electricity needs.

Constraints

In addition to low productivity the industry is constrained by inadequate road network in the Sugar Belt which increases transportation costs for delivery to the factory, plus no access for deep sea vessels in the proximity of the factory. Sugar and molasses have to be transported from the factory by barges a distance of 122 miles to a deep water anchorage offshore from the port of Belize City, resulting in unduly high handling and freight costs.

Inadequate drainage infrastructure was evident after an extended rainy season in 2013 and subsequent flooding in the sugar region delayed the start-up of the harvesting season.

Improvements in the industry

First introduced in 2011-2012, the establishment of an improved delivery system has brought about improved quality of cane delivered, increased efficiency of the sugar factory and consequently improved payments based on the quality of the cane delivered.
Following a feasibility study, stakeholders have agreed to rationalise the factory-to-ship transport of processed sugar and molasses. Once a proposed offshore transfer terminal with modern discharging equipment is installed, there will be higher delivery rates to the ocean going vessel and shorter anchorage time. This will translate into better economies of scale, lower transportation costs and higher returns to the sugar industry.

There is an on-going roads rehabilitation and upgrading program initiated under the Accompanying Measures to Sugar (AMS) programme. Roads were prioritised in 2008 using socio economic selection criteria which used population, land development, agriculture, tourism and other aspects of strategic importance. The GOB has established a road maintenance fund and corresponding implementation unit to ensure that road maintenance are programmed into current use of the road infrastructure.
A project being undertaken by the Caribbean Development Bank (CDB) and the Food and Agriculture Organization (FAO) is developing an investment plan for irrigation and drainage and aims to establish a strategic pilot drainage project in sugarcane.

New Developments in Sugarcane

In 2013 a new foreign owned company, Green Tropics, started extensive land clearing, infrastructure development and establishment of sugarcane plots with a stated intent to establish 20,000 acres of sugarcane in the Cayo District for export into or via the Guatemalan market.

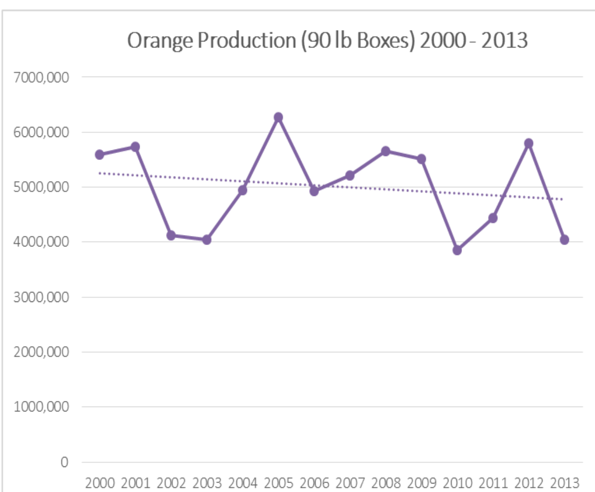
1.3.2 Citrus

Citrus cultivation is concentrated in the southern district of Stann Creek with smaller acreages in the central districts of Cayo and Belize and the southernmost district of Toledo. The total area under cultivation is about 38,813 acres of Valencia oranges and 6,863.8 acres of Grapefruit (White Navel variety). In early 2014 there were 591 citrus growers with 80 large growers accounting for 90% of total citrus production and the remaining 10% produced by some 511 small growers (Personal Communication) Citrus Growers Association, May 2014). Yields are very variable amongst well-resourced and resource poor farmers ranging from about 100 boxes to about 350 boxes per acre prior to 2013.

The industry employs about 1.2% of the national labour force (1,641 workers in 2010), and contributes approximately US$ 69 million to foreign exchange earnings. Its contribution to GDP rose from 2.5% in 2011 to 3.5% in 2012.

In 2012 citrus production totaled 6,007,737 boxes (90lb box) of oranges and 964,180 boxes (80lb box) of grapefruit. Production has since declined to 4.0M (90lb) boxes in 2013 due to the onslaught of the Citrus Greening disease (Huanlongbing, HLB), which could devastate the industry if not controlled in the citrus orchards of the Stann Creek, northern Toledo and Cayo Districts.

<u>**Figure 1 (i): Orange Production (2000 to 2013)**</u>



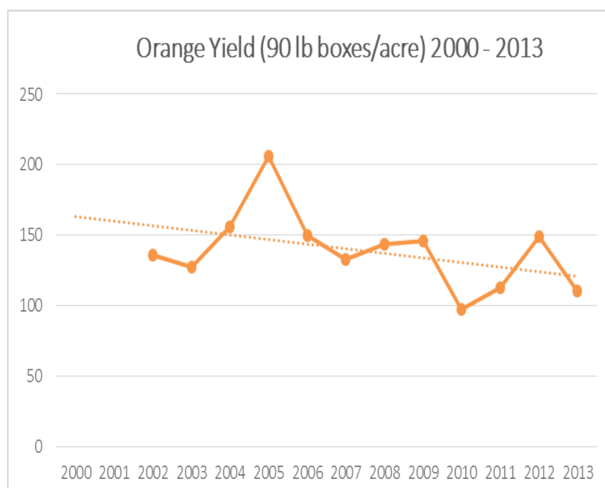


Figure 1 (j): Orange Acreage (2000 to 2013)

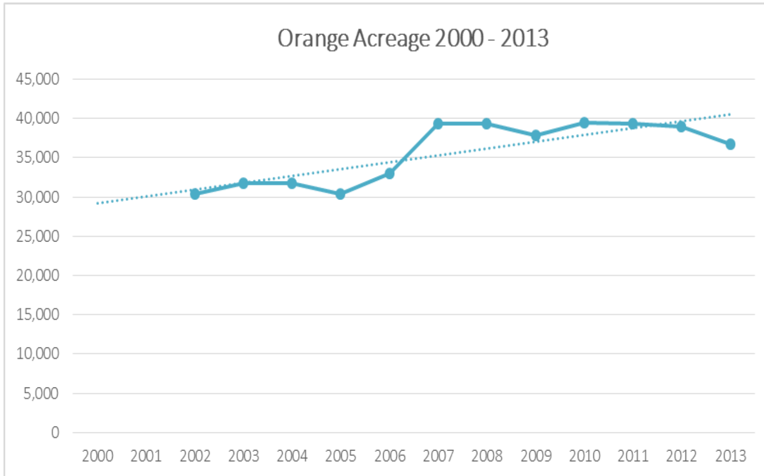
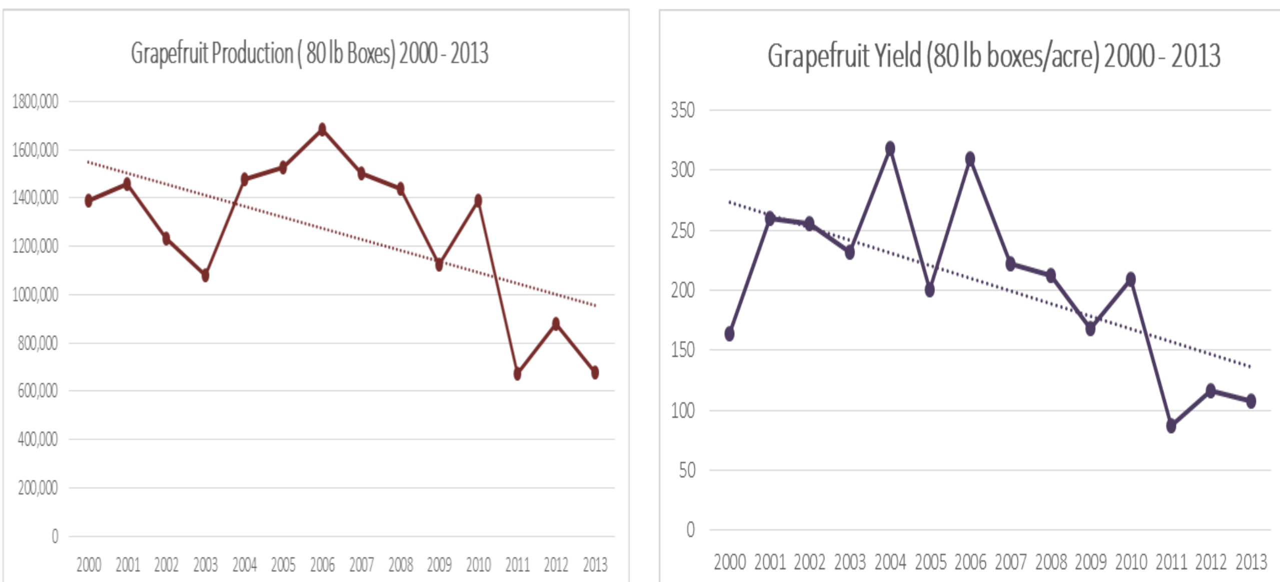


Figure 1 (k): Grapefruit Production (2000 to 2013)

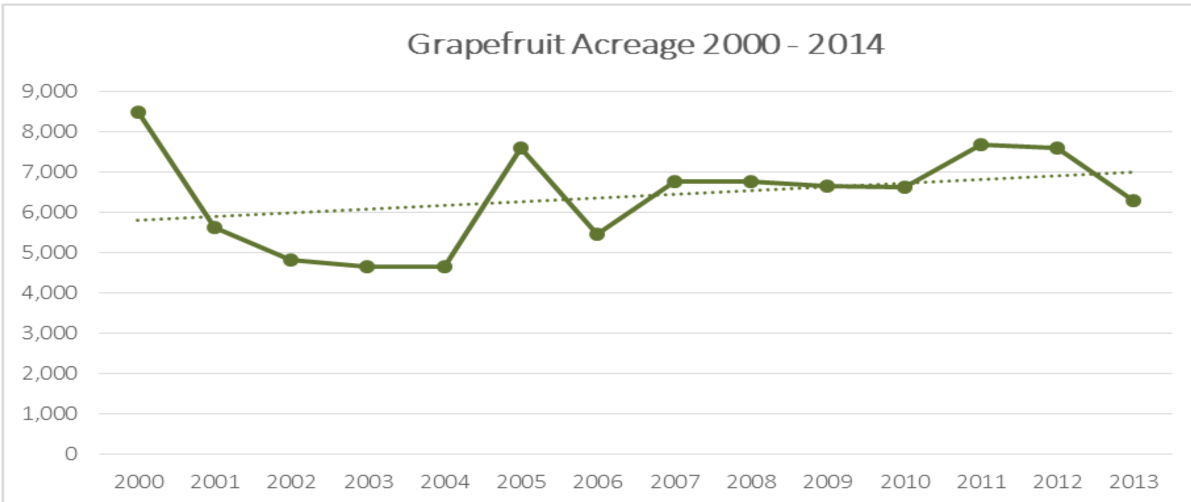


(Source: Citrus Growers Association, 2014)

Structure of the Citrus Industry

The Government of Belize through the Citrus Control Board regulates the industry under the provisions of the Citrus Processing and Production Act, Chapter 277, Revised Edition of 2000. The citrus industry is privately owned and farmers are now organised in two organizations, the long standing Citrus Growers Association (CGA) and the recently formed Belize Citrus Mutual (BCM). Generally the BCM growers have more access to financial resources than the larger numbers of CGA growers. Both associations, amongst others responsibilities, negotiate the price of citrus delivered to the processor, facilitate loans to growers, deal with agricultural inputs, and provide agricultural services. The CGA runs a research and extension program through its technical support arm Citrus Research and Education Institute (CREI).

Figure 1 (l): Grapefruit Acreage (2000 to 2014)



(Source: Citrus Growers Association, 2014)

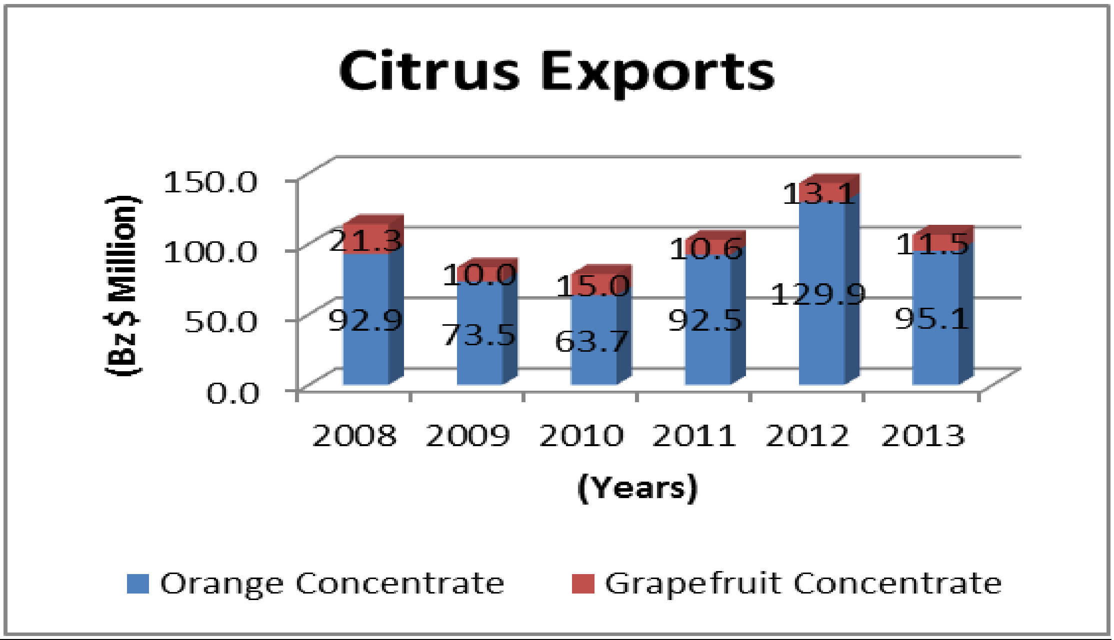
Production and farming practices: Citrus is produced under a rain fed monoculture system that includes extensive use of mineral fertilizers, and the application of dolomitic lime to adjust the extremely low pH soils characteristic of the southern districts. Weeds are controlled by a combination of mechanical, manual and chemical methods and chemical pesticides form part of an integrated pest management system to control other pests and diseases. Citrus production has been plagued by a number of introduced pests and diseases in recent years including the Brown Citrus Aphid, vector of citrus Tristeza virus, exocortis, and leprosis and now the Asian Citrus Psyllid, vector of HLB. Previous to the introduction of HLB the industry has been able to handle the various phyto-sanitary crises due to the vigilance of CREI in monitoring the pest and disease status of the industry and development of remedial measures.

Marketing

Citrus growers provide Citrus Products of Belize Limited, the main processor, with citrus fruits, mainly oranges and grapefruits.

Belize exports most of its citrus products (frozen concentrate) to the United States of America. Other export markets are Japan, Latin America, the Caribbean and the European Union. Total frozen concentrate exports 2008 to 2013 are indicated in the figure below.

Figure 1 (m): Citrus Exports



Source: Ministry of Agriculture and Natural Resources, 2014

Constraints

The major challenge to maintain or increase the level of citrus production is the effective management of the HLB (Citrus Greening) disease through the production of high quality disease-free citrus plants for the rehabilitation of citrus orchards and the planting of new orchards, along with a controlled spray programme to control the insect vector. CGA has limited financial resources partly due to the division in the industry with the formation of the new organization BCM.

1.3.3 Banana

The Banana Industry is fully private sector led and highly commercialized. Foreign exchange earnings rose from US$17.5 million in 1990 to US$45.5 million in 2013 (personal communication General Manager BGA, 2014). It is characterized by a small number of relatively large plantations, all located in the southern districts of Stann Creek and Toledo. At present nine (9) growers/management companies own 23 farms with a total acreage of approximately 7,250 acres and are organised into a single growers association, the Banana Growers Association (BGA).

The industry has benefited substantially from technical assistance, infrastructural, equipment and operational inputs provided under the EU-ACP Special Framework of Assistance for Banana Protocol Countries from 1999 to 2008. The industry will receive further support under the new EU arrangement, the Banana Accompanying Measures (BAMS) which commenced in late 2013.

Production and farming practices

Bananas are grown in a perennial monoculture system. Farms are generally equipped with sprinkle irrigation systems and an extensive network of primary, secondary and tertiary drainage infrastructure since the plants consume a large amount of water but are also very sensitive to water logging. Production practices include extensive use of mineral fertilizers and chemical pesticides for controlling the major pest and disease, the banana nematode *R. similis* and Black Sigatoka disease. The use of disease-free meristem plants are recommended for replanting in new or fallowed land on a ten year rotation basis as best practice for nematode control and attainment of maximum yields. Black Sigatoka is managed on an industry wide basis by controlled aerial spray programmes carried out by the BGA's specialized Sigatoka control unit.

Key cultural practices such as weed control, population control, fruit protection, pest and disease control, fertilizers and nematicide application, drainage maintenance and harvesting are labour intensive. In 2010, 2,688 workers, about 2% of the national labour force, were directly employed by the industry.

Banana production ranged from approximately 3.6M boxes (40 lb) in 2000 to 5.4M boxes in 2013. During this period the highest production was 5.7M boxes in 2012. Banana is harvested on a weekly basis, but the bulk of the banana production is done in the last quarter of the year (personal comm., Banana Growers Association, 2014). The varieties produced are mostly the Grande Naine with smaller amounts of Williams, both of the Cavendish sub group. Yields range from a low of 380 boxes per acre in 2002 to a high of 820 boxes per acre in 2012.

Structure of the Banana Industry

Under the Banana Industry Act, Chapter 205, Revised Edition of 2003, the BGA has responsibility for (1) coordinating the production and the sale of bananas, (2) Ensuring marketing and accounts management with buyer, (3) Implementing disease control (Sigatoka), (4) Recommending quality production standards and giving agronomic advice to the farmers. It also distributes small inputs related to post harvesting and packing. At present no one can export banana except the Banana Growers Association. BGA buys the banana from the growers, sells it to the multinational marketing company, and subsequently pays the growers, deducting a fee for its services.

Marketing

The United Kingdom is currently the only export market for Belize. Bananas are marketed under the duty free quota free Economic Partnership Agreement (EPA) with the European Union. In the UK market, Belize banana has a good quality reputation and competes well with banana from Latin America. Fyffes has been the principal marketer of Belize banana throughout the various trade regimes and the sustainability of the industry will depend to a large extent on its competitiveness vis-à-vis Latin American countries and on its ability to negotiate arrangements with new buyers.

Niche market

About 60% of all the bananas go to non-standard packaging (special packaging prepared on the request of certain supermarkets). As this is difficult to do in other banana-producing countries, it gives Belize a competitive advantage. Usually limited quantities are required and preparation is time consuming (training of personnel and sometimes different materials used). However while for big plantations complying with this requirement is too costly, a small industry like Belize can more easily adapt.

Constraints

Financial management of co- existing enterprises and the need to prioritise investments have pushed some farmers to try and "cut corners" by introducing only some of the components of the optimal agronomic practices.

Inefficiencies in the production still affect significant improvement of yields. Key constraints to yield improvements include insufficient application of good agronomic practices, unscientific and inadequate pest management and need to upgrade old equipment. Deteriorated on-farm infrastructure such as over aged cableways and irrigation systems as well as insufficient capacity of packing facilities is not only increasing production costs but in some instances may already pose a danger for the workers. 25% of production costs is for the acquisition of expensive mineral fertilizers and 16% is incurred for pest and disease control. The recent considerable reduction in the duties paid by the non-ACP banana producers has made competition fiercer and margin of profit smaller for Belize exporters, which could delay indefinitely any serious capital investment by the farmers.

Current Actions and Future Plans

Increase the efficiency of banana production by developing best agricultural practices, while decreasing the environmental impact of the industry, to include composting, recycling, improved management of waste and water management.

Strengthening disease/pest management, which will result in a more resilient and environmentally sensitive industry by adopting an improved scientific approach to disease monitoring (including spore trapping) and control as well as to improve the efficiency of oversight and management of field operations.

1.3.4 Rice

Rice is produced mainly in the Orange Walk, Cayo and Toledo Districts. There are three production systems of rice in Belize, the mechanized irrigated, the mechanized rain-fed and the milpa system. Different varieties of rice are planted under the different production systems.

The mechanized irrigated and mechanized rain-fed systems are practiced in the Orange Walk District with acreages of 1,850 and 1,550 acres respectively.

Cayo and Toledo District farmers practice the mechanized rain-fed and the milpa systems of production. In 2012 the Cayo District cultivated 2,600 acres of mechanized rain-fed and 47 acres of milpa rice. The Toledo District cultivated 450 acres of mechanized rain-fed and 163 acres of milpa rice. In the past (ex. in 2000) the Toledo District was the leading rice producer, mostly by milpa system with 3,500 acres under production. In milpa rice production the crop is planted in late May and harvested in early September and October. All the operations from planting to harvesting are done manually and farmers do not normally use any chemicals.

Socio-economic importance

Rice is one of the main staples of the Belizean diet. It is estimated that some 16 million pounds of milled rice are consumed annually and domestic production is critical for Belize's food security. Although some rice is retained for subsistence use it is produced mainly as a commercial or cash crop, even by milpa farmers, since corn is more the dietary staple grain of the rural communities.

The most significant socioeconomic impact of rice production is in the southern district of Toledo where there are a total of 1,000 rice farmers out of which 120 milpa farmers are dependent on rice production for the major part of their meagre income. Earnings from the sub-sector are spread over a larger number of households in an area that has the highest rate of poverty in the country. Conversely, the bulk of Belize's rice production is done by 10 farmers in the Orange Walk District on large holdings with very sophisticated technology.

Figure 1 (n): Total Rice Production 2000- 2012

Source: Ministry of Agriculture and Natural Resources, 2014

Production

Total average annual rice production for the last 10 years has been 35 million pounds of paddy. Most recent available numbers (2012) show that 390,000 pounds were from milpa with an average yield of 1,779 pounds per acre. Toledo had the highest milpa rice production at just over 327,000 pounds and yields of 2,008 pounds per acre. The most efficient system for rice production is the mechanized irrigated system which yields up to 5,900 lbs. /acre. Rice is affected by a major pest, the Spinki mite, and blast (a fungal disease) that can cause yield losses of up to 20%.

Structure of the Rice Industry

The industry is comprised of a mixture of milpa, small and large mechanized farmers. The milpa and small mechanized farmers in Toledo are organized into the Toledo Grain Growers Association. The Association claims a membership of 1,000 members that farm exclusively in the Toledo District. The 10 large producers in the north are organized into the Belize Grain Growers Association, and produce 90% of the total rice output. The Government of Belize provides policy, regulatory and marketing input through the Ministry of Agriculture, BAHA, Pesticides Control Board (PCB) and the Belize Marketing and Development Corporation (BMDC).

Marketing

Rice production is primarily for the local market. Belizeans consume approximately 16.2 million pounds of milled rice annually which translates to approximately 25 million pounds of rice paddy. The BMDC is the major purchaser of rice paddy from the Toledo Grain Growers Association and the market stabiliser. The larger growers have separate milling operations and market independently under their own brand. This group is always seeking an export market and some of the surplus is being sold to Guatemala and CARICOM.

A niche market for pre-packaged long grain and brown rice has developed in Belize in recent years. This market is still very small but is growing in response to the health food trend that has developed in Belize.

Through the BMDC the GOB has supported rice farmers in the Toledo District with subsidized prices, mainly because of the traditional socio-economic importance of milpa rice production in that impoverished district. The subsidies are, however, also paid to the small mechanized farmers in the district and are considered unsustainable. The farmers practising the mechanized rain-fed system in the Toledo District are the most inefficient rice producers in the country and the government needs to make a policy decision with respect to the subsidies especially for the mechanized producers.

1.3.5 Corn

Corn is produced in all six districts of Belize under two production systems: mechanized rain -fed and milpa. From 2000 to 2012 the acreage under milpa production decreased from about 10,000 acres to about 4,000 acres, whereas mechanized production increased from 24,969 to 29,021 acres.

The Toledo District practices only the milpa system and size of farms range from half acre to 150 acres. The bigger farms are located near to the Belize Guatemala border.

There are approximately 3,000 small farmers located in the southern districts of Toledo and Stann Creek, and 350 large farmers located in the Cayo, Orange Walk and Corozal Districts.

Socio-economic importance

Corn is an important part of Belize's economy because it is used for direct human consumption, as livestock and poultry feed, and as an export commodity. Corn is the most important staple of the Belizean diet and a key commodity from a food security standpoint. It is estimated that the average Belizean household consumes an average of 1 lb of corn daily, and that approximately 100 million pounds are used domestically for both human and livestock consumption on an annual basis.

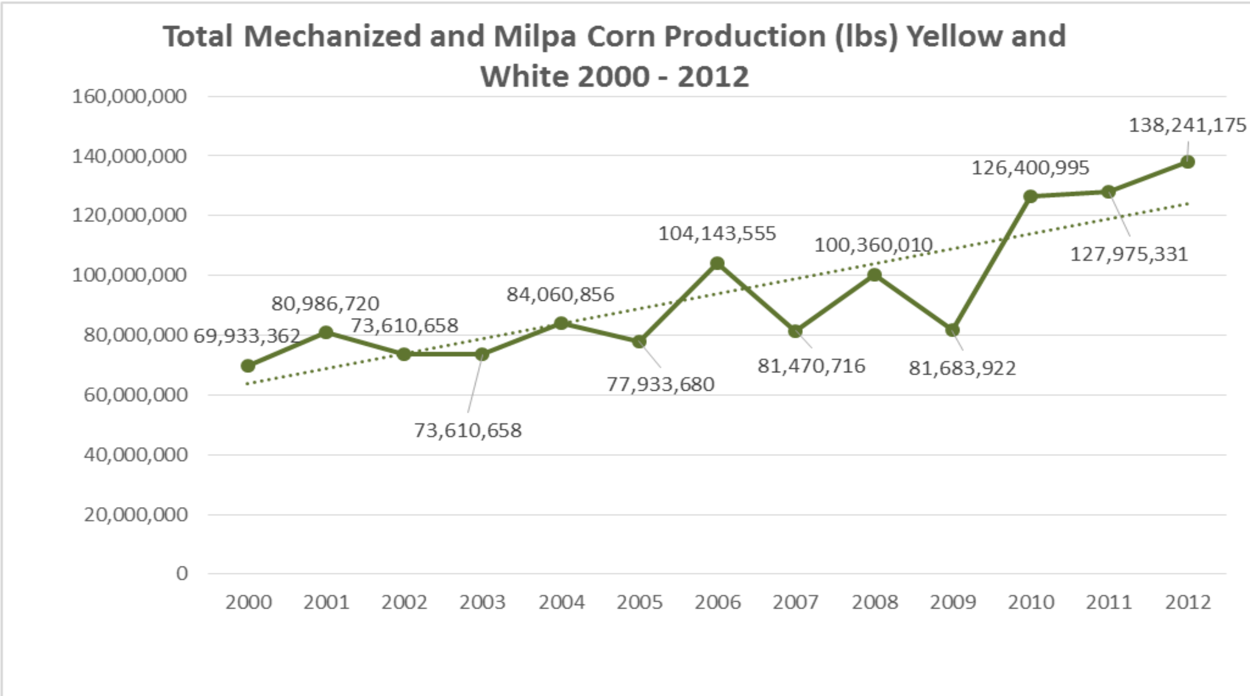
The primary socioeconomic importance of corn is as (i) a food staple for a majority of Belizean households. (ii) as currency for a large portion of small farmers, and (iii) a culturally important component of the diet for several ethnic groups particularly Mestizo and Maya. At the subsistence level, milpa production of corn is important in contributing to the daily diet as well as providing a form of quick currency for rural communities.

Production

Corn is mostly planted in June and harvested in October, with a second season from November to February. The main insect pests are the fall armyworm *(Spodoptora frugiperda*) and the corn earworm (*Helicoverpa zea*). High yielding hybrid varieties are planted under the mechanized system and insect pests are controlled with chemical insecticides. Milpa producers plant mainly "local" varieties of corn which have some natural resistance to the major pests, and consequently, pesticide use is minimal.

Annual corn production increased from 69 M lbs. in 2000 to 125 M lbs. in 2012. Of the 2012 production statistics, 14 M lbs. of white and yellow corn were produced by the milpa system with an average yield of 1,388 pounds per acre.

Figure 1 (o): Total Mechanized and Milpa Corn Production (2000 to 2012)



Source: Ministry of Agriculture and Natural Resources, 2014

Structure of the Corn Industry

The sub-sector is a mixture of milpa (subsistence), small and large mechanized farmers. The milpa farmers are concentrated in four districts (Belize, Cayo, Stann Creek and Toledo) and are generally not organized except in Toledo. In Toledo, a minority of the corn farmers form part of the Toledo Grain Growers Association, which is primarily organized for rice producers.

Large farmers in the Cayo and northern districts are organized into the Belize Grain Growers Association. The association has a membership of 350 farmers that produce about 90% of the combined total of yellow and white corn. These growers have adequate access to technical and financial resources which are made available primarily through the associations. The association is responsible for negotiating on behalf of producers with the Government on policy and regulatory matters and with existing and potential purchasers, primarily foreign markets.

Marketing

Farmers in the Toledo District are poorly organized and they operate and market individually. These farmers have limited negotiating capacity. They generally receive inputs provided through middle men primarily in Guatemala and the product is eventually sold to these same middle men at inferior prices.

The Belize Grain Growers Association and other farmers in the region mainly sell their product to Bel-Car Export and Import Company Limited, a private company which purchases corn, beans and cowpeas from local suppliers and exports to the Caribbean and other parts of the world. In the western and northern regions of the country whole corn and processed corn as mill feed is marketed, locally. Crushed corn for cornmeal is marketed exclusively to CARICOM countries primarily Guyana and Jamaica. Annual exports of cornmeal to Guyana and Jamaica are in the order of 780,000 lbs with 80% going to Jamaica. Twelve million pounds of grain corn are exported to Guatemala annually.

1.3.6 Beans

Beans of the *Phaseolus vulgaris* species which include Red Kidney (RK) beans, small red beans and black beans are generally produced as part of a corn-beans rotation system. The structure, composition, marketing arrangements and production systems of the beans sub-sector is therefore similar to that of corn, except that beans are harvested manually even in the large farm mechanized system. Beans is planted from November and December and harvested in February and March.

Mechanized farms generally produce a variety of R.K beans (usually California Light Red), with yields of about 800 lbs/acre. The sizes of mechanized farms range from 20 to 1,000 acres.

Milpa farmers produce various varieties of black beans or small red beans, which are more suitable to Belize’s agro-climatic conditions than RK beans, and obtain yields up to 1,000 lbs/acre. Milpa farmers plant retained seeds selected from the previous crop.

The major pests of beans are the *Diabrotica* beetles, the bean pod weevil (*Apion godmani*), and a fungal pathogen *(Thanateforus cucumeris)* which causes the disease known as web blight, all of which are controlled with chemical pesticides.

Socio-economic importance

Beans are one of the main staples of the Belizean diet and provide the major protein content of a primarily corn-beans diet for many poor rural households. It is estimated that some 8 million pounds of beans are consumed annually. At the subsistence level bean production is important in reducing household spending.

Bean production fluctuates mainly due to weather conditions and export market opportunities. In 2013 production fell due to adverse weather conditions (higher than normal rainfall), and the price of beans rose to a peak of BZ $3.50/lb on the local market. Total beans production ranged from about 13Mlbs in 2000 to about 20Mlbs in 2012 from respective acreages of 15,800 and 20,713 acres.

It is estimated that about 3Mlbs of beans are exported annually to neighbouring Guatemala at a price of around BZ $0.72/lb wholesale and varied quantities of RK beans are exported to the CARICOM market, primarily Jamaica at BZ$0.92 – 0.98/lb.

1.3.7 Vegetables

Vegetable production is done in all six districts of Belize, but mostly in the Corozal, Orange Walk, Cayo and Belize Districts. The main production systems practiced in the country are milpa or semi-mechanized small open plots and covered structures. Size of open plots ranges from 1/8 acre to about five acres. Covered structures are about 3,000 to 4,000 sq. ft. The main vegetable crops grown are cabbage, cucumber, hot pepper, okra, squash, pumpkin, sweet pepper, tomatoes, Irish potato, onion, carrots, string beans, lettuce, Chinese cabbage, cauliflower, broccoli, celery, cho-cho and sweet corn. Some farmers are organized into cooperatives primarily along product lines and community level. Each cooperative is primarily responsible for marketing the products of its individual members.

Socio-economic importance

Vegetable production is undertaken primarily by small farmers throughout the country.

At the subsistence level vegetable production is important in reducing household spending in the southern districts whereas they are mainly grown as cash crops in the Cayo, Belize, Orange Walk and Corozal Districts. Vegetables are not exported but production for the domestic market provides significant foreign exchange savings whilst contributing to the potential for nutrition security if widespread access and affordability can be secured for consumers across the nation.

Production

Total vegetable production ranged from about 15.6 Mlbs in 2000 to 14.6Mlbs in 2012 from respective acreages of 1,170 and 1,061 acres. Some vegetables are irrigated with a sophisticated drip irrigation system and some smaller plots may be irrigated manually with use of water hoses or buckets.

Figure 1 (p) Total Vegetable Production 2012

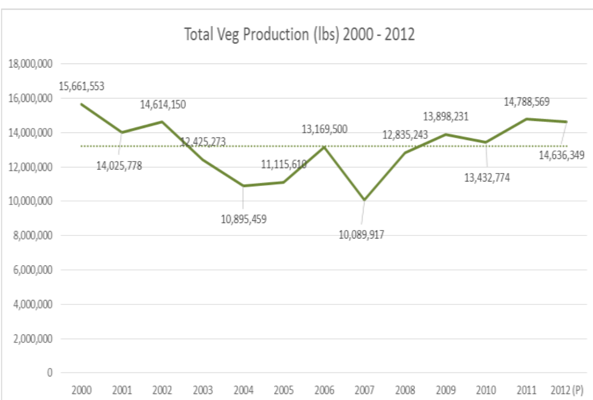
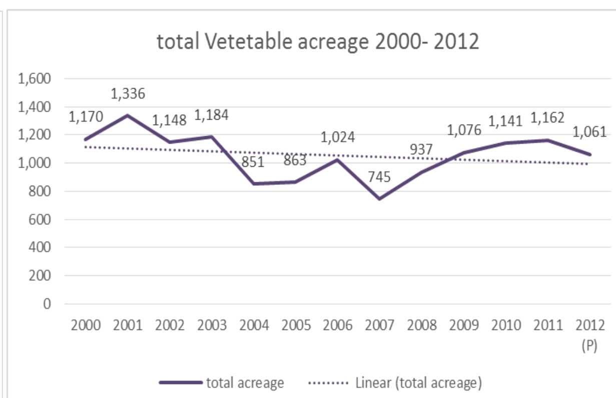


Figure 1 (q): Total Vegetable Acreage 2012



(Source: Ministry of Agriculture and Natural Resources, 2014)

Structure of the Vegetable Industry

The industry consists primarily of small operators who may be loosely organized into local cooperatives and associations at regional and community levels, although many vegetable producers operate individually. There are no buying centres and products are marketed through cooperatives. Most cooperatives provide financial assistance to members through bulk purchasing and price negotiation. All vegetables are marketed locally through farmers markets or retail outlets.

In the Cayo District there are about 105 farmers organized into two main cooperatives, the Valley of Peace Farmer Group which produces mostly cabbage and other vegetables, and the Mennonite

Communities (Springfield, Upper and Lower Barton Creek and Bird Walk, Santa Marta) which produces lettuce, carrots, potatoes, broccoli, cauliflower, eggplant and onions. The production system used in the Cayo District is mostly open field production, although there are a few functioning covered structures for the production of tomatoes and sweet peppers.

In the Belize District, there are about 48 farmers producing on a total of 62 acres organized into two main cooperatives, the Maskall Group and the Nagu Bank Group. They produce mainly melons, sweet peppers, onions, cilantro and tomatoes on plots with average size of 1.5 acres. Both groups produce in the open field irrigated production system as well as with the use of protective covered structures.

Constraints

Production is constrained by high incidence of pests and diseases, high cost of production, competition from low-cost subsidized products from across borders, limited up-to-date and cost effective technology, limited access / usage of weather data and temperature and water requirements which restrict the seasonality of production for some vegetables. Vegetables are particularly vulnerable to the effects of climate change since they are generally very sensitive to both waterlogging and drought conditions, plus several of Belize's most consumed vegetables have optimum temperature requirements which are already exceeded, (for example , onion, cabbage and carrots) or likely to be exceeded according to temperature forecasts.

1.3.8 Livestock (Cattle)

Cattle production is done in all six districts of Belize, but the highest concentrations are in the Orange Walk, Cayo, Belize and Stann Creek Districts. The main production system practiced in the country is free range pasture. Herd size ranges from two heads to a few thousand heads.

Production

Cattle rearing is capital intensive and small scale operations have a low internal rate of return. However some small operators invest very little and keep cattle only as a quick source of cash for financial emergencies. The current size of the national herd is estimated at 100,000 animals; of that number, approximately 75,000 heads are owned by about 1,500 farmers. Some 500 farmers own 5 heads or less. Many farmers use improved pasture and large farmers in particular complement the cattle feed with a prepared mixture of corn, concentrate and molasses.

The Orange Walk District is the largest producer followed closely by the Cayo District. The third largest producer is the Belize District followed by Stann Creek, Toledo and lastly Corozal.

Structure of the Livestock Industry

Farmers in the cattle industry are organized into the Belize Livestock Association (BLPA). The board of directors set up to manage the industry's affairs is selected by the Ministry of Agriculture and the Belize Agricultural Health Authority (BAHA) is the regulatory agency. While membership in the BLPA is obligatory there is no penalty for non-participation. The purpose of BLPA is to lobby on behalf of farmers, register brands, provide technical and financial support, and act as a clearing house for cattle transactions.

Marketing

Of the 25,000 to 30,000 heads that are available for sale annually, about 15,000 heads are consumed locally and 15,000 heads are exported to Guatemala. Live animal prices have increased from BZ$ 1.00/lb in 2008 to about BZ$ 1.75/lb currently. About US$ 15M in foreign exchange earnings is generated annually through export.

Constraints

Industry concerns include losses due to preying on new-borns and pregnant mothers by jaguars, limited access to markets due to incomplete animal health standards and limited access / usage of weather data.

Current Actions and Future Plans

An on-going cattle sweep program which is in its second phase, will improve market access by allowing our local herds to be declared free of tuberculosis and brucellosis. After the third phase is completed, Belize's cattle can be shipped to the Mexican market and to the USA. The aim is to open up new international markets for Belize's cattle. The industry also seeks closer collaboration between the regulatory agencies and the stakeholder organizations, to improve management practices, (such as electric fences) to address losses caused by jaguars and to continue to create an improved marketing relationship with Guatemala.

1.3.9 Aquaculture

The pond aquaculture sector in Belize is divided into two main subsectors based on species cultured; namely shrimp, *Litopeneus vannemei*, and tilapia, *Orechromis* spp (including hybrids of *O. nilotica*, O. *mossambicus, O. hornorum and O. aureus*). Shrimp production dominates the sector and is concentrated in the Stann Creek District, with seven of the eight farms currently in production located there. At present there are 4,000 acres under production with another 500 acres coming online within the next 6 - 8 months.

Freshwater tilapia production is being done primarily at the subsistence level, with only one large farm in operation. Total acreage in this sector is divided between the one large operation at 200 acres and 47 small operations with a combined total of 17 acres. The total number of farmers is unknown at this time.

Shrimp represents Belize's single largest and most economically important fisheries export. Despite a drastic fall in production and price since 2008, shrimp production still accounts for some BZ$84 million in export earnings. The sector directly employs approximately 1,500 persons and an additional 200 indirectly. It is a high risk, capital intensive operation that is controlled by a few individuals. In addition the sector benefits from export promotion incentives.

Socio-economic importance

The shrimp aquaculture sector is an important contributor to the economy of the southern districts of Belize. Toledo and Stann Creek Districts have the first (46.2%) and third (43.7%) highest poverty rates respectively, both of which are above the national average of 41.6%. These are also the districts with the smallest populations, 24,226 and 25,543 respectively. As a result, any economic activity is certain to be reflected in the socioeconomic wellbeing of the two district populations. The 1,500 persons directly employed are primarily semi-skilled and unskilled workers from southern Stann Creek and northern Toledo. Skilled positions, particularly administrative and technical, are filled primarily by foreigners and persons from outside the district. Of significance is the fact that the three processing facilities employ primarily unskilled single mothers, thus providing very valuable income contributions.

Production

Three systems are currently utilized for shrimp production in Belize; semi-intensive, intensive and super-intensive. Farms range in size from 100 – 1,500 acres. In the semi-intensive system ponds are stocked at 60,000 -100,000 per acre and grown out for 5-6 months. Pond preparation involves culturing and maintaining a healthy algal bloom that is maintained throughout the grow-out cycle. Feeding is a combination of natural productivity and prepared feed. Aeration is done when needed to maintain dissolved oxygen levels above 4 mg/l. Production is approximately 1,500 – 2,000 lbs per acre at a survival rate of 70% - 80%. In intensive and super-intensive systems stocking is done at 600,000 to 800,000 per acre. Yields at 70% - 80% survival are between 8,000 – 12,000 lbs per acre. At these stocking densities, feed and aeration are required inputs. With the exception of Biofloc technology that is used in the super-intensive system, fertilizers and lime (CaO) are the only other agrochemical inputs that are used in the industry.

At the height of production in 2006 – 2007 when there were 16 farms in operation, total production reached over 28,000 metric tons. After the recession of 2008 and the fall in shrimp prices, some farms went out of operation. At present there are eight farms in operation with a total production of just over 6,500 metric tons.

Structure of the Sector

The current legal and institutional framework for aquaculture is a bit convoluted. The sector has traditionally been under the mandate of the Fisheries Department. However, while the Fisheries Legislation makes provisions for licensing and certain administrative details, it has no legal control over the sector. Animal health issues are under the jurisdiction of Belize Health and Agriculture Authority (BAHA) and Environmental Impact and effluent concerns are addressed through the Department of the Environment (DoE). The Aquaculture Industry Development Act that was passed in 2007 has still not been brought into force by the Governor General. This particular piece of legislation is under the Ministry of Trade. There is further fragmentation in that both the Ministry of Agriculture and the Ministry of Fisheries share responsibility for aquaculture depending on the method being used.

The industry has organized itself into an association primarily for advocacy and protection purposes. Decisions are made by mutual consent and compliance is voluntary.

Stakeholders

The major stakeholders in the Shrimp Industry are the farmers and the Government of Belize. The farms are under the direct control of individual or corporate owners. The Government of Belize through BAHA is responsible for animal health and food safety. Through the DoE, GOB is also responsible for environmental impacts and effluent control. The Belize Shrimp Growers Association (BSGA) is a legally registered but not legally mandated body that seeks to organize the industry around issues of common concern. All research and development is currently done on the individual farms, sometimes with the explicit consent of the relevant government agency.

Marketing

Approximately ninety percent of the total shrimp production is exported. Over the last five years, approximately 62% of exports went to Mexico whole and packed in ice, 14% to the Caribbean, 13% to North America and 10% to Europe. The remaining 1% has been sold primarily to Southeast Asia. The exports to North America are primarily tails packed in 5 lb. blocks while there is some value added for the European market.

Niche Marketing

The Mexican market can be considered a niche market for the moment because the shrimp are harvested, packed in ice and loaded directly unto the trucks at the loading dock on the farm. While the price is the lowest per pound, there is no processing or value added so costs are kept to a minimum. Nonetheless, the demand is high and the sales are brisk. Shrimp for the Mexican market normally have an individual weight of 10-15 g. For the North American and European market individual weight are between 15- 24 g. The other possible niche market is the Jamaican market that is purchasing 40g shrimps from one particular farm.

Constraints

The present concerns in the industry stem primarily from what is considered to be insufficient regulatory oversight. This translates to functions that should be performed by the regulatory agencies but which are perhaps not being delivered at the level that they should. The primary concerns are pest and disease control, animal health, water quality and shoreline protection.

Also of concern is the cost of getting regulatory services delivered. The matter of cost recovery for the services provided by regulatory agencies is one that adds an additional layer to the production costs.

There is insufficient and sometimes ineffective communication of pertinent information and decisions. This is critical for an industry that is high investment and high risk.

The small number of trained technical professionals in the country makes it difficult to fill skilled positions at short notice. This usually requires bringing in foreign expertise.

Current Actions and Future Plans

The BSGA has developed a Strategic Plan and Policy document. This document outlines the association's objectives for the industry over the next five years. In the meantime the association is expecting that the government will address the concerns identified as critical to the survival and adaptability of the sector. The growers are of the opinion that outside of policy, regulatory and capacity issues that need to be addressed by the Government, the sector will be able to adapt to climate change through adoption of good practices and management techniques, some of which are already being used.

1.4 Institutional and Regulatory Framework

1.4.1 Institutional Framework

The MFFSD has been designated as the government agency responsible for the coordination and implementation of Climate Change policies in Belize. The MFFSD plays a leading role in the National Climate Change Committee (NCCC) which has wide representation from various sectors and is responsible for coordinating climate change actions at the local, regional and international level. The NCCC is organized into sub-groups to address the various aspects of climate change.

The policy and institutional framework pertaining to the agriculture sector will guide the adaptation strategy in determining decisions to be made and decision makers, the most suitable entities to implement the various actions, the availability of the necessary human and material resources, what appropriate measures have already been initiated, complementarity and partnering needs, supportive proposed and/or adopted policies and systems, jurisdiction, improvement needs, and degree of difficulty for necessary changes.

1.4.2 Regulatory Framework

1.4.2.1 Ministry of Natural Resources and Agriculture

Agriculture is currently incorporated into the Ministry of Natural Resources and Agriculture, but the governmental structure has often changed with the incoming of new political administrations. For ease of reference the agriculture department can be referred to as the Ministry of Agriculture (MoA). The Mission of the MoA emphasizes food security, income, foreign exchange earnings, and employment and conserving natural resources in order to grow the economy, reduce poverty and empower the local population for sustainable development. Headed by a minister and Chief Executive Officer, it includes the Agriculture Department headed by a Chief Agricultural Officer, and a Policy and Economics unit headed by a Policy Analyst. It is responsible for setting and implementing agriculture policies and strategies along with its partners in development and stakeholders. MNRA provides agriculture extension services mainly to the non-traditional sector, and especially to small/medium commercial farms, and provides some regulatory function to the sugar and citrus industries through its seat on the SICB and the Citrus Control Board. Along with the National Authorizing Office (NAO) the ministry oversees the EU assistance programmes for the banana and sugar sectors (Banana Accompanying Measures (BAMS) and Accompanying Measures for Sugar (AMS) respectively) and any other EU funded agricultural projects. It collects annual statistics on crop and livestock production and conducts crop and livestock related research at Central Farm. Resources are mobilized through an annual GOB budget, plus projects and programme funding from partners in development. The MNRA includes the Cooperative Department which is responsible for organizing, training and monitoring the legal actions of agriculture cooperatives.

1.4.2.2 Belize Agricultural Health Authority

The Belize Agricultural Health Authority (BAHA) is a statutory body established by the Belize Agricultural Health Authority Act, Chapter 211 of the Laws of Belize, Revised Edition 2000. It is governed by a Board of Directors and its main purpose is to safeguard agricultural health for the nation and to facilitate trade and commerce. BAHA has departments responsible for plant health, animal health, food safety, quarantine and inspection. BAHA upholds sanitary standards for the importation and export of live plants and animals and any derived product that could pose a threat to the agriculture industry. The Authority is responsible for risk analysis for introduction of any organism or microorganism prescribed for support to agriculture health. Under the revised Act BAHA assumes responsibility for regulating issues pertaining to biosafety (genetically modified organisms (GMO's) and to organic production. The quarantine department conducts an on-going surveillance programme to maintain Belize's Mediterranean Fruit Fly- free status necessary to allow for fresh fruit export to the USA.

1.4.2.3 Belize Livestock Producers Association

The Belize Livestock Producers Association (BLPA) is established under the Meat and Livestock Act Chapter 214 of the Laws of Belize. Its mission is to promote development of the livestock industry and protect its members. The objectives of BLPA are to provide technical assistance, training and educational facilities, solicit funding to enable affordable financing to producers, access improved genetics and promote national and international marketing of livestock products (the Belize livestock industry - a brief account by Harold Parham, CEO ,BLPA April 29, 2009). BLPA previously operated a "fondo ganadero" programme which provided fattener stock to farmers on "loan" terms, with payment due after sale of animals. The law stipulates mandatory membership in BLPA for all livestock producers and includes mandatory cess payment for all cattle sale transactions. BLPA currently regulates the national sanitary cattle sweep programme required for export of cattle to Mexico, and intends to maintain a database and monitor/regulate local and regional movements of cattle in compliance with the Mexican agreement.

1.4.2.4 Pesticides Control Board

The Pesticides Control Board (PCB), a statutory body governed by a board of directors, is responsible to safeguard the health of the Belizean people and the environment through pesticide regulation and capacity building. The PCB Act Chapter 216, Revised Edition of 2003, provides for control of the manufacture, importation (including for experimentation), sale, storage, use and disposal of pesticides. PCB conducts regular training for agriculture workers in the safe use of pesticides including aspects of rational use, application methods and calibration, protective gear and equipment maintenance. PCB also participates in efficacy trials for new pesticides along with the ministry of agriculture and pesticides sales agencies.

1.4.2.5 Belize Marketing Development Corporation

Formerly the Belize Marketing Board, the Belize Marketing and Development Corporation (BMDC) established under the Revised Act , Chapter 281 of 2003 , gives the mandate to support the marketing of primary or value added agricultural products from small and medium enterprises through technical support, distribution systems, market intelligence, market linkages and direct marketing for the promotion of new product developments. Through this mandate BMDC assisted the launching of Belize's national production of onions, potatoes and carrots through direct marketing assistance. BMDC currently continues to focus on marketing of rice -purchase, processing and distribution and importation in times of national deficit.

1.5 Research

1.5.1 Caribbean Agriculture Research and Development Institute

The Caribbean Agriculture Research and Development Institute (CARDI) is a regional organization responsible for meeting the research needs of individual countries whilst contributing to regional research objectives. Its policies/programmes are set by a regional Board of Directors with national oversight at country level. In Belize CARDI research focuses on agronomic practices, cultivar selection, seed production and germplasm maintenance of cereal grains and legume crops, especially corn, soybeans, peanut and cowpeas. CARDI also takes the lead role in the production of nucleus and commercial seeds for the hot pepper production industry.

1.5.2 Citrus Research and Education Institute (CREI)

CREI is owned by the CGA and is overseen by an appointed committee. CREI conducts agronomic research on citrus production and provides extension service (including a quarterly newsletter) for all commercial citrus growers. The institute manages a clean planting stock nursery and is mandated to ensure compliance of commercial nurseries to provide disease free planting stock to all citrus growers. CREI develops pest and disease management plans for the citrus industry which includes liaison with development partners and mobilization of resources in regards to major threats to the industry.

1.5.3 Sugar Industry Research and Development Institute (SIRDI)

SIRDI is mandated to conduct research on agronomic aspects of sugarcane production and to provide advisory/extension services to sugarcane producers. SIRDI is undergoing a rapid process of development with financial assistance under the AMS.

1.5.4 Central Farm Research and Development Station

Central Farm (CF) is the research and development division of the Ministry of Agriculture comprised of livestock, agronomy and farm mechanization sections. It maintains improved breeding stocks of cattle, sheep and pigs for sale to livestock farmers, provides a bull rental service for small livestock farmers and maintains field legume banks for distribution of legume cuttings (planting material) to livestock farmers for pasture improvement. CF conducts research on new pasture grass and legume species, vegetables, protective cropping technology, organic methods and selected field crops. Field nurseries are maintained for distribution of planting material of selected cultivars to farmers. CF operates a coconut hybridization programme providing lethal yellowing resistant varieties of coconut to growers countrywide.

1.5.5 National Coordinating Committee for Agricultural Research and Development

The National Coordinating Committee for Agricultural Research and Development (NCCARD) was established in 2004 and reorganized in 2010. NCCARD arose from a regional mandate under CARDI leadership. This committee is responsible to coordinate research at a national level driven by expressed needs of the private sector, and includes representatives of the productive sector, research entities and policy makers.

1.5.6 Agriculture Mission of the Republic of China on Taiwan

The Republic of China on Taiwan (ROC) had an agricultural mission stationed at Central Farm and conducted research on agro-processing, rice production technologies, introduction of new vegetable cultivars and production technologies and use of small machinery. The mission liaised with the Asian Vegetable Research and Development Centre which is instrumental in developing cultivars of popular vegetables and fruits that are adapted for production in tropical climates. The ROC recently handed over this research to the MNRA and now focuses on implementing projects in aquaculture, Citrus Greening, information technology and small ruminants in collaboration with MNRA.

1.6 International Development Partners

1.6.1 Inter-American Institute for Cooperation on Agriculture (IICA)

IICA is a specialized agency of the inter-American system to support efforts of Member States to foster agriculture development and rural well-being in their territories.

IICA provides technical assistance, support for policy development and innovations in agriculture technology especially focusing on improved production and post- harvest practices in grain production in Toledo. IICA also supports the organic agriculture development initiative, and training via visiting professionals and scholarships for post graduate studies. IICA is an active member of the National Rural Development Coordinating Committee formed for the implementation of a Belize Rural-Area based Development Strategy, elucidated through the Central American ECADERT[2] process.

1.6.2 International Regional Organization for Agricultural Health (OIRSA)

OIRSA is a technical organization established to provide administrative and technical support to Ministries or Secretariats of Agriculture from its member countries, and to protect and develop their agricultural resources for the well- being of their populations. It is focused on projects and plans for plant and animal health, food safety and facilitation towards agricultural commerce. OIRSA operates northern and western border quarantine treatment facilities to spray (chemically treat) incoming vehicles to prevent entry of agricultural pests and diseases. OIRSA accesses regional resources to support efforts of BAHA in combating pest and disease outbreaks of national importance and is currently involved with the citrus greening control programme along with CREI and BAHA. OIRSA was instrumental in setting up a biological control laboratory (run by BAHA) to produce a beneficial parasitic wasp to control the pink hibiscus mealy bug (PHMB) in Belize, since the movement of this devastating pest has regional implications.

1.6.3 Caribbean Community Climate Change Centre (CCCCC)

The CCCCC coordinates the Caribbean region's response to climate change. It is the official repository and clearing house for regional climate change data, providing climate change-related policy advice and guidelines to the CARICOM Member States through the CARICOM Secretariat. The CCCCC is working on setting up climate change models for each country and is trying to detect local changes in Belize's watershed (Executive Director Dr. Kenrick Leslie, KREM TV, and October 29, 2013).

1.6.4 Food and Agriculture Organization of the United Nations (FAO)

FAO has been Belize's most consistent and reliable donor for agricultural projects for the last 25 years. FAO has funded several emergency projects in response to natural disasters. The recent policy is to assist countries in developing strategies for preparedness and resilience rather than provide emergency relief whenever there is a natural disaster. This is in recognition of the more frequent nature of these events in the region and thereby the need to change the approach. That objective was promoted with the recently funded project "Improved national and local capacities for hurricane related disaster preparedness, mitigation and response in the agricultural sector in Belize" which produced a set of strategies and action plans for disaster mitigation. FAO offers two major programmes of assistance which are:

1) Technical Cooperation Projects (TCP) – technical assistance for the development of strategies and technologies for improving management of natural resources and food production. FAO funds a maximum of US$400,000 for each TCP project.

[2] Central American Strategy for Rural Development

2) Telefood projects – FAO provides up to US$10,000 in material inputs for food production aimed at assisting the rural poor in getting a head start to improve their economic conditions. The Telefood projects are executed within a one year period and must be designed to ensure sustainability.

1.6.5 European Union (EU)

The European Union supports Belize through the EU-ACP partnership under the Cotonou Agreement revised of June 2010. The banana sector has benefited from Budget Line funding for the Banana Support Programme 1999-2008, and continues to be supported through the recently commenced Banana Accompanying Measures. The sugar sector is being supported under the Accompanying Measures for Sugar where 45 million euro has been earmarked for ensuring employment security and improved competitiveness in the sugar industry. Agriculture has also been the major focus of the European Development Fund (EDF) 9 and EDF 10 with Envelope A funding allocated to the Belize Rural Development Programme (BRDP) and the BRDP 2 respectively. The EU is instrumental in supporting climate change adaptation initiatives in the CARICOM region.

1.6.6 United Nation Development Programme (UNDP)

The UNDP programme in Belize is designed on four overarching goals: Poverty reduction and achievement of the Millennium Development Goals.; Democratic governance; Crisis prevention and recovery and Environmental and sustainable development. Their Global Environmental Facility (GEF) Small Grants Programme has supported several small agriculture projects in the last decade and more recently UNDP has partnered with the EU and the Ministry of Agriculture to undertake larger agriculture projects with a national focus. UNDP is active in the National Climate Change Committee and is currently implementing two projects in partnership with the GOB (1) the EU funded “Enhancing Belize’s Resilience to Adapt to the Effects of Climate Change” and (2) Enabling Activities for the Preparation of Belize’s Third National Communication to the UNFCC funded by the GEF. Both projects have a component on climate change vulnerability and adaptation and aim to facilitate the mainstreaming of climate change initiatives into GOB’s sectoral and national development plans.

1.7 Policy Framework

1.7.1 Horizon 2030 National Development Framework

Horizon 2030 asserts the tenet that Belize’s economic development is contingent on preserving its environment and its wealth of natural resources, including planning for the effects of Climate Change. Agriculture features prominently as a driving force for economic stability and the need to support its resilience is elaborated through emphasis on appropriate infrastructure, technology, financial access, incentives and security (insurance) for farmers, marketing, value adding and education in agriculture and entrepreneurship. Very importantly the framework espouses the critical need for community cooperation and planning for effective agriculture development. It emphasizes that party politics in Belize is a divisive and stagnating force which limits the potential of Belizeans as a whole to unite and build strong, resilient communities.

1.7.2 Land Use Policy

The land use policy proposes zoning for appropriate land use according to the most socio-economic and sustainable potential in reference to agriculture, aquaculture and other land-based activities. The policy considers what is termed the intrinsic value of land and how its use for one purpose can negatively affect a greater purpose. It recommends a National Land Use Planning Office equipped with a comprehensive and interactive mapping system. Agriculture and climate change policies consider the importance of watersheds, wetlands, coastline mangrove systems and biological refuges for long term sustainability of agriculture systems. This policy looks at the management of water and energy sources for maximum efficiency and reliability (water storage and incentivising non-water based renewable energy sources) and at agriculture and other settlement patterns with respect to flood prone areas. It recognizes the potential effect of CC on food security and the role of the small producer as regards access to good agricultural land. The policy suggests that higher quality land requiring less investment should be allocated to the resource poor farmers.

1.7.3 Water Policy

The national water policy recognizes that water is essential to agriculture, but that it is finite and likely to become less available with decreased precipitation expected due to climate change. It proposes the establishment of a National Integrated Water Resources Authority (NIWRA) with responsibility to regulate water usage, with domestic use being number one priority. Significantly it proposes mechanisms to verify and safeguard water resources as pressures for its utility increases simultaneously with decreased supply, and introduces the concept of "economic" value of all water resources.

1.7.4 Agriculture Policy and Strategy

The overarching goal of the agriculture operational strategy is to increase the competitiveness (particularly of small farmers) of the agriculture commodity sector in order to realize the ministry's mission objectives. Three main interlinked programmes elaborated under this strategy are: Incentive Policies and Institutional Development (institutional coordination and collaboration strengthening, and placing special attention to disadvantaged areas and social groups); Development of Agricultural Markets (domestic and international) and Enterprises; and Agriculture Technology Development and Diversification. It emphasizes private, public and community sector linkages and the importance of agricultural trade policy and trade negotiations in shaping consumption, production and marketing. It promotes improved information, technology and management systems as critical catalysts to change and sustainability with improved integration at the international, regional, national and local levels to improve coordination, decrease duplication and increase synergies in tackling shared objectives especially those with the same target beneficiaries. The strategy sees the development of an organic agriculture industry as a highly rated opportunity area and proposes to strengthen the Belize Organic Producers Association (BOPA), link with the BMDC and the Belize Tourism Industry Association (BTIA) to develop local markets for Belizeans and tourists, and strengthen initiatives to exploit international market opportunities for Belizean organic products. A computerized management tool (CMT) is proposed to facilitate the management and monitoring of the strategy. Agriculture is in the process of re-writing or updating its current policy and the new policy is expected to include the issue of Climate Change.

1.7.5 Plan of Action for Disaster Risk Reduction in Agriculture (POA)

Under the POA, strategies and action plans are elaborated to institutionalize Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) within the Ministry of Agriculture, improve knowledge and access of local communities to climate information and early warning messages tailored to the needs of agricultural producers, enhance application of good practices interventions at local level to increase resilience against natural hazards and climate risks, reduce hazard impacts and losses in agriculture (savings, insurance), adopt an efficient and effective Community Based Disaster Risk Reduction (CBDRR) process at community level, enhance public awareness of DRR and CCA in agriculture and strengthen complementary collaboration with key stakeholders.

1.7.6 Energy Policy

The energy policy speaks to reducing the cost of energy through cost efficient renewable energy sources as well as use of energy efficient equipment to minimise energy usage. It speaks to designing production systems to maximize energy efficiency and the need to manage the farm as an ecosystem, rediscovering the more sustainable agricultural practices of ancestral farmers whilst incorporating appropriate scientific advances into agricultural systems. With oil being a finite resource the use of renewable energy to replace fossil fuels in agricultural systems is proposed for long term sustainability, cost effectiveness of farming operations (e.g. irrigation), health aspects and mitigation of Climate Change effects. There is a proposal for use of biomass as a renewable energy source and an alternative economic product of farms, thereby helping to build resilience in the farm enterprise.

1.7.7 Biosafety Policy

Belize's biosafety policy is predicated on the 'Precautionary principle', as provided for in the Cartagena Protocol on Biosafety, "Lack of scientific certainty due to insufficient relevant scientific information and knowledge regarding the extent of potential adverse effects of genetically modified organism (GMO) on the conservation and sustainable use of biological diversity in the Party of import, taking also into account risks to human health shall not prevent that Party taking a decision, as appropriate, with regard to the import of the GMO in question, in order to avoid or minimize such potential adverse effects."

This policy sets the overall framework in which adequate safety measures will be developed and put into force, so that Belize can minimize possible risks to human health and the environment while extracting maximum benefit from any potential that modern biotechnology may offer. It recognizes the need to safeguard the knowledge, practices and benefits of Belize's traditional techniques, and focuses on risk analysis; trade issues; consumer rights; and cultural and socio-economic considerations for decision making as regards the use of GMOs.

1.7.8 Aquaculture Policy

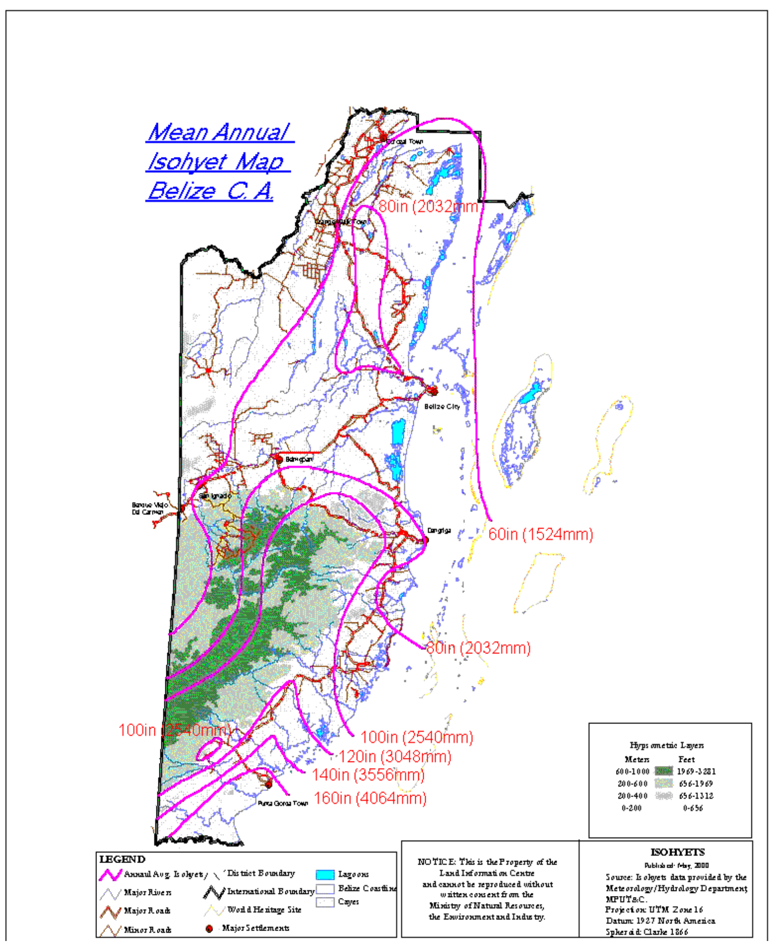
The very exhaustive draft aquaculture policy presents a zoning scheme which delineates the most suitable land and coastal areas for aquaculture development. It defines policies and strategies to manage the natural resource environment to achieve efficiency of operation and long term sustainability of the aquaculture industry. It underscores the need for diversification of species and habitats to minimize risk as well as capitalize on economic opportunities presented by expanding aquaculture development. The policy emphasizes the need for planned development of the aquaculture industry which will involve research (especially alternative feed, species selection, reproduction by local hatchery and production systems), and regulation and management of the industry to safeguard its health status. It further promotes the need for meaningful broader community involvement in the planning and implementation process to allow for equitable access to resources and benefits to be derived from an expanded aquaculture industry. A new Strategic Plan and Policy document developed by the Belize Shrimp Growers Association addresses concerns identified as critical to the survival and adaptability of the sector including issues related to Climate Change.

2. PROJECTED CLIMATE CHANGE IMPACTS ON THE AGRICULTURE SECTOR

2.1 Current climate

Climatological data from the National Meteorological Service of Belize (NMS) database were used in identifying the trends in average rainfall and temperatures. Since all observation stations were not established at the same time, the best or most consistent period for each station was used. The data were subjected to strict quality control measures. In situations where large quantities of data were missing the month was simply deleted and no attempts were made at generating or interpolating information for missing data. Agriculture production, yields and agronomic information were sourced from the Agriculture offices in Belmopan and Central Farm (Ministry of Natural Resources and Agriculture), and from private

Figure 2.1: Isohyets of mean annual rainfall (mm) for Belize



producers.

2.1.1 Current Climate of Belize

Under the Köppen climate classification, the climate in Belize can be described as tropical rainforest (Am)[3] in the higher terrain of the central mainland and southern districts, and tropical wet and dry (Aw)[4] in the remainder of the country, tempered by the Caribbean Sea (WMO, 1997, FAO-SDRN, 1997). The climate also exhibits seasonal subtropical characteristic during the cool period that runs from December through February.

There are two distinct rainfall seasons: a rainy season which normally commences around mid-May in the south and early June in the north, and last until November; and a dry season which stretches from mid-February until May.

A cool, wet transition period extends from December until February (DJF) during which Belize experiences incursions of arctic air masses from the continental USA and Canada, which often results in night time minimum temperatures dropping to about 10˚C or less in the higher terrain of the Mountain Pine Ridge in extreme cold events. This cool transition period rainfall (DJF) accounts for about 11-20% of the annual total rainfall for most districts of Belize (Table 2.1).

The rainfall pattern during the wet season is bi-modal over central and northern Belize and characterized by a short dry spell of 10-14 days, locally known as the ‘maga” season or the "mid-summer drought”, which normally occurs in late July or August, after the initial onset of the rainy season. In the south, this mid-summer dry spell is less pronounced and the rainfall pattern is modal.

Annual average rainfall varies from 1,524 mm (60 inches) in the north to 4,064 mm (160 inches) in the south (See Figure 2.1). Seasonal differences in rainfall are greatest in the northern and central regions of the country, where monthly rainfall less than 100 mm is not unusual in March and April. The dry season is shorter in the south, normally lasting from March to mid-May. Table 2 (a) is a summary of the seasonal and annual mean rainfall for key stations around Belize.

[3] Tropical monsoon
[4] Tropical wet and dry

Table 2 (a): Average seasonal and annual rainfall at key meteorological stations in Belize

	Seasonal Mean Rainfall (mm)				Annual Mean (mm)	Percent of Mean Annual Rainfall (%)			
Stations	DJF	MAM	JJA	SON		DJF	MAM	JJA	SON
Libertad	162.9	193.4	548.6	523.5	**1428.4**	11	14	38	37
La Milpa (Rio Bravo)	140.1	159	555	531.4	**1385.5**	10	11	40	38
TowerHill	187.9	173.8	599.8	461.3	**1422.8**	13	12	42	32
PSWGIA	383.2	225.5	662.5	737.3	**2008.5**	19	11	33	37
Belmopan	370.2	173.1	806.8	669.8	**2019.9**	18	9	40	33
Central Farm	343.4	164.7	600.7	572.6	**1681.4**	20	10	36	34
Middlesex	462.5	290.2	1091.4	914	**2758.1**	17	11	40	33
Pomona	455.2	299.5	987.3	935.3	**2677.3**	17	11	37	35
Melinda	451.6	248.6	746.3	873	**2319.5**	19	11	32	38
Mayan King	336.6	214.8	1008	870.6	**2430.0**	14	9	41	36
Big Falls	335.2	299.9	1212.9	871.9	**2719.9**	12	11	45	32
PG Astat	448.8	330.5	1851.1	1050.1	**3680.5**	12	9	48	27
TRDP (Blue Creek)	353.4	287.5	1591.9	854.2	**3087.0**	11	9	52	28

(Source of data: period 1970 - 2000, National Meteorological Service, Belize)

2.1.2 Temperature

The temperature regime in Belize is moderated by the Caribbean Sea, such that the coastal zone exhibits a maritime climate, while conditions in the interior are more extreme, particularly during the height of the dry season and during significant change in air mass during the cool transition months. Average maximum temperatures are near 85 °F / 29 °C and lows may drop to the low 70s or 21 °C. The summer months are about 8 degrees warmer than those months in the cool period. Minimum temperatures in the interior are about 5 degrees cooler than at coastal locations, but in the higher elevations of the Mountain Pine Ridge, minimum temperatures are often 10 degrees cooler than coastal locations.

2.1.3 Extreme Rainfall Events

Generally three types of events result in intense rainfall throughout Belize. In June and July tropical waves and cyclones produce thunderstorms, which generate intense but localized rainfall. Soil moisture is often below field capacity after the long dry season and runoff does not achieve its full potential, except in urbanized areas. In late August, September and October Belize normally experiences significant and prolonged rainfall during the height of the hurricane season. Substantial runoff occurs, resulting in localized flash floods in the hilly terrain, ponding and inundation along flood plains and low-lying coastal areas. In November through January, significant but less intense rainfall can occur, caused by incursions of frontal systems across the area. During extended and intense dry seasons ground water tables may drop and base flow is the only source of water for the major rivers and tributaries. In the coastal zone of the Belize and Corozal Districts, these recurrent drought conditions result in the advance of the salt water lens deep into the coastal aquifers, and some distance up the main rivers and tributaries.

2.1.4 *Agro-climatic Zones in Belize*

Four agro-climatic zones have been identified for Belize. These are listed below along with a few agro climatic stations representative of the zones:

- Northern Zone: *Consejo, Libertad, La Milpa (Rio Bravo) and Towerhill;*
- Central Coastal Zone: *Philip S. W. Goldson International Airport (PSWGIA) and Melinda;*
- West Central Zone: *Belmopan, Central Farm and Spanish Lookout;*
- Southern Zone: *Middlesex, Mayan King, Big Falls (South), Punta Gorda Agricultural Station* (at five miles), *and the Toledo Research and Development Project site (TRDP), Blue Creek Village).*

2.1.5 *Current Climate in Northern Zone: Corozal and Orange Walk Districts*

Figure 2.2 (a-b) are climate charts of average maximum and minimum temperatures, monthly average rainfall and evapotranspiration for Libertad and Towerhill agro meteorological stations. The climate charts show that the growing season (where monthly rainfall P, exceed evapotranspiration rates E, moisture surplus) is about five months in the Corozal District, running from June until October, and about six months in the Orange Walk District extending from June to November.

Figure 2.2 a: Climate Chart, Libertad, Corozal District

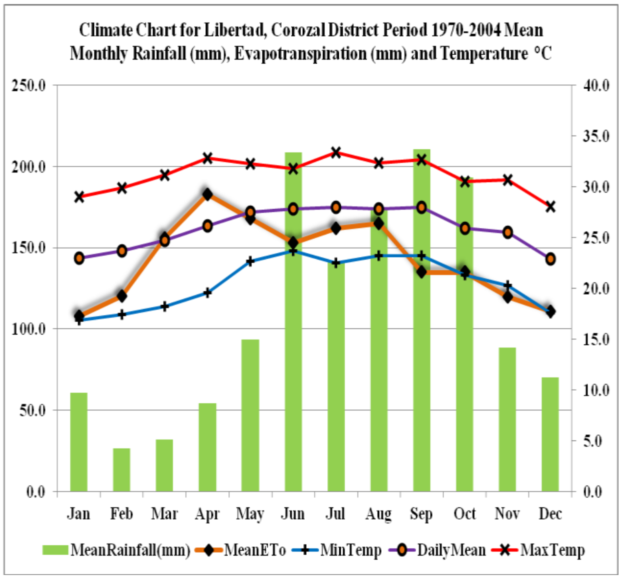


Figure 2.2 b: Climate Chart, Tower Hill, Orange Walk District

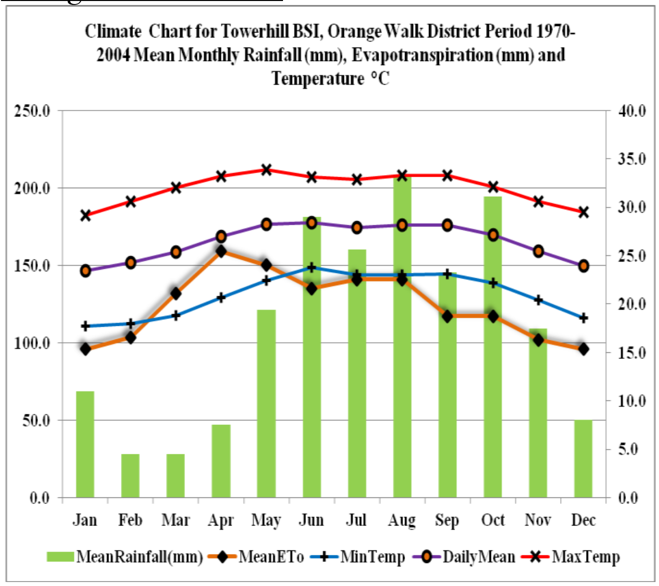
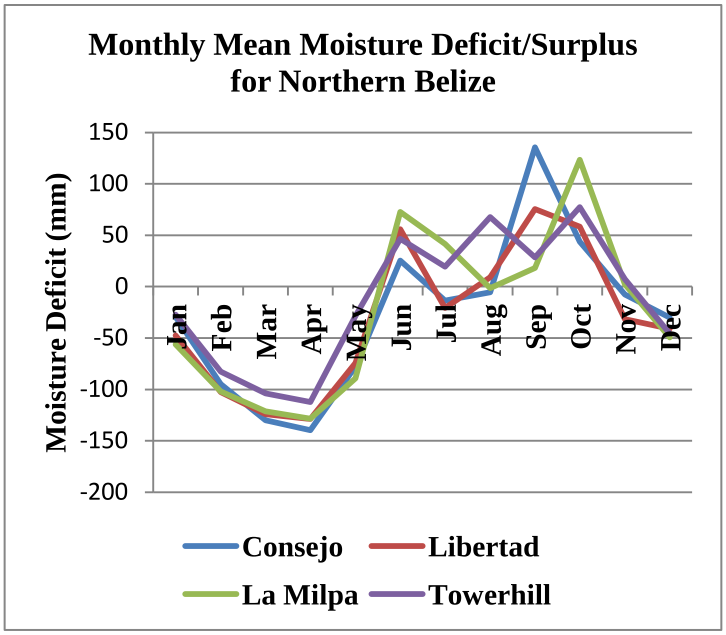


Figure 2.2c: Mean moisture deficit/surplus, Northern Belize



Average monthly temperature over northern Belize varies from 24 °C in the cool months of December and January to about 28 °C in the warmer months of May through September. The mean, monthly maximum temperature is near 34 °C from April through September both at Libertad and Towerhill. The warmest months are April-May, and the highest historic maximum temperature recorded in northern Belize was 40 °C in May 1998.

In the Northern Zone, mean annual rainfall range from 2032 mm in the southern Orange Walk District, to around 1500 mm in the Rio Hondo River border area of the Corozal District. Peak maximum rainfall occurs in June and September at Libertad, and August and October at Towerhill. Rainfall surplus is evident from June until October.

Rainfall deficit (where Rainfall P < Evapotranspiration E) is evident from November at Libertad, and December at Towerhill, to the end of May (Figure 2.2 c). The peak of the water deficit is April. The local climate in the North can be described with UNEP aridity index (AI) of 0.8 or tropical wet/dry[5]. The annual aridity regime is 4 months and the annual rainfall deficit is -540 mm. The onset of the rainy season is normally around 1st June. This agricultural zone is prone to moderate-severe droughts and requires irrigation for sustained and improved agricultural yields. Saline intrusion into the groundwater is problematic in some areas during the dry season. Sugar cane fields and other crop plantations in the floodplains of the Rio Hondo River and tributaries, and the New River are prone to floods, which have become annual events in recent decades. Extensive floods in the Douglas-San Antonio area of the Rio Hondo, and the Towerhill – Concepcion – Copper Bank area of the New River occurred in December, 2013.

2.1.6 Current Climate for Central Coastal Zone: Belize and Central Stann Creek Districts

In the Central Coastal Zone (Belize and Northern Stann Creek Districts), the mean annual rainfall ranges from 2000 mm in the Belize District to around 2500 mm over the central Stann Creek. Peak maximum rainfall occurs in June and October at Melinda and at the Philip S. W. Goldson International Airport, PSWGIA (Figure 2.3 a-b). Surplus of rainfall is recorded from June until January. The record daily rainfall was 457 mm in October 2000 at PSWGIA associated with Hurricane Keith that resulted in extensive flood in the Rio Hondo flood plains, the New River, the Belize River and tributaries,

[5] (UNEP Aridity Index, 2005: AI ≤ 0.6 Moist, 0.6 <AI< 0.8 Dry/Moist; AI > 0.9 Moist).

Sibun, North Stann Creek and Sittee Rivers, which severely impacted agriculture production and commerce.

Figure 2.3 a: Climate Chart for PSWGIA

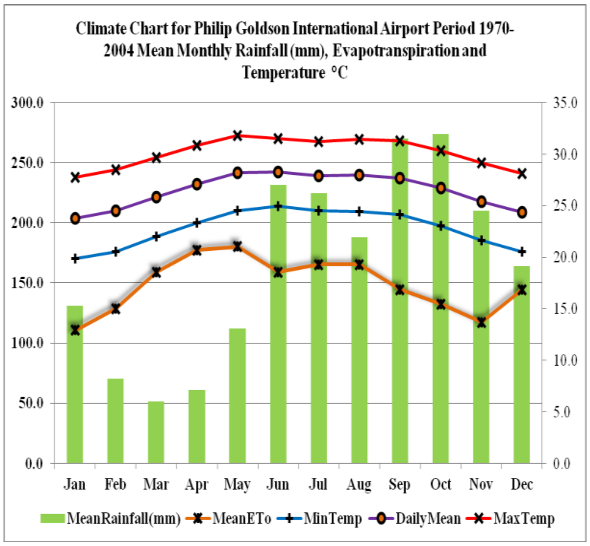
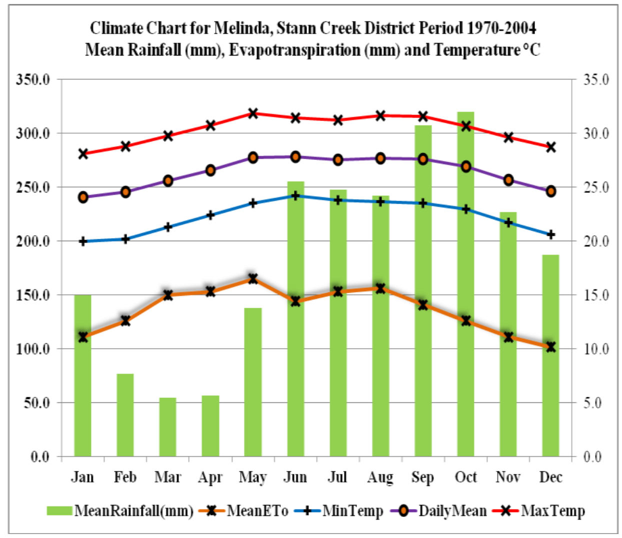


Figure 2.3 b: Climate Chart for Melinda, Stann Creek



The highest historic maximum temperature recorded in the Central Coastal zone was 37 °C in May at the PSWGIA in 1988 and 1991. The climate regime along central coastal Belize is prone to mild – moderate droughts and moderated by the sea breeze. Vegetable farmers along the Old Northern Road (Boston-Maskall-Bomba-Corozalito) are affected by annual floods, while rangeland livestock farmers in the Belize River Valley are usually impacted by 10-year top gallon floods, but which have become more frequent in recent years. Livestock farmers in the Belize River Valley are also vulnerable to droughts that are becoming more frequent and severe (Cayetano-NEMO/IDB, 2013).

2.1.7 Current Climate in the Stann Creek District

In the main citrus growing area of the Stann Creek District the mean monthly temperature varies from around 25 °C in the cooler months of December and January to near 28 °C in May-June-July at Middlesex (Figure 2.4a). The monthly minimum temperature ranges from 20 °C in the cool transition period (January-February), to near 25 °C in June. The warmest month is May, with an average

Maximum reaching 32 °C at Melinda, Middlesex and Mayan King Banana farm (Figure 2.4 b). rainfall at Middlesex is in June and September, while further south at Mayan King the modal peak occurs in August. All stations in the Stann Creek District exhibit a similar rainfall deficit / surplus seasonal pattern (Figure 2.4 c). The deficit extends from mid February until mid May at all localities,

Figure 2.4 a: Climate Chart, Middlesex, Stann Creek District

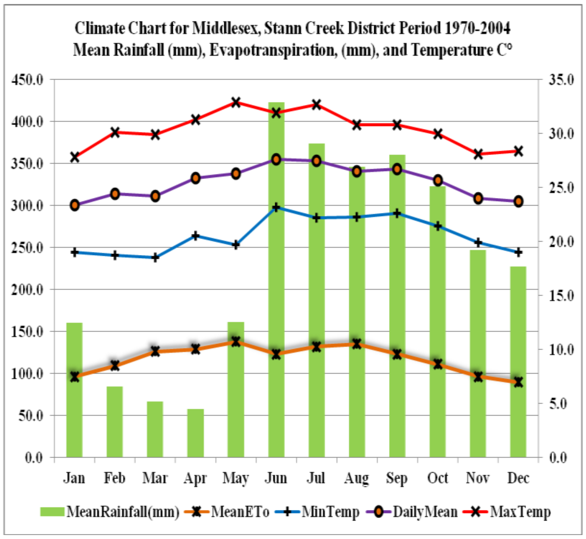


Figure 2.4 b: Climate Chart, Mayan King, Stann Creek District

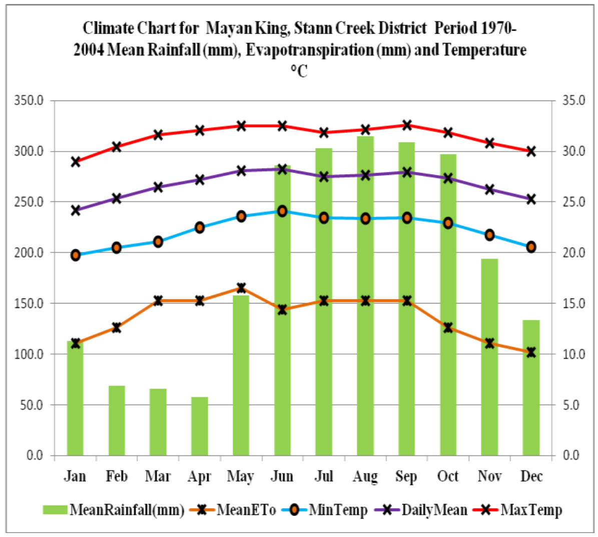
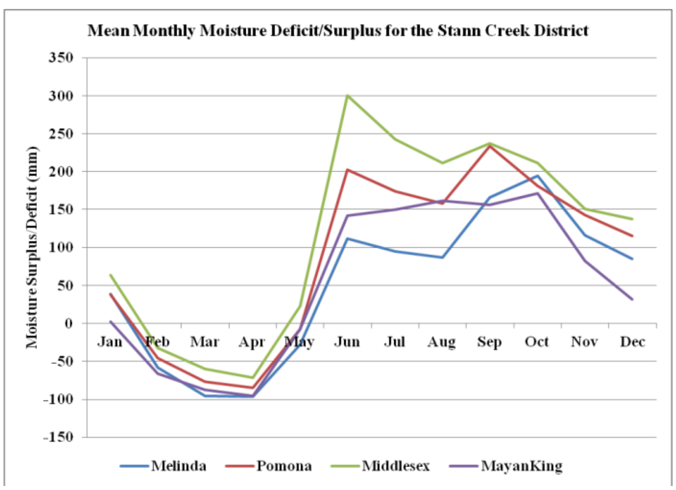


Figure 2.4 c: Mean moisture deficit/surplus, for Stations in the Stann Creek District



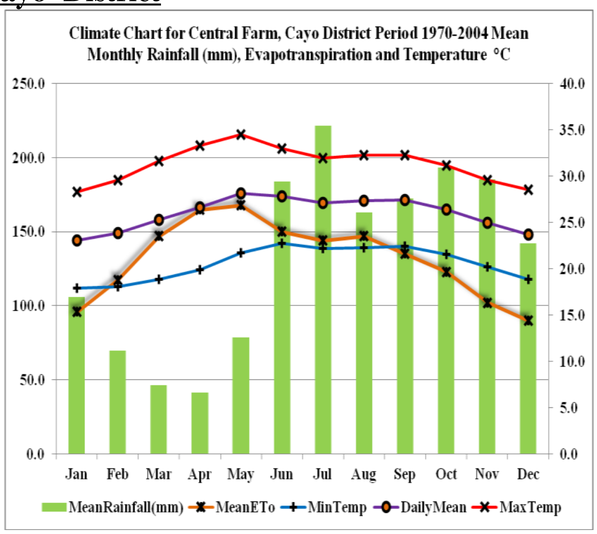
and the rains set in by end of May. The mid-summer drought (maga season) is less evident at the

southern station of Mayan King (purple line, Figure 2.4 c), but all stations show rainfall peaks in June and October. The Growing season runs from May until January.

2.1.8 Current Climate for West Central Zone: Cayo District

In the West Central Zone mean annual rainfall ranges from 2540 mm in southern Cayo District to around 1524 mm in the north and north-western border areas. Peak maximum rainfall occurs in July and October at Central Farm and June and September at Belmopan. Rainfall surplus is evident from June until January. The mean maximum temperature varies from 29°C to near 35°C at Belmopan and 28^0C – 35^0C at Central Farm (Figure 2.5 a and b). The warmest month is May, the coolest month is January, and the highest historic maximum temperature recorded in Western Belize was 43°C in May 1976 at Belmopan and 41°C in May 1974 at Central Farm.

<u>Figure 2.5 a : Climate Chart, Central Farm, Cayo District</u>



<u>Figure 2.5 b: Climate Chart, Belmopan, Cayo District</u>

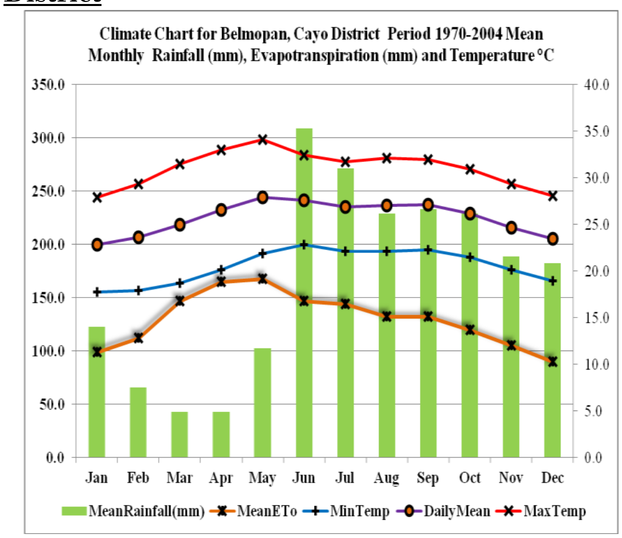


Figure 2.5 c: Mean, monthly moisture deficit /surplus for the Cayo District

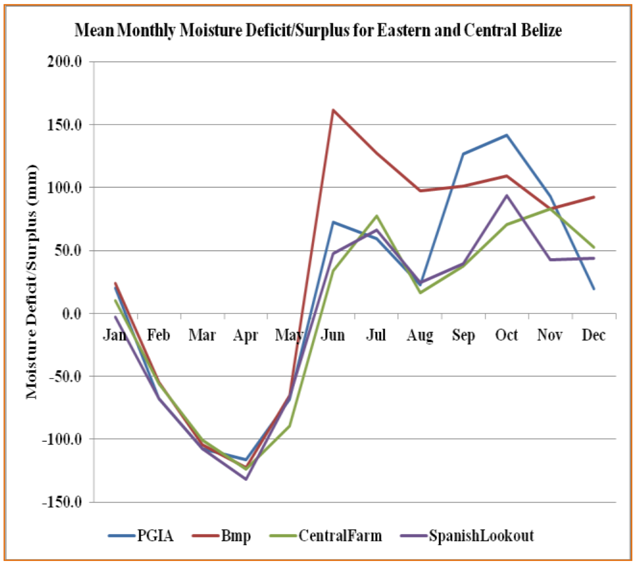
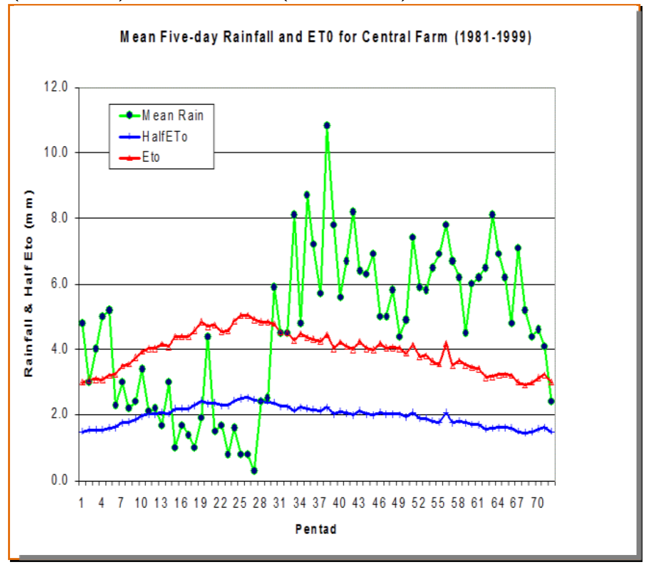


Figure 2.5 d: Historic Five-day rainfall (green line) and potential evapo-transpiration ETo (red line) & 0.5ETo (blue line) for Central F.



The record daily rainfall was 267 mm in April 1983 at Central Farm and 334 mm in June 2002 Belmopan. Rainfall deficit (P < E) extends from February to May (Figure 2.5 c). The peak of the water deficit is April.

Figure 2.5 d is a plot of the historic, average five-day rainfall, potential or reference evapotranspiration (ETo)[6] and half-ETo for Central Farm for the period 1970-1990. This type of rainfall and reference-evapotranspiration analysis is an essential tool farmers can use for irrigation scheduling, as it clearly defines the expected average rainfall at each locality for every five days and delineates the growing season, and cropping season and the normal onset and end of the wet season.

2.1.9 Current Weather for the Southern Zone: Southern Stann Creek and the Toledo Districts

In the Southern Agro climatic Zone mean annual rainfall range from 3024 mm in central and south Stann Creek District to around 4064 mm in the Blue Creek (TRDP site) and Punta Gorda Agricultural Station (PGAgstat) in the Toledo District. Peak maximum rainfall is in July (Figure 2.6 a-b). Months with rainfall surpluses are from mid-May until February. The mean maximum temperature varies from 29 °C to near 35 °C at Blue Creek, and 28 °C to 32 °C at the Punta Gorda Agricultural Station (Figure 2.6 a-b).

[6] The evapotranspiration rate from a reference surface, not short of water, is called the potential or reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_o (FAO 2014, www.fao.org).

Figure 2.6 a: Climate Chart for Punta Gorda Agriculture Station, Toledo District

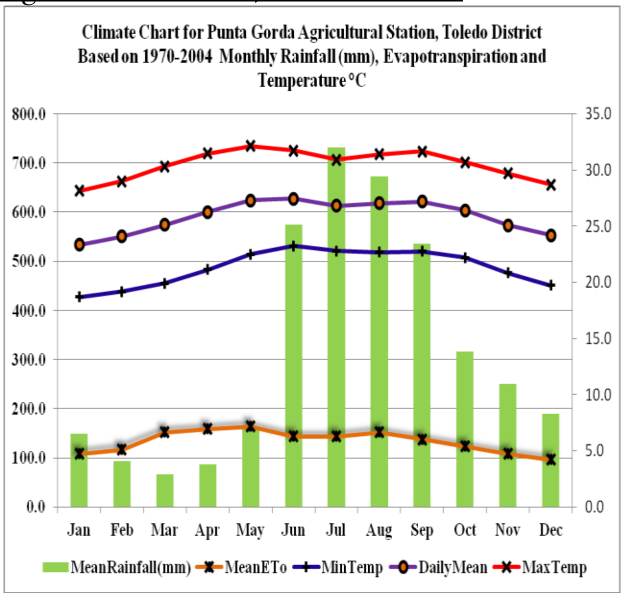


Figure 2.6 b: Climate Chart for Blue Creek (TRDP) Toledo District

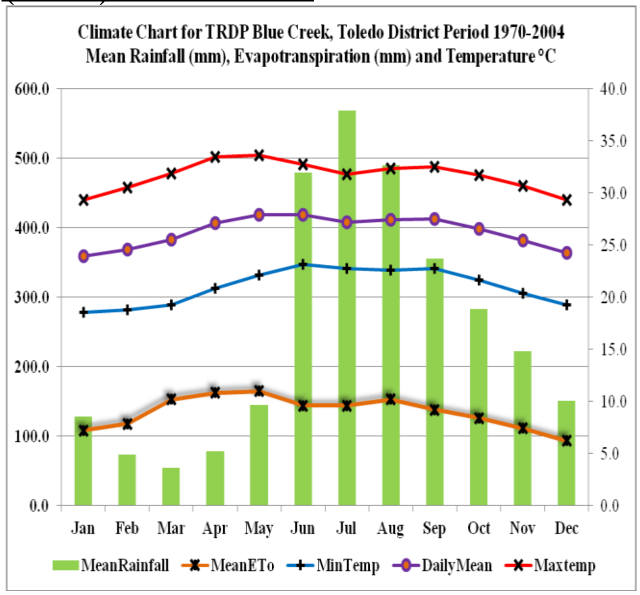
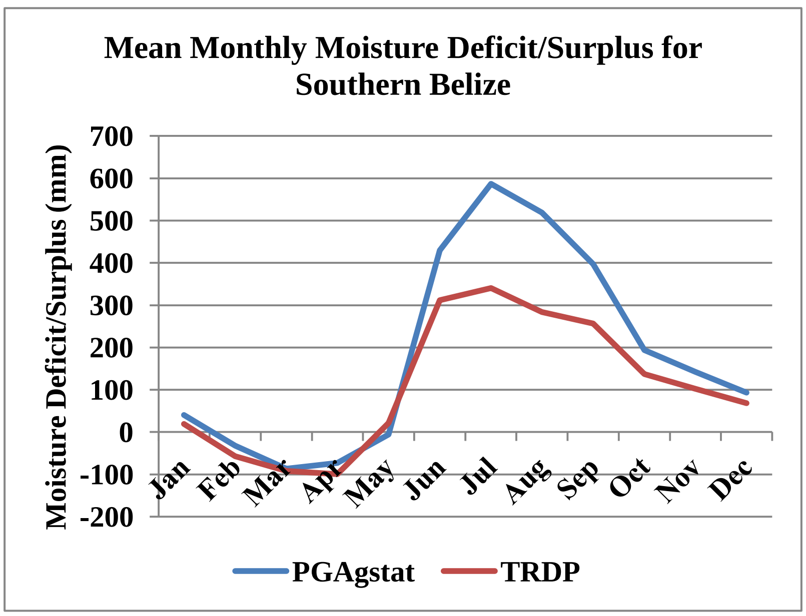


Figure 2.6 c: Mean monthly moisture deficit/surplus for the Toledo District



The warmest months are April-May, and the highest historic maximum temperature recorded in southern Belize was 38 °C in May 1994 at Punta Gorda Agriculture Station, 40 °C in May 1995 at Blue Creek and 38 °C at Big Falls in 1998-99. The record daily rainfall was 210 mm in July 1995 at Punta Gorda Agricultural. Rainfall deficit is evident from February to April (Figure 2.6 c). The peak of the water deficit is March – April. The local climate in the South has UNEP aridity index (AI) of 2.4 Very Moist. The Annual Aridity regime is 2 months and the annual Rainfall Deficit is -198 mm. The onset of the rainy season is normally in the second to third dekad of May. This agricultural zone is very moist, with a short dry season and a growing season that extends almost year round.

2.2 PRECIS Regional Climate Model

For the discussion on regional climate model verification and future model projection of temperature, rainfall, evapotranspiration and other agro-climatic variables, it is important at this juncture to introduce the Hadley Center, United Kingdom, PRECIS Regional Climate Model. PRECIS stands for **P**roviding **Re**gional **C**limates for **I**mpact **S**tudies**.**

PRECIS is a Regional Climate Modelling (RCM) system derived from the Hadley Centre Global Climate Model (GCM)**.** It is a PC-based regional climate model. PRECIS can be set up and run over any area of the globe. The model is available for free and has two resolutions: 25 and 50 km. PRECIS is a modelling tool for dynamical downscaling, meaning it is forced at its boundaries by other global models such the Hadley Model HADAM3P GCM, HADCM3, and the European Centre Hamburg Model (ECHAM).

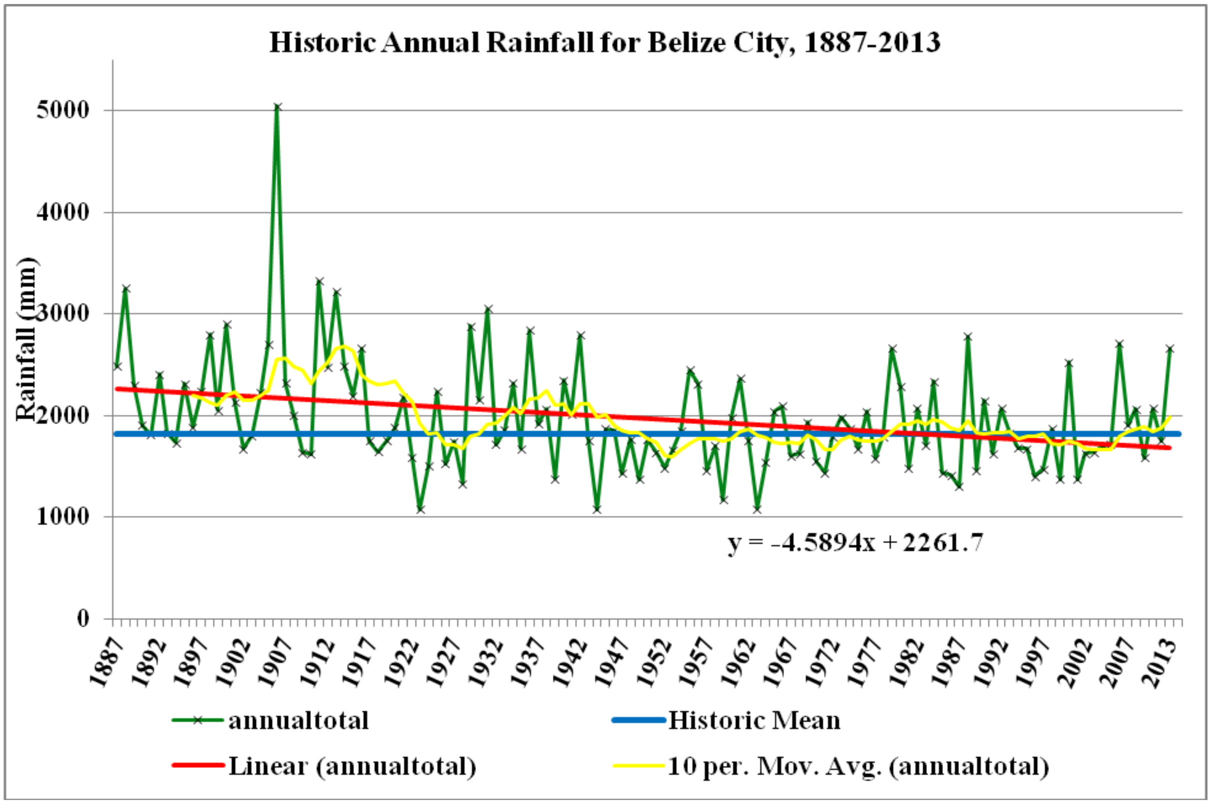
The GCMs, PRECIS-Echam4, PRECIS-Echam5, and PRECIS HADCM3 model projections of changes in temperature, rainfall, evapotranspiration for the Caribbean Region and Belize under the A2 (business-as-usual emission scenario), B2 (low emission scenario) and B1 (medium level emission scenario) for 50 and 25 km resolution were used in the analysis. See Annex 4-A for a brief discussion on the IPCC's Special Report on Emission Scenarios (SRES).

2.2.1 Historic Climate Trends

Rainfall (P)

Data collected from local meteorological stations from 1960 to 2013 indicate evidence of climate change during this period. The meteorological data for the central observation station at the PSWGIA was used to validate the PRECIS Model projections under the A2 and B2 emission scenarios (SRES) for recent historic trends. The data set for this central meteorological station is continuous and homogeneous over any 30 year period since 1961 to the present, and trends are representative of the climatic tendencies elsewhere around Belize. Time series for other meteorological stations in Belize and climate database for Belize from other sources such Tyndall Center for Climate Research (Mitchell, TD et al, 2013 www.cru.uea.ac/uk/~timm), University of Oxford (McSweeney et al. 2009, 2010) were used for some of the analysis.

Figure 2.7: Historic annual rainfall for Belize City (1887-2013)



The historic annual rainfall trend (red line) for Belize City Figure 2.7 shows decreasing tendency in annual rainfall from 1887 to 2013, at the rate of near - 4.6 mm per annum (negative slope of equation of the trend line) or 46 mm per decade, which translates to a decrease of around 480 mm over the 126 years rainfall record for Belize City. The long term mean rainfall for Belize City (blue line) is 1822 mm. The decadal or ten-year running mean (yellow line) highlights the decadal cycle of higher annual rainfall during 1905 -1922, 1933 - 1943, which damps away after the 1950s through 2010, with a rising tendency after 2010.

The annual rainfall trend (millimeters) for the PSWGIA for the period 1960-2013 is presented in Figure 2.8. The red line is the annual rainfall trend and the yellow line is the 10-year running average. Over the fifty-three years spanning 1960 – 2013, the analysis shows a slight increase in rainfall of about 1.4 mm per annum (slope of trend-line equation), which amounts to about 74 mm increase in observed rainfall at PSWGIA for the entire period under review. The annual average rainfall at this locality is 2003 mm for the period 1970 – 2000.

Figure 2.8: Annual rainfall for Philip Goldson International Airport (1960-2013)

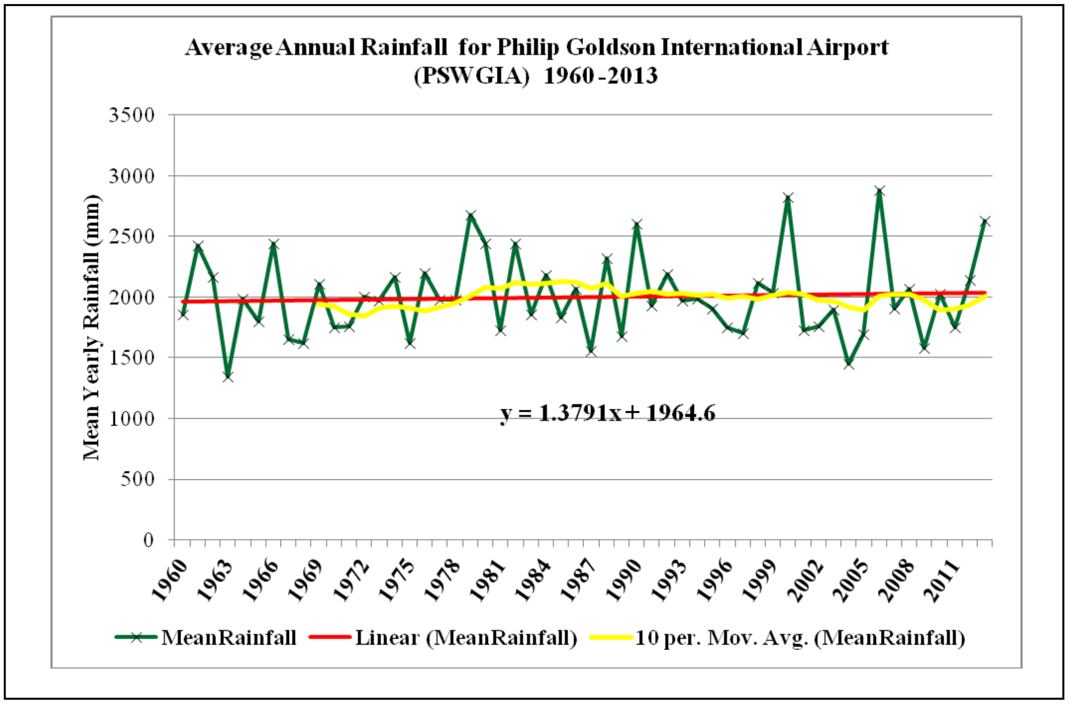
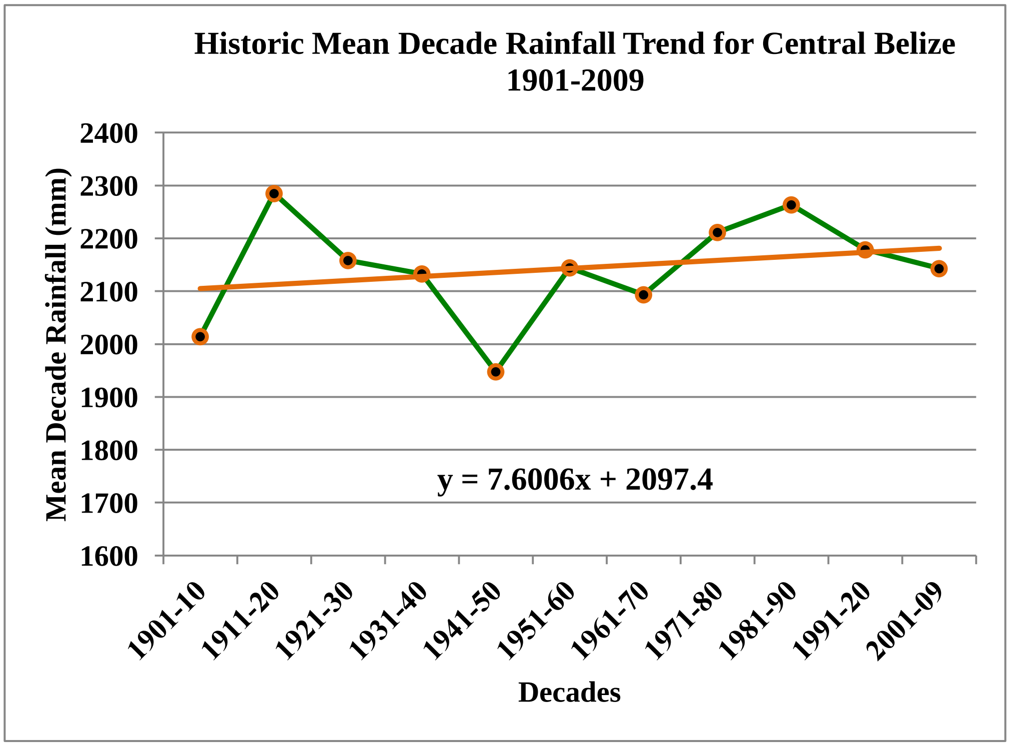


Figure 2.9 is a trend analysis of decadal or ten-year rainfall for central Belize for the period 1901–2009 (Mitchell, UEA, 2013). The analysis shows an increasing trend over the past century of 7.6 mm/decade or about 82 mm increase over the 108 year period. This result is consistent with the increasing trend for PSWGIA for the period 1960-2013, but is in the opposite direction of the decreasing trend for the Belize City historic rainfall records, which explains the high variability in long term tropical rainfall.

Figure 2.9: Historic Mean Decadal Rainfall for Central Belize (2001-2009)



Analysis by Author. Source of data: (Mitchell, University of East Anglia, UK, 2013)

Regression analysis for observed annual rainfall and PRECIS-Echam4 A2 scenario for some meteorological stations indicated poor correlation (not shown), with the modeled rainfall explaining less than 10% of the observed annual rainfall. In most instances, under the A2 SRES scenario, PRECIS-Echam4 over-estimates the rainfall and has poor skill in resolving the historic extreme rainfall events.

Figure 2.10 a - d are Time Series analysis of measured annual rainfall for Tower Hill, Central Farm, Melinda and Punta Gorda Agriculture station, and PRECIS-Echam4 A2 annual rainfall projections for the period 1991 to 2013 and 2014 to 2050. In each case the PRECIS-Echam4 A2 RCM over estimates the historic rainfall and misses the high rainfall events. The model projection shows a general decreasing trend in the annual rainfall to mid 21st century, except at Punta Gorda, where the change in rainfall from the climatological mean (1961-1989) is not significant. The high variability of tropical rainfall may be part of the Regional Climate Model (RCM) inability to resolve current and future rainfall signatures, and hence the lingering uncertainty with climate model prediction of precipitation; however, the model shows greater skills in evaluating changes in the pattern or trends of rainfall for the Caribbean region (Taylor, *et al*. 2007, AMS, 2013) and Belize.

Figure 2.10 a Tower Hill, Orange Walk District

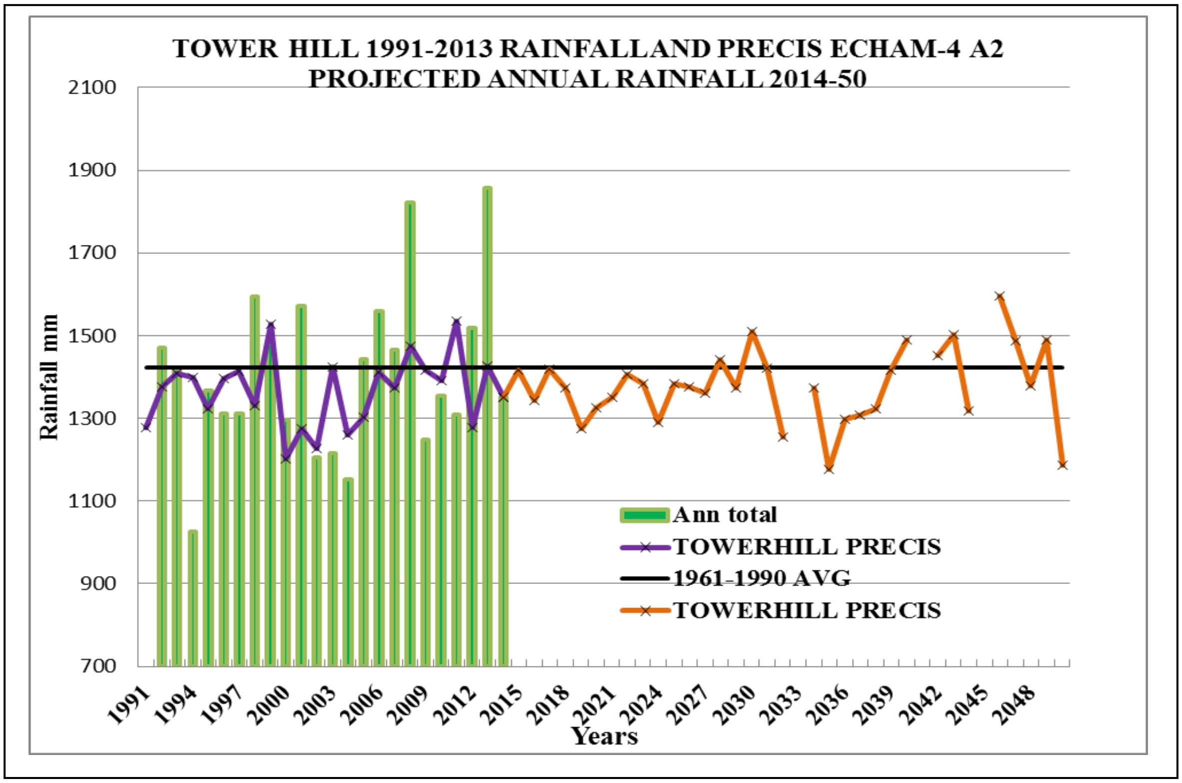


Figure 2.10 b Central Farm, Cayo District

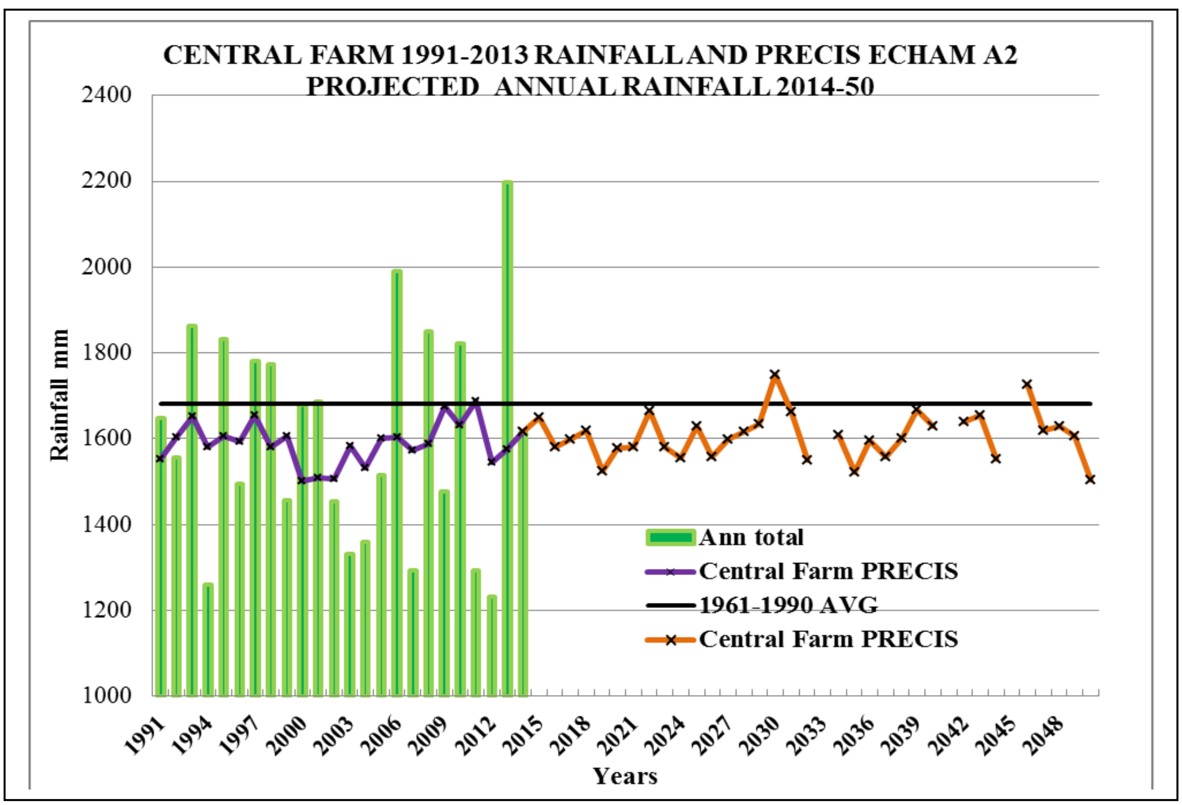


Figure 2.10 c: Melinda, Stann Creek District

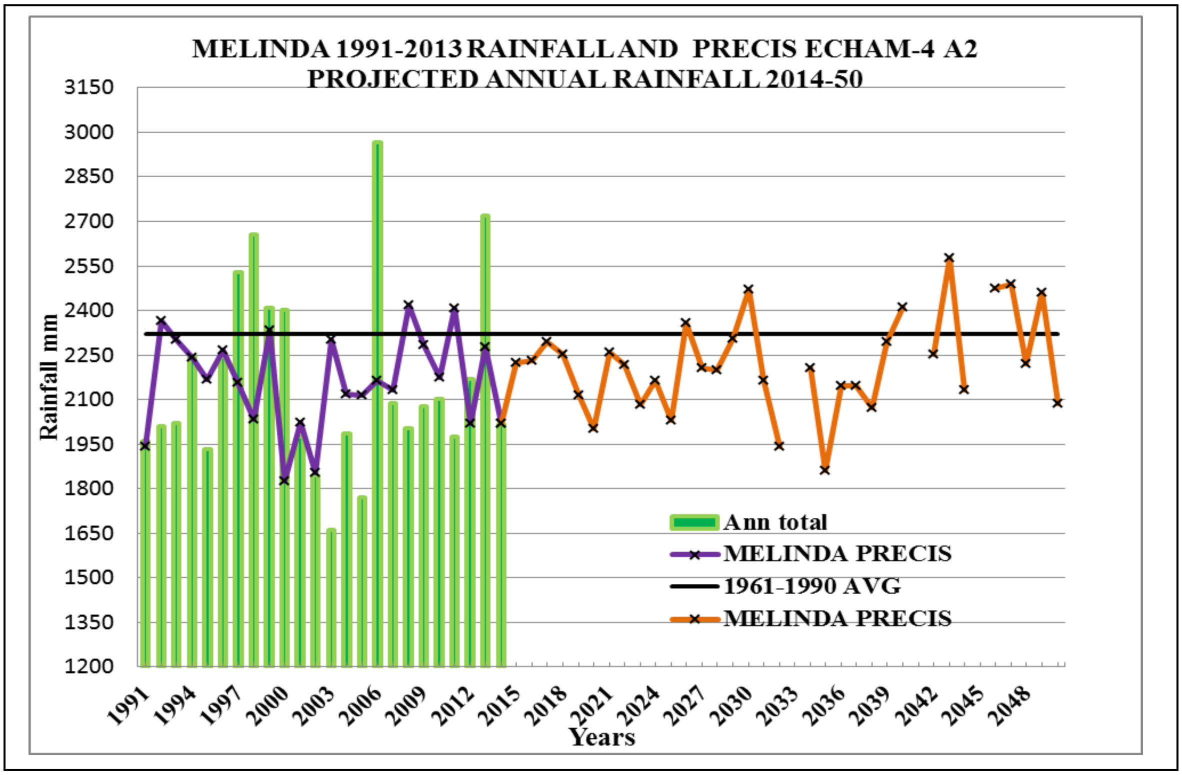
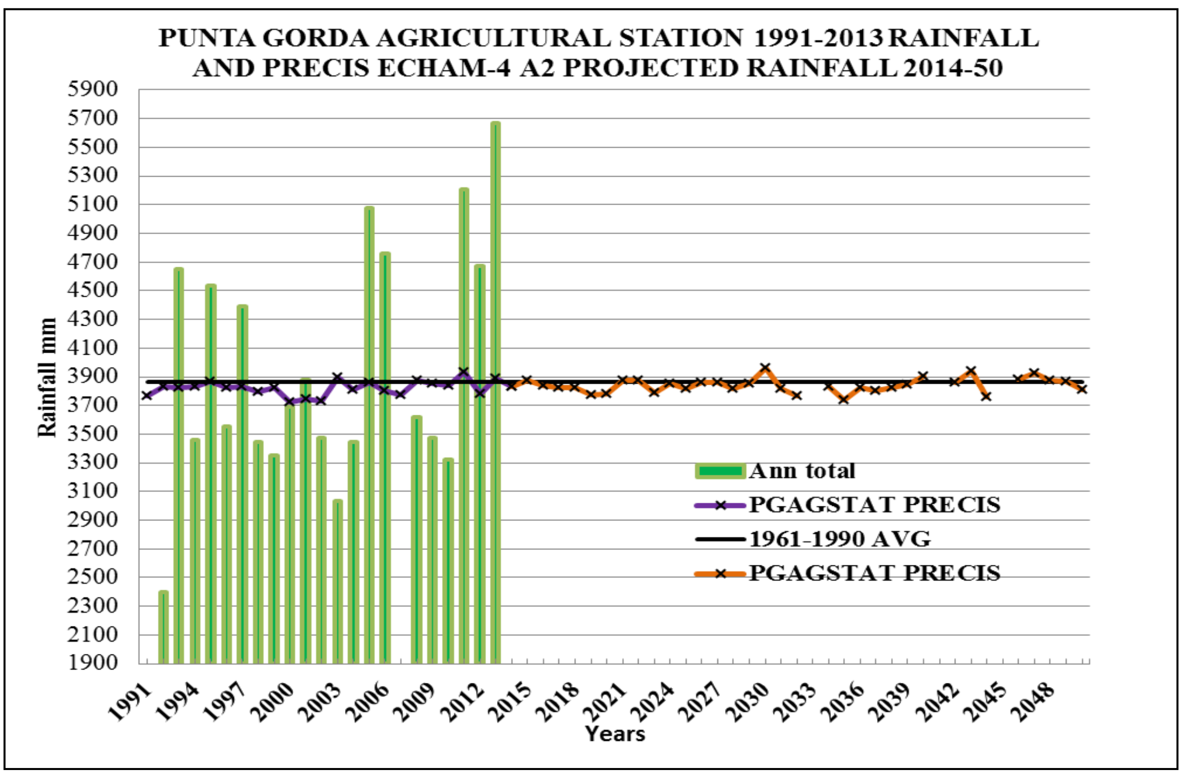


Figure 2.10 d: Punta Gorda Agricultural Station, Toledo District

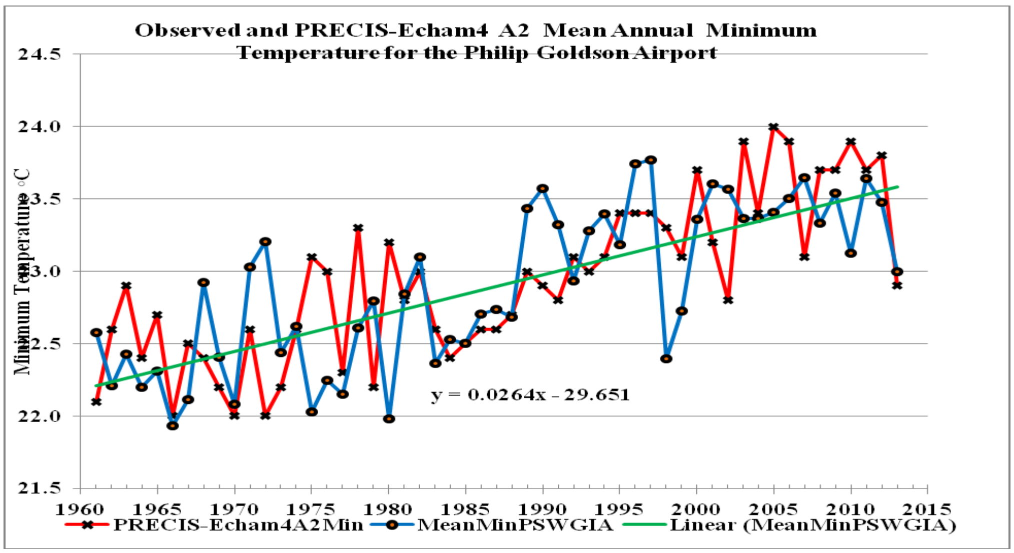


Temperature (T)

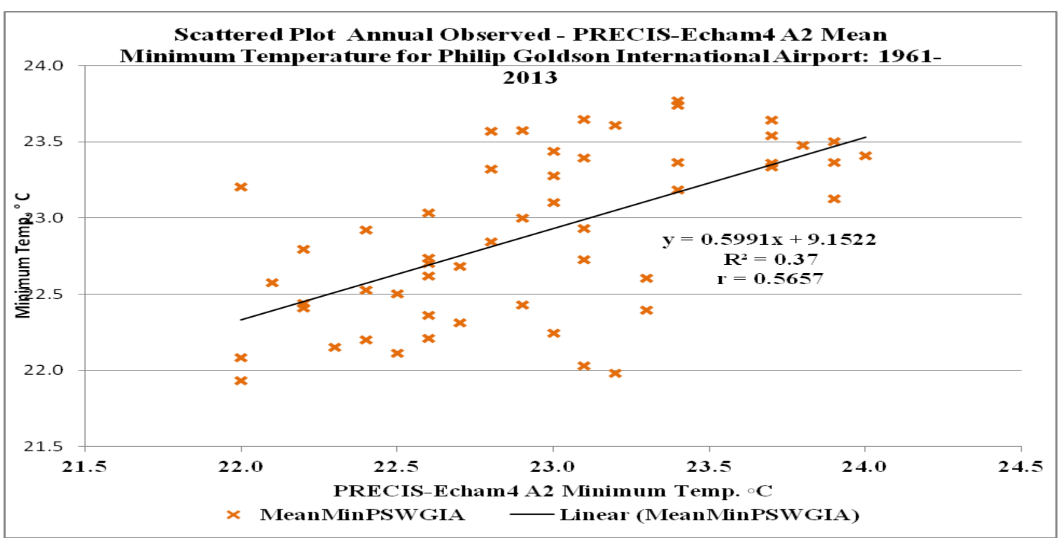
Historic and Regional Climate Model Temperature Trends: Validation of PRECIS-Echam4 RCM under A2 & B2 Scenarios

Figure 2.11(a) is the observed and the PRECIS-Echam4 A2 mean, annual minimum temperature trend for the Philip S. W. Goldson Airport (PSWGIA) for the validation period 1961 to 2013.

Figure 2.11 a–b: Observed and PRECIS-Echam4 A2 Mean, Annual Minimum Temperature Trend for the Philip Goldson International Airport, Belize (1961-2012)



(a): Observed and RCM-PRECIS-Echam4 A2 Mean Minimum Temperature Trend for PSWGIA: 1961-2012



(b): Scattered diagram of actual average minimum temperature and PRECIS- Echam4 A2 projected minimum for PSWGIA, Belize (1961-2013)

The model projected minimum temperature trace (redline) closely follows the observed, mean minimum temperature (blue line). The curves show an increasing trend in minimum, night-time temperature at the Airport. The observed trend in the mean, minimum temperature show an annual increase of near 0.026 °C per annum or an increase of about 1.4 °C over the 52 years under review.

Figure 2.11 b is a regression analysis of observed and PRECIS-Echam4 A2 mean annual minimum temperature for PSWGIA for the period 1961- 2012. The correlation coefficient '***r***' is 0.57, which is fairly good, meaning that PRECIS–Echam4 is explaining at-the-most 57 % of the PSWGIA mean annual minimum temperature.

Figure 2.12 is a plot of observed monthly mean and seasonal mean minimum temperature and PRECIS-Echam4 A2 model projection for the Airport for the period 1961-2012. As can be observed, the modeled minimum temperature projection follows closely the observed mean minimum temperature for this locality.

A plot of the mean minimum temperature at the Philip Goldson Airport for the more recent period 1991 – 2012, and the PRECIS-Echam4 A2 projection for the same period showed that the model was resolving the observed minimum temperature fairly well as depicted in Figure 2.13. An increasing trend in the mean minimum temperature of 0.01 °C per year or 0.22 °C increase in the 22 year period was evaluated. A regression analysis of observed and modeled mean minimum for the Philip Goldson Airport for 1991-2012 is presented in Figure 2.13 b which shows a fairly good correlation (*r* = 0.83) between the actual mean minimum temperature and the model output for the Philip Goldson Airport.

Figure 2.12: Monthly and seasonal, mean minimum temperature (1961-2012) and the PRECIS-Echam4 model projections for the Philip Goldson Airport

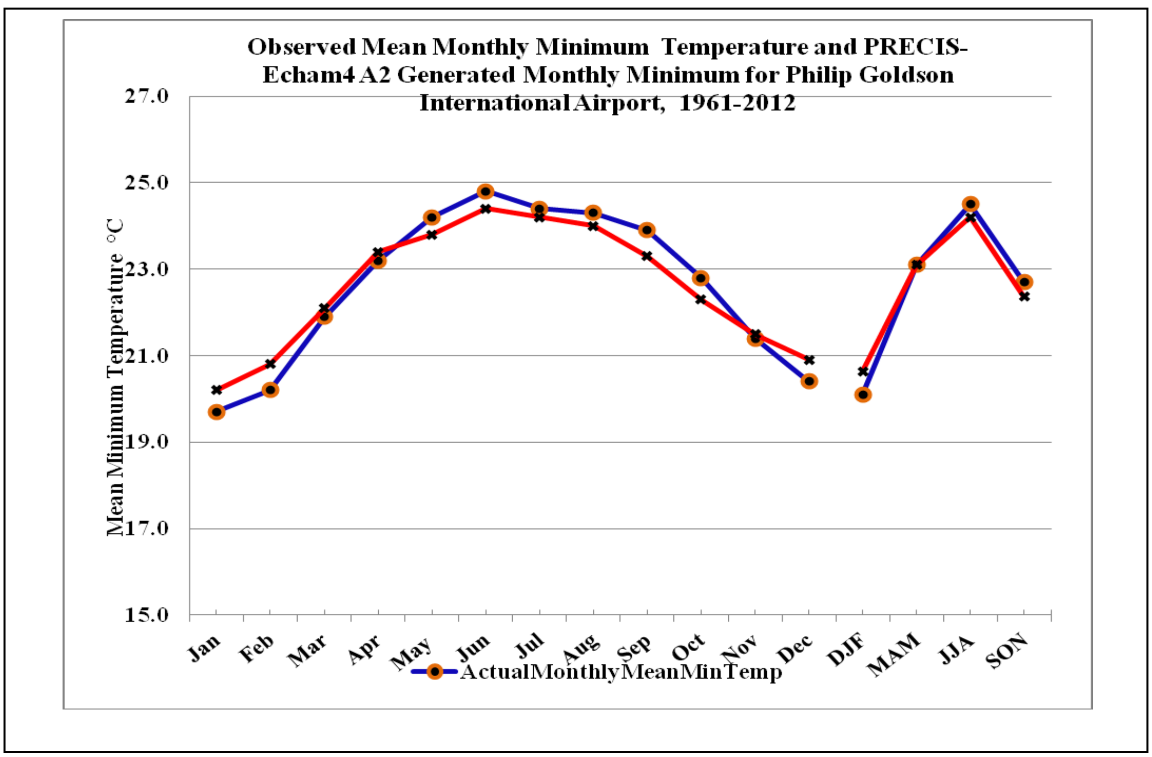


Figure 2.13 a: Actual and PRECIS-Echam4 A2 mean minimum temperature for PSWGIA, 1991-2012

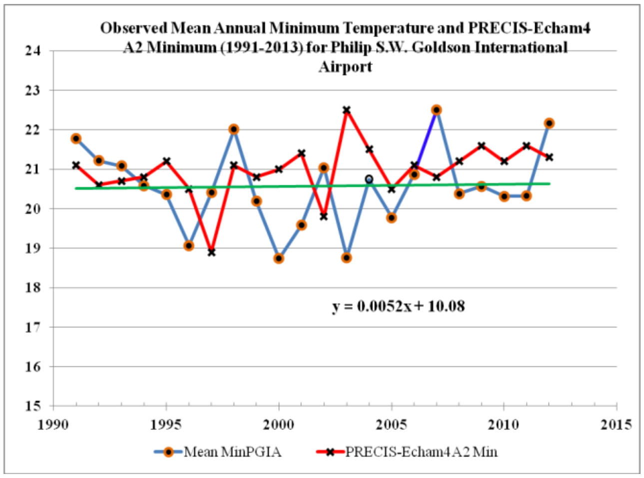


Figure 2.13 b: Scattered plot of Actual and PRECIS-Echam4 A2 projected mean minimum temperature for PSWGIA, 1991-2013

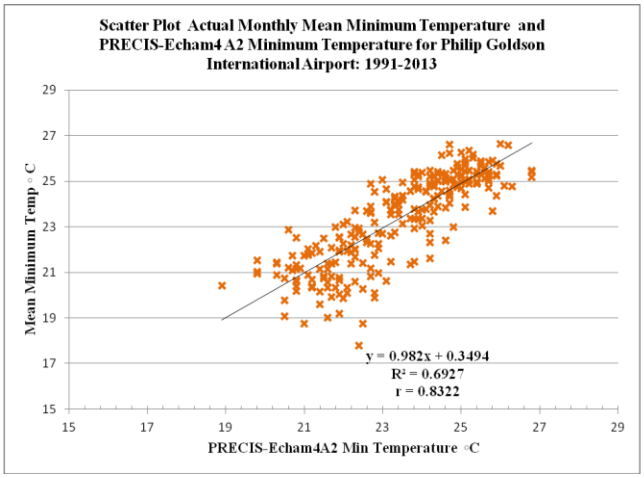


Figure 2.14 a: Maximum Temperature Trend and PRECIS-Echam 4 A2 Projection for PSWGIA: 1967-2013

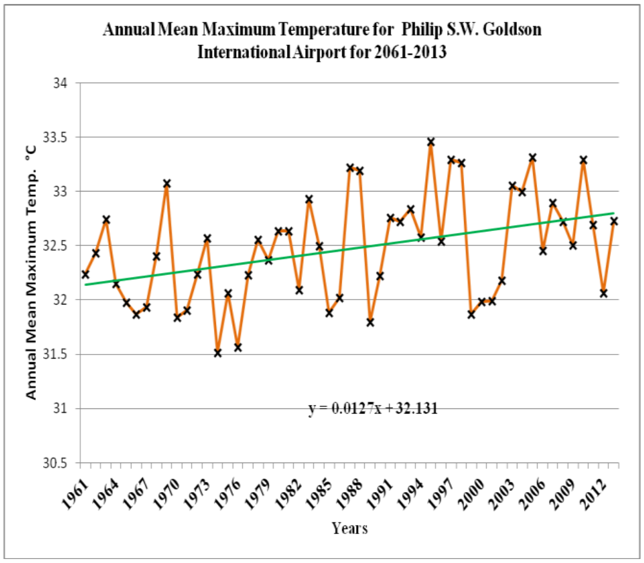
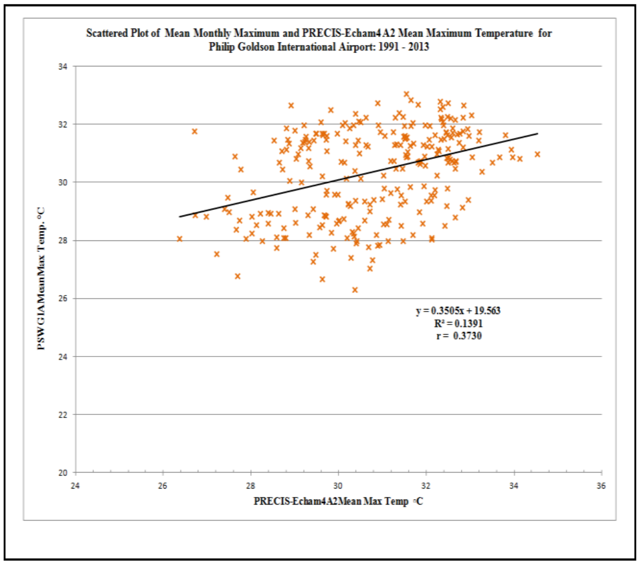


Figure 2.14 b: Scattered plot of mean maximum temperature and PRECIS-Echam4 A2 maximum temperature for PSWGIA 1991-2013



Maximum temperature trend

Figure 2.14 (a) is trend analysis of the annual mean maximum temperature for Philip Goldson International Airport for 1961-2013. The results show an increasing trend in the maximum at an annual rate of 0.013 °C. This is equivalent of a rise of 0.66 °C over the 52 year period since 1961.

Evapotranspiration (E)

Trend analysis of seasonal evapotranspiration rates for central Belize for the period 1980 – 2010 is displayed in Figures 2.15 a - d. The results show an increasing trend in evapotranspiration rate for all seasons during the period under consideration.

Mean Annual Evapotranspiration trend for Central Belize, 1980-2010

Figure 2.15 a: Eto - DJF Central Belize 1980 - 2010 (Source: Tyndall dataset, Mitchell 2013

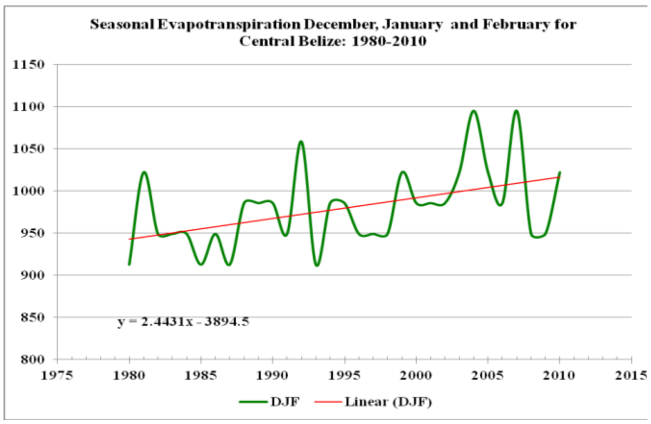


Figure 2.15 b: Eto - MAM Central Belize 1980-2010

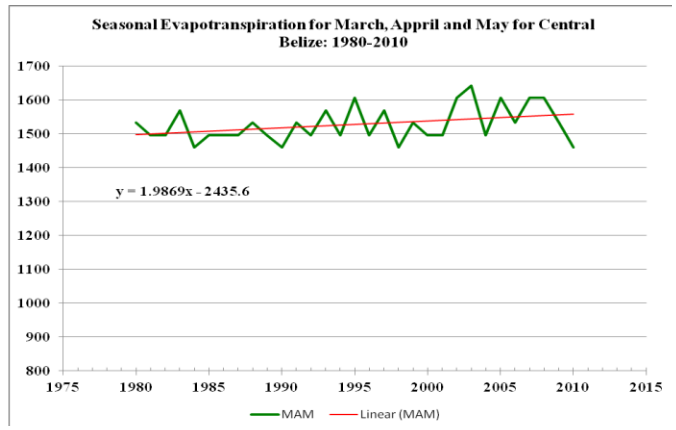


Figure 2.15 c: ETo - JJA Central Belize 1980-2010

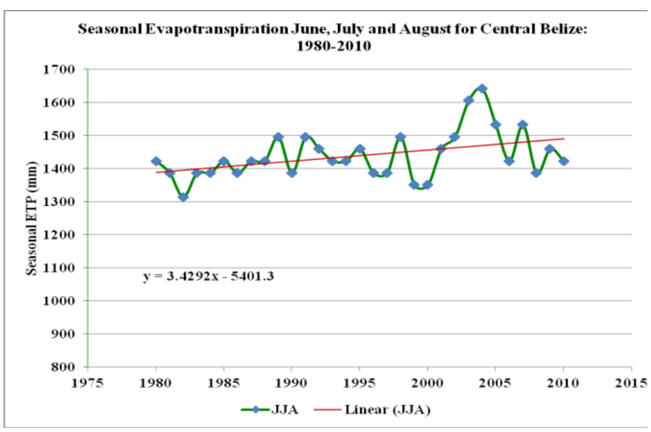
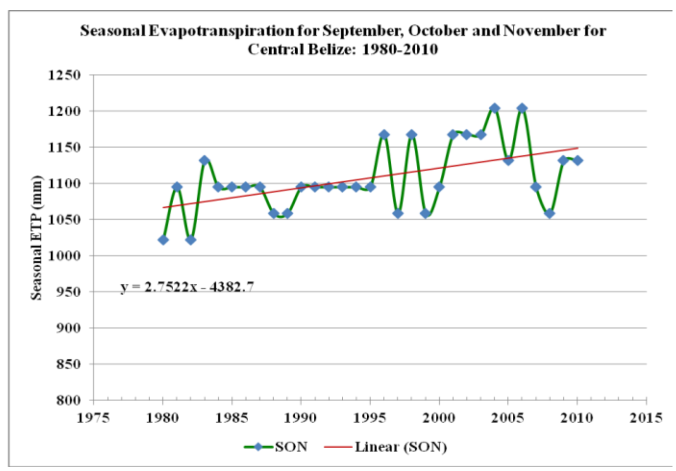


Figure 2.15 d: Eto - SON Central Belize 1980-2010



The trend analysis indicates that the greatest increase occurred during the June – July – August (JJA) period at the rate of 3.4 mm for JJA over the 30 year period 1980-2010. Climate change model projections indicate that this trend will continue under warmer climatic conditions in 21st century as summarized in Table 2 (b) below.

The projections show that daily E rate change will be greater in the JJA and SON seasons under both the A2 and B2 scenarios by mid 21st century and in 2075-2080 as summarized in Table 2 (b) below.

Table 2 (b): Climatology (1980-2010) and Model Projection of Evapo-transpiration rates for Central Belize

	Evapo-transpiration *E* Climatology Central Belize			Projections PRECIS-ECHAM4					
Seasons	*E* Climatology Central Belize	*E* rate change 1980-2010	*Total E* Change 1980-2010	*E* Change 2020-2025*		*E* Change 2050-2055*		*E* Change 2075-2080*	
Quarters	mm/d*	(mm/yr)	mm	A2	B2	A2	B2	A2	B2
DJF	4.4	2.4	72.0	2.0	7.9	9.9	12.0	16.7	19.6
MAM	5.7	2.0	60.0	5.7	9.9	13.4	16.5	25.3	24.0
JJA	5.4	3.4	102.0	10.2	5.7	17.8	19.6	37.8	26.5
SON	4.4	2.8	84.0	8.9	10.4	19.0	26.5	31.9	23.2
(**A2** – Business-as-usual emission scenario ; **B2** - Low emission scenario)									

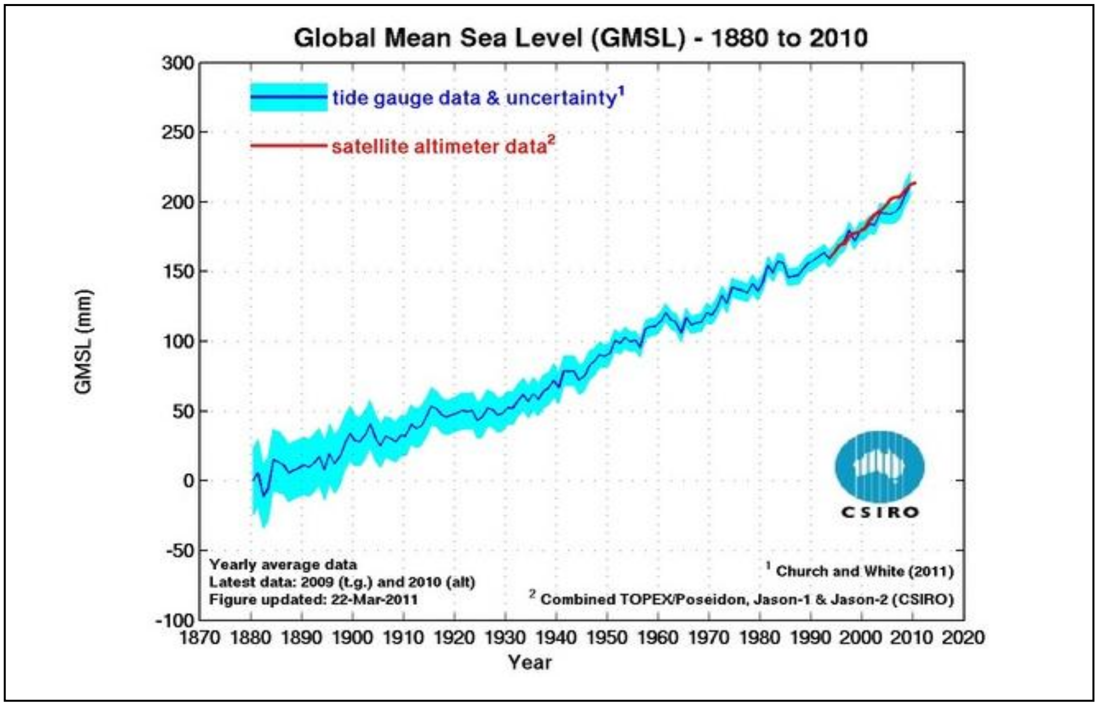
Table 2 (b): Climatology (1980-2010) and model projection of evapo-transpiration rates for central Belize (Source of data: Mitchell, 2013). * millimeters per day

This means that the atmospheric water demand will increase during Belize's cropping season

Sea Level Rise: Historic Trend

Local sea level rise can now only be inferred from global averages since no data is available locally. Global trends indicate that sea levels have risen at the rate of about 0.0162 cm per annum or some 21 cm since 1880 (Figure 2.16) Although the rise in sea levels will not be the same globally (IPCC, 2007) low lying coastal zones at or near mean sea level will be the first impacted by rising seas.

Figure 2.16: Global Sea level 1880-2010 (Source: CISRO, 2011)



2.3 Climate Change Projections

2.3.1 IPCC AR5 Global Climate Model Projections for Central America and the Caribbean

The Climate Modelling Inter-comparison Project 5 (CMIP-5) GCM projections under the Representative Concentration Pathways Scenario 4.5 (RCP4.5), projects annual temperature increase of 1.2 °C at the low end to 3.0 °C for the high end for Central America by 2100. Precipitation change is projected to range from -17% to +9 % by the end of the century. The model projections for the Caribbean are less but significant. An increase of 0.7 °C is projected at the low end to 2.4 °C at the high end by 2100; and percent precipitation change is projected between -10% to +14 % (SPM WGI, IPCC 2013). See Annex 4 for more detail on the RCP4.5 climate projection for the two sub regions of Central America and the Caribbean.

2.3.2 Projected Sea Level Rise

The coastal lowlands in northern Belize will be vulnerable to sea-level rise according to the global climate model projections.

By the 2090s, sea-level in this region will rise relative to 1980-1999 sea-level between:

0.18 to 0.43m under SRES B1 scenario
0.21 to 0.53m under SRES A1B
0.23 to 0.56m under SRES A2

Consequently, the region will be at high risk of coastal inundations, and increased saline intrusion into the ground and surface water, which will reduce freshwater availability for domestic and agricultural use. Other risks attributed to climate change are increased droughts and heat waves, intense rainfall events and stronger hurricanes threatening this region of Belize (IPCC, 2007; UNDP, 2009; GOB, 2nd National Communication to the UNFCCC, 2010).

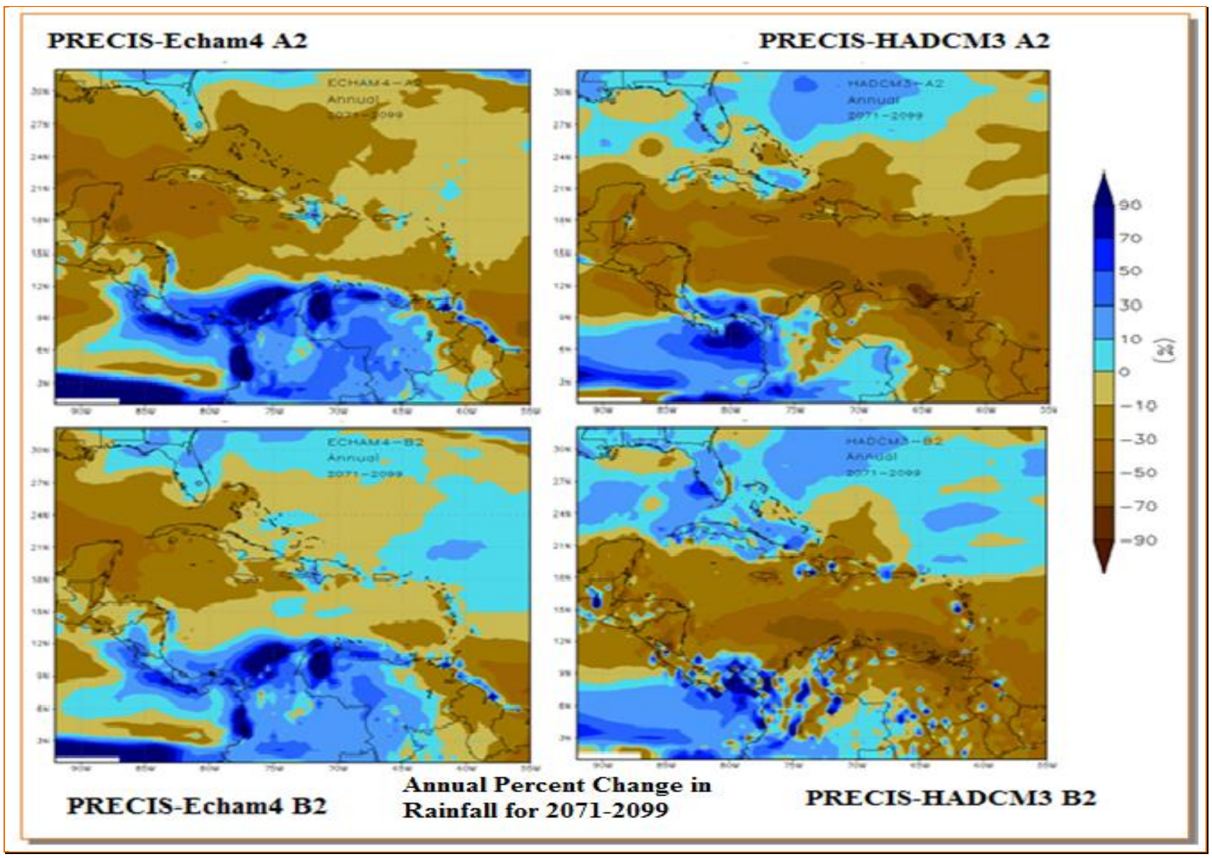
In its Summary for Policy Makers for the Fifth Assessment Report, Working Group I of the IPCC (SPM WGI AR5, IPCC 2013) reported that global mean sea level rise for 2081–2100 relative to 1986–2005 will likely be in the ranges of 0.26 to 0.55 m for RCP2.6; 0.32 to 0.63 m for RCP4.5; 0.33 to 0.63 m for RCP6.0; and 0.45 to 0.82 m for RCP8.5 (medium confidence). For RCP8.5, the rise by the year 2100 is 0.52 to 0.98 m, with a rate during 2081 to 2100 of 8 to 16 mm yr^{-1} (medium confidence). These ranges are derived from CMIP5 climate projections in combination with process-based models and literature assessment of glacier and ice sheet contributions.

2.3.3 Regional Climate Projections

PRECIS-Echam4 and PRECIS-HADCM3 Regional model results for Caribbean, Central America and Belize, under Climate Scenarios A2 and B2.

Figure 2.17 shows contour maps of the PRECIS-Echam4 and PRECIS-HADCM3 under the A2 and B2 scenario for mean annual rainfall change in per cent (%) across the Caribbean for the period 2071-2100. The greater change in mean annual rainfall is in the north western Caribbean and Belize in the order of -30 to -50 % change from climatology (1970-2000) under the A2 (business as usual) scenario for both the PRECIS-Echam4 and PRECIS - HADCM3 regional climate models. The per cent change in the north-western Caribbean under the B2 (lower emission) scenario is in the range of -19 to -30 per cent for both models. These changes in rainfall coupled with the projected 3 – 4 °C increase in mean surface temperature under the A2 scenario will very likely have far reaching effects on the Caribbean region agriculture and food security, if prompt actions are not implemented to curb the global emissions of greenhouse gases.

Figure 2.17: PRECIS-Echam4 & HADCM3 A2 & B2 projections of annual rainfall change (%) in 2071-2099 relative to climatology. (Source: CCCCCs, Belize 2012)



A summary of GCMs (Table 2.b-2) and PRECIS Regional Climate Model projections of mean surface temperature, precipitation, sea surface temperature and tropical cyclones future tendencies for the western Caribbean and Belize is contained in Table 2.3. Projected increases in sea surface temperatures (SST) range from +0.7 °C to +2.7 °C by the 2080s. This trend of warmer SST will energize the hydrological cycle and will likely favour more intense hurricanes. However, the overall impact of climate change on tropical cyclone is still unclear (IPPC, 2007). Some authors indicate that storm tracks may change and storm intensity will increase, but tendency of increased frequency is still unresolved (SPM, Working Group I &II, IPCC 2007; Salinger et al. 2000).

Table 2 (b)-2: Summary of Global Climate Models (GCMs) projections Caribbean and Belize

Temperature	Regional Climate Model (RCM) projections indicate increases between 3.5˚C and 3.6˚C in mean annual temperatures by the 2080s, in the higher emissions scenario
Precipitation	General Circulation Model (GCM) projections of rainfall span both overall increases and decreases, ranging from -34 to +13 mm per month by 2080 under the scenario with slow economic growth and technological change. Most projections tend toward decreases. The RCM projections, driven by HadCM3 boundary conditions, indicate large decrease in all seasons (-26%) and decreases of (32%) with ECHAM4
Sea Surface Temperature	GCM projections indicate increases in SST throughout the year. Projected increases range from +0.7˚C and +2.7˚C by the 2080s across all three emissions scenarios.
Tropical Storms and hurricanes	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

(Source: Climate Change Risk Atlas (CCCRA, CARIBSAVE, 2009-2011)

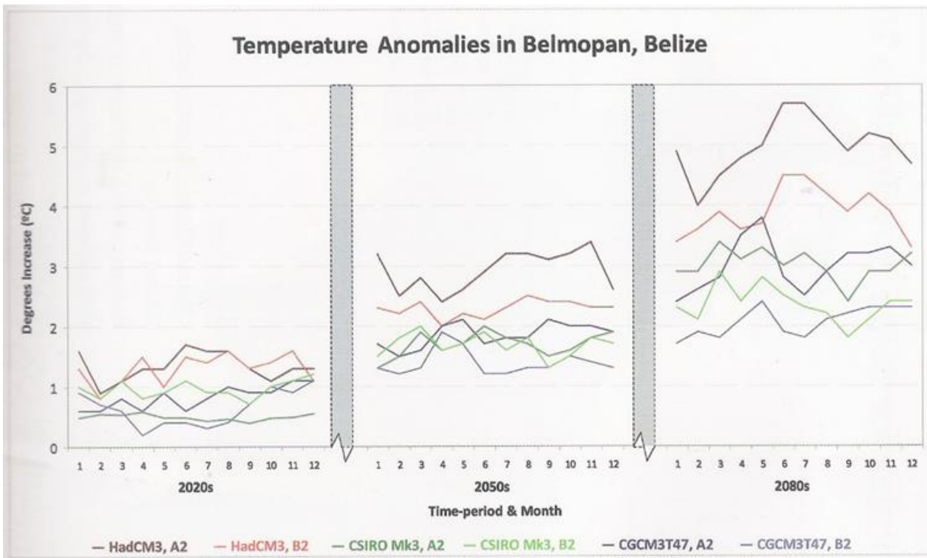
2.3.4 Oak Ridge National Laboratory and NASA Meso-scale Modelling System, version 3.6, (RCM) for Mexico and Central America

Downscaled global model projections using the Oak Ridge National Laboratory and NASA Meso-scale Modelling System, version 3.6 for Central America (2005) at a resolution of 12 km, was used to project mean temperature and precipitation for Mexico, Central America and the Dominican Republic by personnel of the Water Centre for the Humid Tropics of Latin America and the Caribbean, CATHALAC (Anderson, *et al.* 2008). Using various GCMs results for boundary conditions and for both the A2 and B2 climate scenarios, the meso-scale model generated monthly temperature anomalies and per cent changes in rainfall from the baseline period 1961-1990 for the 2020s, 2050s and 2080s for Belize. Figure 2.18 a-b shows the monthly anomalies of temperature and per cent change in rainfall for Belmopan, which was one of several outputs from the climate experiments.

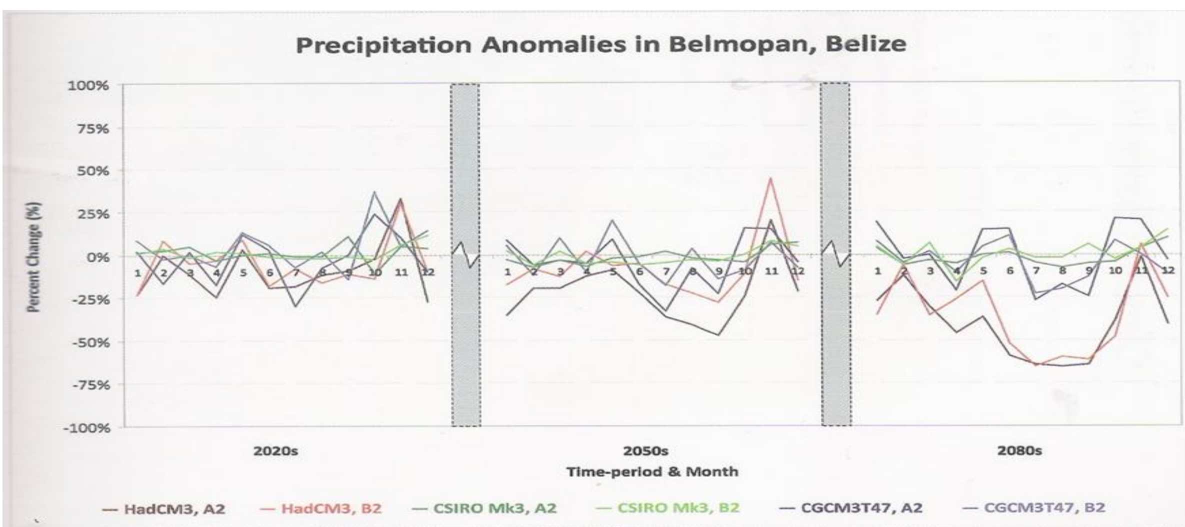
The results show a warming trend from close to 1 °C increase in the 2020s to near around a median of 3 °C by the 2080s. Decreasing changes in rainfall will be greater in the May through October period, ranging from -25 % to near -60 % by the 2080s in the Belmopan area. Another output was a Climate

Change Severity Index evaluated for the region, including Belize. The Climate Change Severity Index is a combination of the Temperature Severity Index and the Rainfall Severity Index. It shows that by the 2020s the Toledo and Corozal Districts, and the highlands of the Cayo District will be approaching significant change in temperature and rainfall, while the rest of central and western Belize, including most of the Orange Walk District will experience significant changes that will vary annually. Annex 4 shows a map of the Climate Change Severity Index after Anderson *et. al.* (2008).

Figure 2.18 a-b Temperature and Rainfall anomalies for Belmopan for: 2020s, 2050s and 2080s



a



b

(Source: Anderson, et. al., 2005)

2.3.5 PRECIS Climate Model Projections

Table 2 (c) below shows a summary of the PRECIS-Echam4 A2 & B2 model projections of mean surface temperature (°C) and per cent (%) change in rainfall in June-July-August (JJA) for various localities in Belize for 2020-2025 and 2080-2085 relative to the baseline period 1970-2000. The model results under both the A2 and B2 SRES scenarios at the regional level for the western Caribbean (Figure 2.14) and at the local level over Belize project greater negative changes in the June-July-August rainfall around and beyond mid-21st century. Mean surface temperatures at all localities in Belize are projected to rise to near 1.0 °C by 2020-2025 relative to the 1970-2000 climatology, and to near 4 °C by 2080-2085 (Table 2 c).

Table 2 (c): Regional Model projections of mean surface temperature and % change in rainfall for some stations in Belize for 2020-2025 and 2080-2085 relative to the period 1970-2000

Station	**Temp Trend 1961-2013**	**PRECIS-Echam4 Projected Temperature Change deg. C**				**Rainfall Trend 1961-2013**	**PRECIS-Echam4 Projected % Change in *JJA* Rainfall**			
	deg. C/decade	**2020-2025**		**2080-2085**		**mm/decade**	**2020-2025**		**2080-2085**	
	± Min/Max/Mea	**A2**	**B2**	**A2**	**B2**	**±**	**A2**	**B2**	**A2**	**B2**
Libertad		0.8	1.3	4.2	2.9		-30.9	-25.1	-64.8	-54.5
Towerhill	- 0.20 °C (Mea T)	0.8	1.3	3.5	2.9	+ 120 mm	-32.6	-26.4	-68.9	-60.4
PSWGIA	+ 0.10 °C (Min T) + 0.15 °C (Max T)	1.1	1.3	4.0	2.9	+ 14 mm	-28.3	-24.5	-79.2	-74.0
Central Farm		1.1	1.4	4.2	3.0		-10.3	-2.0	-65.2	-51.0
Melinda		0.6	1.0	3.0	2.2		-49.6	5.1	-79.3	-38.7
Mayan King		1.1	1.3	4.0	2.2		-13.5	-26.9	-50.5	-83.3
PGAgstat		1.1	1.4	4.1	3.0		0.1	-8.8	-15.6	-57.3
TRDP		1.1	1.3	4.2	3.1		-5.0	12.1	-4.6	-22.5

(Source: PRECIS RCM climate projections, CCCCC, Belize 2014)

Figure 2.19: Actual and PRECIS-Echam4 A2 plot of annual mean minimum temperature for PSWGIA 1991-2013, and PRECIS model projection to 2099

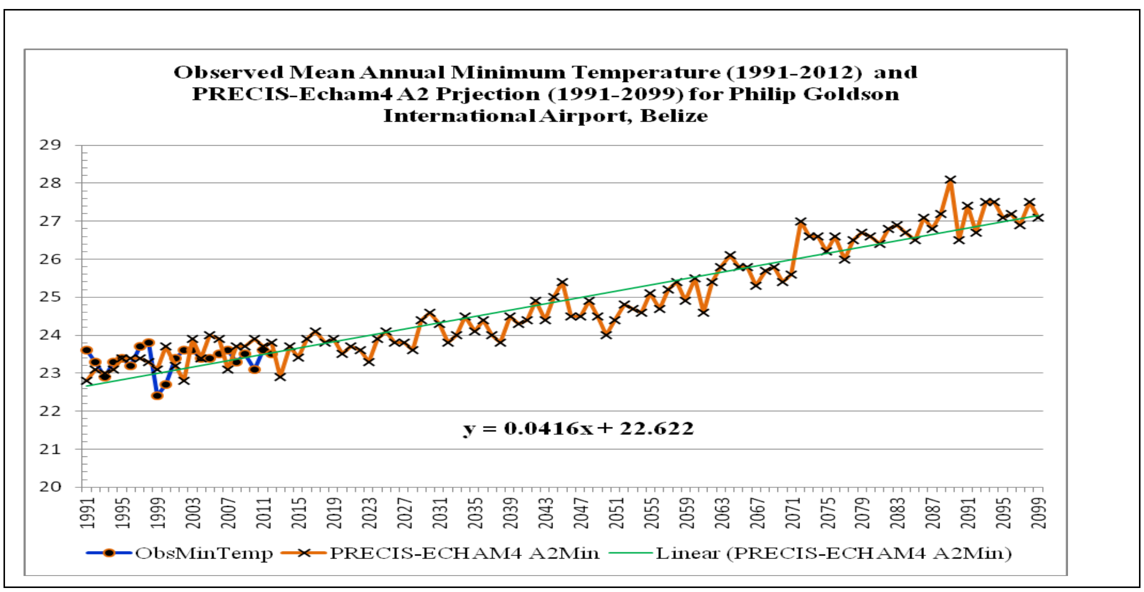


Figure 2.19 shows the observed and PRECIS-Echam4 A2 model projection of the annual mean minimum temperature for Philip Goldson International Airport for the validation period 1991 to 2012, and PRECIS model projection to 2099. The model is projecting an increase of around 3.5 °C at this central locality by 2100 under the A2 scenario.

2.3.6 PRECIS-Echam4 A2 and B2 projections of per cent change in rainfall for Belize

Tables 2.(d) - 2.(g) show per cent changes in seasonal rainfall relative to the baseline period 1961-1990 for the agro-climatic zones of Belize as generated by PRECIS-Echam4 under the A2 and B2 scenarios for the period 2020-2025 and 2080-2085. As can be observed from the tables, the larger per cent changes in seasonal rainfall are projected to be in the wet months of JJA & SON, later in the 21st century (2080-2085), specifically over areas north of the Toledo District. The large changes in excess of -60% of climatology is for the business-as-usual scenario A2, but even with the low emission scenario B2, the per cent anomalies are large. A comparison of the PRECIS Echam4 B2 per cent change in rainfall projections for Belmopan for the wet months JJA–SON, with those from the Meso-scale Modelling System for Central America (Anderson, *et.al*. 2008), show that both regional models concur with changes of ranging from around -20 % to -55% from climatology by 2080s. Future temperature projections for central Belize (i.e. the Belmopan area of Cayo District) as resolved by both RCMs downscaled using different Global Climate Models, also show that under both emission scenarios, the results are comparable, ranging from about 1 °C rise from climatology by 2020-2025 to 4 °C rise by 2080-2085.

- *Corozal and Orange Walk Districts, Northern Belize*

Table 2 (d): PRECIS-Echam4 projection of per cent change in seasonal rainfall for Northern Belize

Precip % Change PRECIS-ECHAM4 A2					Precip % Change PRECIS-ECHAM4 A2			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
Consejo	-26.9	-7.9	-30.9	0.7	-60.7	-11.7	-64.8	-44.5
Towerhill	-29.3	-6.2	-32.6	-4.6	-58.5	-17.7	-68.9	-46.7
RioBravo	-21.3	-5.5	-26.4	-4.2	-54.2	-10.4	-63.6	-36.9
Precip % Change PRECIS-ECHAM4 B2					**Precip % Change PRECIS-ECHAM4 B2**			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
Consejo	-3.8	12.6	-25.1	-23.3	-27.1	5.8	-54.5	-41.3
Towerhill	-0.9	14.5	-26.4	-27.5	-33.3	3.1	-60.4	-44.3
RioBravo	-0.9	11.7	-10.3	-24.7	-25.7	-1.1	-58.7	-39.0

(Source: PRECIS RCM climate projections, CCCCC, Belize 2014)

- *Cayo District, Western Belize*

Table 2 (e): PRECIS-Echam4 projection of future per cent change in rainfall for Western Belize

Precip % Change PRECIS-ECHAM4 A2					Precip % Change PRECIS-ECHAM4 A2			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
PGIA	-20.2	-11.3	-28.3	-13.9	-55.2	-15.1	-79.2	-54.0
Bmp	-23.2	-15.1	-20.5	-7.1	-48.8	-26.2	-55.2	-31.9
CF	-27.2	-6.1	-10.3	-5.4	-49.8	-2.9	-65.2	-36.1
Precip % Change PRECIS-ECHAM4 B2					**Precip % Change PRECIS-ECHAM4 B2**			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
PGIA	2.2	19.1	-24.5	-35.5	-39.2	-4.2	-74.0	-49.3
Bmp	-4.7	18.1	5.1	-19.2	-30.6	21.8	-52.5	-20.4
CF	10.4	13.0	-2.0	-28.7	-31.5	2.0	-51.0	-41.2

(Source: PRECIS RCM climate projections, CCCCC, Belize 2014)

- *Stann Creek District, Southern Belize*

Table 2 (f): PRECIS-Echam4 projection of future per cent change in rainfall for the Stann Creek District

Precip % Change PRECIS-ECHAM4 A2					Precip % Change PRECIS-ECHAM4 A2			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
Mdlsex	-23.2	-15.1	-20.5	-7.1	-48.8	-26.2	-55.2	-31.9
Melinda	-38.9	-23.0	-49.6	-13.0	-18.1	-22.6	-79.3	3.2
MayanKing	-10.3	0.6	-13.5	-20.9	-33.1	4.5	-50.5	-47.2
Precip % Change PRECIS-ECHAM4 B2					**Precip % Change PRECIS-ECHAM4 B2**			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
Middlesex	-4.7	18.1	5.1	-19.2	-30.6	21.8	-52.5	-20.4
Melinda	-7.1	28.2	5.1	-11.2	-14.8	-2.1	-38.7	-17.9
MayanKing	3.5	13.6	-26.9	-35.1	-49.6	-7.2	-83.3	-35.8

(Source: PRECIS RCM climate projections, CCCCC, Belize 2014)

- *Toledo District, Southern Belize*

Table 2 (g): PRECIS-Echam4 projection of future per cent change in rainfall for the Toledo District

Precip % Change PRECIS-ECHAM4 A2					Precip % Change PRECIS-ECHAM4 A2			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
BigFalls	-33.5	-11.6	-19.9	-5.9	2.5	-5.9	-53.2	-31.1
PGAgstat	-19.5	-3.0	0.1	-0.1	-5.0	9.4	-15.6	-22.5
TRDPBlueCrk	-24.7	-2.5	-5.0	14.3	-9.0	0.1	-4.6	-9.2
Precip % Change PRECIS-ECHAM4 B2					**Precip % Change PRECIS-ECHAM4 B2**			
	DJF2020-25	MAM2020-25	JJA2020-25	SON2020-25	DJF2080-85	MAM 2080-85	JJA2080-85	SON2080-85
BigFalls	-4.7	8.4	-3.5	-10.3	-27.4	11.3	-42.6	-27.8
PGAgstat	1.1	16.5	-8.8	-31.4	-31.5	7.5	-57.3	-41.7
TRDPBlueCrk	8.0	11.9	12.1	-17.6	-16.6	17.3	-22.5	-21.6

(Source: PRECIS RCM climate projections, CCCCC, Belize 2014)

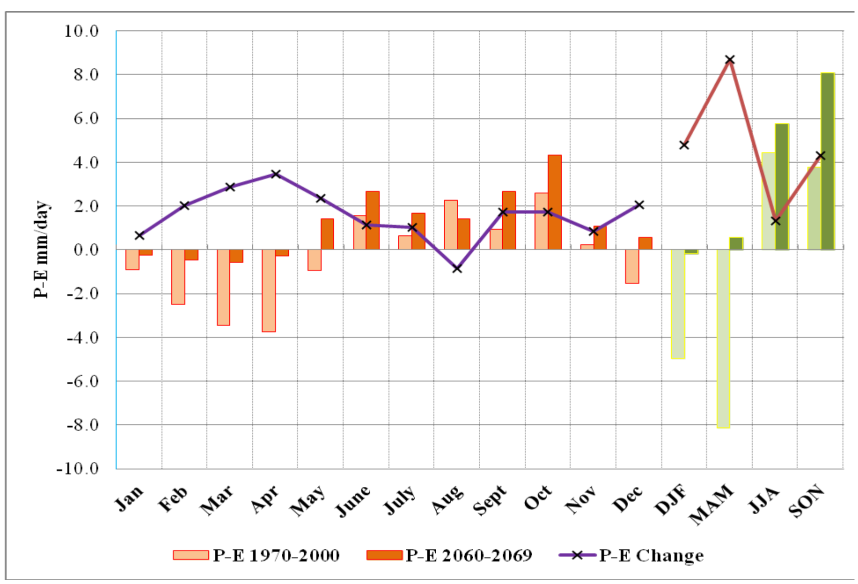
2.3.7 Changes in Moisture Deficit/Surplus, Precipitation - Evapotranspiration (P – E, mm/day) between PRECIS-Echam5 A2 Projections for 2060 – 2069 relative to 1970 – 2005 for Agro-climatic Zones in Belize

Summaries of monthly and seasonal changes in current and future moisture deficit/surplus (i.e. Rainfall – Evapotranspiration, P-E) for the agro-climatic zones in Belize are presented in Figures 2.19 – 2.23. In all cases the atmospheric demands for water increases, as current moisture surpluses during the wet season decreases by 2060-2065. The analysis shows that for some localities the dry months deficit during 2060-2069 will decrease slightly, indicating less intense dry conditions in March-April-May (MAM). Warmer climatic conditions in the future with increased rainfall variability will favour drier spells in the wet season. This scenario may result in a change in the main planting season which could have negative consequences on agriculture in Belize.

2.3.8 Towerhill, Orange Walk, Northern Zone: Sugar cane and mechanized irrigated rice

The climatology (1970-2005) and the PRECIS-Echam5 A2 scenario projection of Mean Monthly and Seasonal water deficit / surplus, (*Rainfall – Evapo-transpiration*, P-E) for 2060-2069 is shown in Figure 2.20 for Towerhill. Water deficit (P<E) is observed during the drier months (January-May) in the historic record and in the future period under review, albeit at reduced rates in the latter, while water surplus (P>E) is evident in the wet months (June – November).

<u>Figure 2.20: Changes in Mean Monthly and Seasonal P-E (mm/day) for 1970-2005 and PRECIS-Echam5 A2 projections (2060-2069 for Tower Hill</u>



The change in water deficit/surplus for the future period 2060-2069, relative to the reference period shows decreasing water deficit (P<E) in the drier months (a positive change or a bit more moisture), and increasing water surplus (P>E) in June, July, September and November, except during August when a decreasing trend in water surplus or a negative change is noted. Seasonally, the change in P-E will be such that December – May will see decreasing deficit or slightly more moisture. June-August (JJA) and September – November (SON) will see increasing surplus or a positive change, more so in SON.

The results indicate a decreasing tendency in the dry season water deficit at Towerhill for the period 2060-2069 and a higher surplus of 2 to 4 mm/day of moisture in the wet season, with the higher positive change in SON period. However, these projections are contingent with how well the model resolves the variability of the rainfall and evapo-transpiration locally. Analysis shows that the RCM has poor skills in resolving the extreme rainfall events, but does much better in resolving the rainfall tendency or trend.

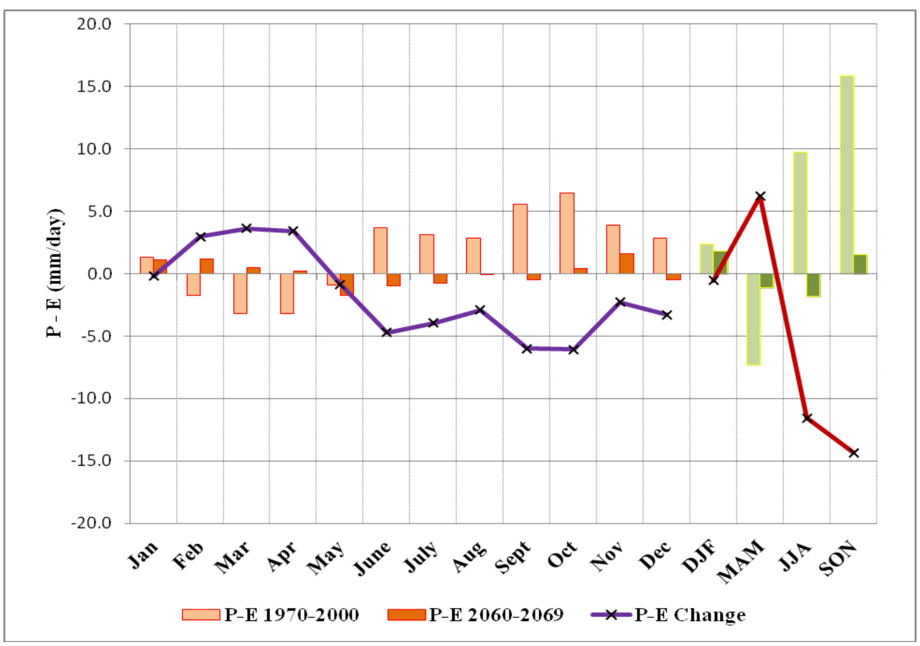
2.3.9 Melinda, Stann Creek District: Citrus

The changes in P-E in the case of Melinda shows decreasing deficit (P < E) or positive change for February – May, and decreasing surplus (negative change) for June through December as can be observed in Figure 2.21.

Seasonally, the analysis shows fewer deficit or positive change for January-February (JF) and March-April-May (MAM), and significantly less surplus or negative change in wet months, namely June-July-August (JJA) and September-October-November (SON).

The agronomic implications of this means that around Melinda by mid-21st century the dry season will be slightly less extreme, but there will be decreasing surplus of water for crops in the wet months, which concur with earlier PRECIS-Echam4 and PRECIS-HADCM3 A2 and B2 scenario climate predictions experiments for the western Caribbean which show drier JJA season by the 2071-2099 period (CCCCC, 2012)

Figure 2.21 Changes in Mean Monthly and Seasonal P-E (mm/day) for 1970-2005 and PRECIS-Echam5 A2 projections for 2060-2069 for Melinda, Stann Creek District



The effects for citrus is more water stress in the wet season during fruit development phase for established groves and the planting period for newly established groves.

2.3.10 Mayan King, Southern Stann Creek District: Banana, Aquaculture, Corn

Figure 2.22: Changes in Mean Monthly and Seasonal P - E (mm/day) for 1970-2005 and PRECIS-Echam5 A2 projections for 2060-2069 for Mayan King, South Stann Creek District

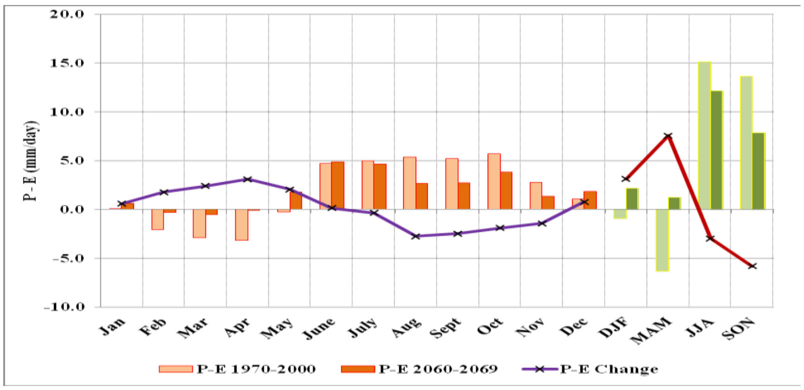
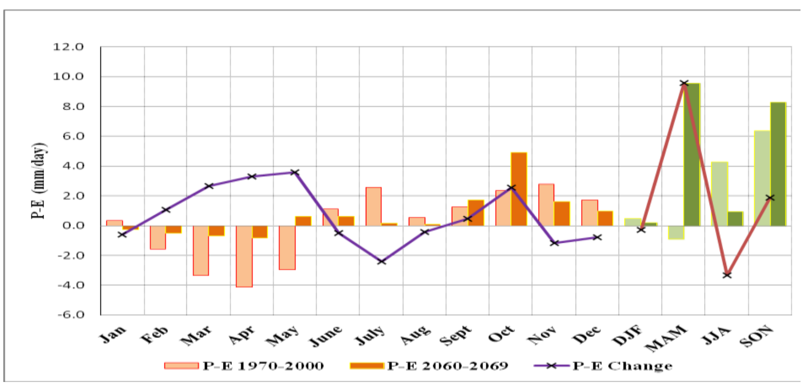


Figure 2.23: Changes in Mean Monthly and Seasonal P-E (mm/day) 1970-2005 and PRECIS-Echam5 A2 projections for 2060-2069 for Central Farm, Cayo District



In the Mayan King Area of South Stann Creek the analysis of changes in P-E for the period 2060-2069 with respect to the climatology (1970-2005) is shown in Figure 2.22. Small decreases in the dry season water deficit is evident (i.e. positive monthly changes), but again decreasing surplus (P > E) are observed in August through November (negative changes).

Seasonally, the analysis show less water deficit for the DJF and MAM periods (positive changes), but decreases in water surplus in the wet periods of JJA and SON (i.e. negative changes). This means that the mid-century dry season will be similar or a bit less dry than the present, but the rainy seasons will be drier than the current. The banana crop water requirements during the future rainy season will have to be supplemented with expanded and improved irrigation system, especially for the August dry spell periods that could be much more extended and extreme.

2.3.11 Central Farm, Cayo District: Corn, Beans, Citrus, Livestock

At Central Farm the analysis of changes in P-E for the PRECIS-Echam5 A2 projections for 2060-2069 with respect to the climatology (1970-2005) is presented in Figure 2.23. It shows decreasing deficit (P<E) or positive changes in the dry months and decreasing surplus or negative changes in the first half of the wet season (JJA), but increasing surplus in the second half of the wet months (September and

October). A drop in the November – December water surplus is also resolved by the model for mid-21st century.

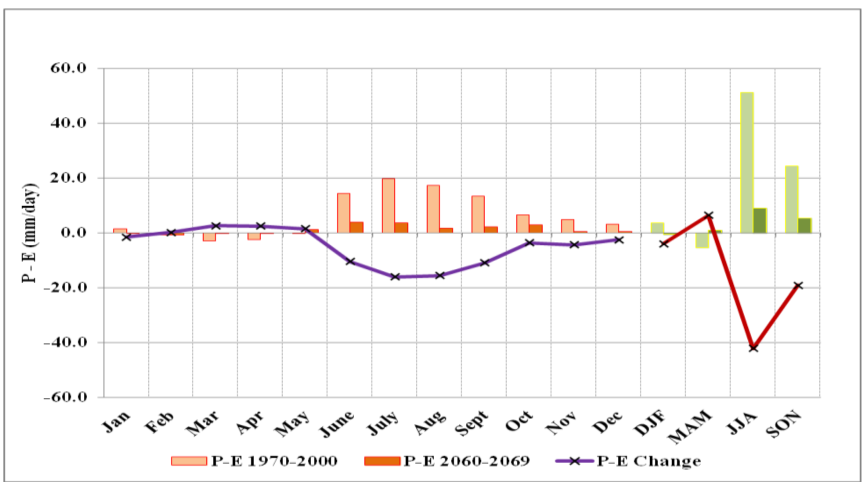
Seasonally, positive changes or gains in water deficit is observed for MAM, negative changes or less surplus in the first half of the wet season, and positive changes or increased surplus in the latter part of the wet season.

Again, model projection of less water availability during JJA for the western Belize concurs with earlier PRECIS-Echam4 and PRECIS-HADCM3 A2 and B2 climate prediction experiment for the western Caribbean which shows less rainfall in the north western Caribbean and Belize during JJA in 2071-2099 period (CCCCC, 2012)

2.3.12 Changes in P – E (mm/day) Between PRECIS-Echam5 A2 Projections for 2060 – 2069 Relative to 1970 – 2005

- *Punta Gorda Agricultural Station, Southern Zone: Upland Rice, Milpa Rice, Corn and Beans*

Figure 2.24: Changes in Mean and Seasonal P - E)mm/day) for 1970-2005 and PRECIS-Echam5 A2 projections for Punta Gorda Agricultural Station, Toledo District



In the South at the Punta Gorda Agricultural Station (PGAStat) model projections of the changes in rainfall deficit/surplus (P-E) for 2060-2069 period compared with the climatology (1970-2005), shows small decrease in the deficit (P<E) or positive changes from January through May, and marked decreased (negative change, P-E = -40 mm/day in JJA) in the wet months water surplus for June through December (Figure 2.24). Seasonally, the small gains in available moisture during the January-February and March-April-May periods are overshadowed by the larger losses in water surplus during the wet months in southern Belize.

This mid-21st century moisture availability scenario for southern Belize does not hold well for main cropping season in May-June, and sensitive phases of plant growth and crop development later during the cropping season. These conditions will warrant major shifts in crop management in South in the medium and long term period to avert the impacts of climate variability and change on food production.

In summary, water availability for crops by mid-21st century according to the model projections will be adequate for sugar, pastures, rice and other crops in the Northern zone during the cropping season, but water stress could increase later. Other areas of the country are projected to experience drop in water surplus during the wet months, which will be stressful for crops during critical periods of plant growth and development in the main planting period, which will very likely result in reduced yields.

2.4 Crop Model Results and Impact of Climate Change in Agriculture

2.4.1 Summary of climate-crop modelling done in Belize

A review of recent crop/climate model studies for Belize indicate that the country will likely experience drop in yields of the traditional commercial crops such as Sugar cane, orange and banana in a 2 °C increase in temperature and variations of ±10 to ±20 % change in rainfall. Losses are also projected for staple crops such as corn, beans, and rice due to warmer temperature by 2060 and 2080-2100. One of the recent study on the impact of climate change in Agriculture production in Belize (Ramirez *et al.*, 1013), indicated accumulated losses by 2100 on the agricultural sector as a whole approximating 35% of GDP for the baseline year of 2007, using a discount rate of 2%. The study revealed that the greatest economic losses will be as a result of variations in rainfall.

Table 2 (h): DSSAT3 resultant crop yields for 2°C increase in temperature and ±20% change in rainfall. Yields for maize and beans are means for 30 seasons; for rice are means for 10 seasons (Frutos and Tzul, 1995)

Crop	Scenario	Season Length (days)	Temperature Change °C	% Change in Rainfall	Yield (kg/ha)	% Change in Yield
Dry beans C3	Baseline 1995, Carib A	87	0	0	1353.61	
		85	+2	+20	1163.68	-14%
		85	+2	-20	1092.64	-19%
Rice C3	Baseline 1995, Carib A	124	0	0	3355.50	
		113	+2	+20	3014.40	-10%
		113	+2	-20	2887.50	-14%
Maize C4	Baseline 1995, Carib A	104	0	0	4510.64	
		97	+2	+20	3736.57	-22%
		97	+2	-20	3759.43	-17%

The crop model "Decision Support System for Agro-technology Transfer (DSSAT3) was used to simulate yields for upland rice, dry beans and corn under climate change scenarios of 1 and 2 °C increase in temperature and ± 20% change in precipitation (Tzul and Frutos, 1995). The baseline level of CO_2 was kept near the current atmospheric concentration of 330 ppm during the simulation, and adaptation measures by farmers to prevent losses were not considered. The objective of the simulation was to determine the future impact of climate change on these grains.

The results as summarised in Table 2 (h) show that projected climate change caused simulated crop yields to decrease. Percentage decrease in yields for dry beans were of the order of -19% (from the 1995 baseline) for -20% changes in rainfall, to -14% for a change +20% in precipitation. For rice, yields varied from -14% for a -20% change in rainfall to -10% for a +20% change in rainfall. Meanwhile, for corn the drop in yields varied from -17% for a -20% change in rainfall to -22% change in yields for a +20% change in rainfall.

The U.S. Country Study Programme through which vulnerability studies for various sectors were carried out in Belize (GOB/ UNFCCC, 2002) also funded a vulnerability study for coastal areas that predicted a 50 cm increase in sea level by 2075. Sea level rise of this magnitude would exacerbate saline intrusion into the coastal aquifers and surface water systems and would impact agriculture especially sugar cane and banana. Coastal flooding would require farmers to look farther inland for arable land, and search for new sources of potable water in the country's interior. This scenario would put more pressure on scarce arable lands and force farmers to use marginal lands and hillsides, thus increasing the needs for intensive farming.

Santos and Garcia (2008) simulated crop yields under different climate scenarios using DSSAT4 crop model. Environmental conditions for corn will worsen with decreasing rainfall in the first half of the rainy season (JJA) as projected by the GCMs and RCMs under different climate change scenarios. Similarly, a potential increase in temperature can cause a decrease in yields arising from a reduction in the duration of the crop cycle. The study showed that climate change could favour corn production only of the amount of rain rose during the summer and nitrogen deficiency can be managed effectively.

The same study simulated sugar cane yields based on two climate scenarios that predict increases between 1 °C and 2.5 °C along with ± 12% in rainfall by 2028, and ±20% by 2050. A 12% reduction was observed in sugar cane yield by 2028, and a 17% reduction by 2050 (Table 2.10). An increase in temperature shortens the growth periods of the crops, inhibits grain filling and decreases yields. Changes in rainfall did not affect the growth season, but they did affect the yields, especially when there is high rainfall variability. With efficient and low-cost irrigation systems, sugar cane is projected to survive in a warmer climate since it tolerates a wide range of temperatures.

Table 2 (i): Change in yields for sugarcane and citrus for 2028 and 2050 (Garcia & Santos, 2008)

Period	Temperature Change	Precipitation Change	Change in Yields	
			Sugarcane	Citrus
2028 & 2050	+1C to +2.5C	±12% & ±20%	- 12% to -17%	-3% to -5%

Simulation of citrus yields predicted a reduction of 3% by 2028 and 5% by 2050. The increase in temperature shortens the vegetative period of crops which decreased their yields.

Ramirez *et al.* (2013) analysed the potential impacts of climate change on the agriculture sector, looking at the impacts on all agriculture production as well as the sub-sector of crops and livestock. The crops considered in the study included the important economic crops such as sugar cane, maize, bean and oranges.

The results of the analysis of the sectorial production function using a Ricardian model that considers the integrated effects of temperature and rainfall revealed that climate change will have negative impacts on the agricultural sector due to increased temperature and rainfall variability. The accumulated losses by 2100 on the agricultural sector as a whole approximate 35% of GDP for the baseline year of 2007, using a discount rate of 2%. It was found that the greatest economic losses will be as a result of variations in rainfall (see Annex III F) for the year 2100 under the A2 scenario.

A look at scenario A2 and B2 and a 4% discount rate accumulated until 2050, losses would be about 12% and 5% of the 2007 GDP, respectively. Counting the negative impacts until 2100 with the same discount rate, the accumulated economic losses will make up 16% and 7% of 2007 GDP, respectively. In view of a 2% discount rate, losses will increase to 35% under the A2 scenario and to 16% in the B2 scenario by 2100. In the case of Crop production at 2% discount rate under scenario A2 and B2, losses by 2100 will be about 30% of GDP and about 15% of GDP, respectively.

The economic impacts of climate change on corn, beans, sugar cane and orange for both B2 and A2 scenarios for discount rates of 0.5, 2.0, 4.0 and 8.0 % of GDP for 2007 was also conducted. Under the B2 and A2 scenarios and a 2% discount rate, Ramirez, *et al.* (2013) evaluated losses in corn crop production by the year 2100 of the order of 5 % under both scenarios; 1.4 % to 2.4 % of 2007 GDP losses in beans by 2100; and losses of 4% and 6% of 2007 GDP for orange under the B2 and A2 scenarios respectively. In the case of sugar cane, the results of the modelling show that production of this crop will tend to fall in the medium to long term future. Under the A2 scenario the model reveals major decline, even dropping to zero by the end of the period. The depressed yields do not factor in possible adaptation measured farmers my implement in the future. It can be seen that the positive effects that climate change could bring to sugar cane production in the short term would reverse over the long term; in accumulated terms by 2100, the economic effects would be negative, reaching losses of between 2% and 5% of 2007 GDP. This would occur at a discount rate of 2%, but lower rates would produce greater adverse effects.

Singh *et al.* (2013) use the crop model DSSAT-CANEGROW to simulate aerial dry biomass at harvest (t/ha) and sucrose dry mass at harvest (t/ha) for sugarcane production in the Orange Walk District with observed Tower Hill station and modelled ECHAM5 and HadCM3Q11 climate data for 2000-2009 decade.

The results showed that for 2060-2069 production of aerial dry biomass for sugarcane at harvest will be reduced by -12.7% with the PRECIS-ECHAM5 model, and -20.9% with the PRECIS-HadCM3Q11 model. In the case of sucrose dry mass at harvest, the simulation results show a reduction of -21.7% with the PRECIS-ECHAM5 and -28.2% with the PRECIS-HadCM3Q11 model respectively.

Increased temperature results in increased rate of photorespiration which causes the sugar cane to convert sucrose to glucose and fructose, reducing sugar concentration which leads to a reduction in yields (Singh *et al*., 2013).

CROPWAT 8.0 Simulation of Future Yields for Dry Beans and Corn in Belize

A simulation a was conducted for dry beans and corn to determine per cent yield reduction in the year 2050 through 2055 using FAO CROPWAT 8.0 crop modelling software. The agronomic and climate reference year was 1998, and the future climate projection for the period was derived from the output of the PRECIS-Echam5 A2 (25 km resolution) experiment conducted for the western Caribbean.

The crops chosen for the simulation were Dry Beans and Corn, primarily because of their importance as staple grains in Belize. Red Kidney beans was the variety of choice but the crop coefficient for R. K. beans was not available, therefore the reference crop coefficient value for dry beans was utilized which is similar to that of R. K. beans.

Three sites were selected for the simulation, namely: Central Farm (Cayo District), Towerhill (Orange Walk District) and the Toledo Research and Development Project site (TRDP) near Blue Creek Village, Toledo District. The main agronomic parameters considered in the simulation were soils: primarily light sandy, medium loam and heavy clay. The cropping system was assumed to be rain-fed mechanized, and in the case of Corn, the simulation was run for early planting (one month before the normal planting period in June), normal and late (one month after the normal planting period in June). The normal planting period in December was use in the simulation for Dry Beans. The simulation was run for each year from 2050 to 2055.

Table 2 (j): CropWat simulation of per cent yield reduction for corn and dry beans for 2050-2055 based on PRECIS-Echam5 A2 climate projections for Belize

Per Cent Yield Reduction		Reference			2050			2053			2055		
		Soil			Soil			Soil			Soil		
CORN	Planting Time	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy
	Early	0	0	0	53.9	7.5	22.6	73	13.3	33.1	51	0.7	15.5
Central Farm	Normal	0	0	0	60.6	18.6	34.0	72.1	17.7	36.9	49.2	3.9	18.2
	Late	0	0	0	42.5	3.5	17.0	48.7	3.3	17.7	59.2	5.4	22.7
	Early	0.0	0.0	0.0	17.0	0.0	0.0	49.8	1.3	15.9	36.6	0.0	7.9
Towerhill	Normal	0.0	0.0	0.0	34.9	0.0	7.4	55.7	8.4	24.2	23.2	0.0	0.3
	Late	2.9	0.0	0.0	18.0	0.0	0.0	38.6	0.3	10.8	5.5	0.0	0.0
	Early	0.0	0.0	0.0	46.0	0.0	0.0	34.0	0.0	4.0	24.7	0.0	0.7
TRDP	Normal	0.0	0.0	0.0	16.8	0.0	0.0	44.4	0.9	13.6	16.6	0.0	0.0
	Late	0.0	0.0	0.0	1.1	0.0	0.0	30.5	0.0	3.8	10.3	0.0	0.0
Per Cent Yield Reduction		Reference			2050			2053			2055		
		Soil			Soil			Soil			Soil		
DRY Beans	Planting Time	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy
Central Farm	Dec.	0.2	0.0	0.0	47.8	9.8	20.6	70.5	25.6	40.7	50.4	11.4	23.5
Towerhill	Dec.	0.0	0.0	0.0	23.6	0.0	2.9	48.0	10.5	21.9	34.1	3.8	13.1
TRDP	Dec.	0.0	0.0	0.0	8.3	0.0	0.0	33.8	2.4	11.3	23.7	0.1	5.0

(Source: Frutos and Gladden, 2014)

Table 2 (j) shows the per cent yield reduction for Corn and Dry Beans for the reference year 1998, and for 2050, 2053 and 2055. The results for future Corn yields, shows a per cent reduction in yields from the reference year 1998, ranging from zero change in some instance, primarily for the medium and heavy soils, to reduction in the order of 60 to 73 per cent of baseline yield, for the normal and early planting period in 2050 and 2053 respectively. Note also that these large percentage reductions in yields are specifically for the light sandy soils. In general, the least per cent reduction in yields are noted with the medium loam and heavy clay soils over the three years under review, and a later planting date.

In the case of Dry Beans, the greater per cent reduction in yields were noted for the light soil at Central Farm and Towerhill for the three years under review, and smaller per cent reduction in yields for the medium loam soil at TRDP and at Tower Hill for all three years under review. The simulation did not considered agronomic practices or new technology that can help mitigate the unfavourable conditions that might cause the reduction in yields.

Based on the results of this simulation that considers the projected increased in water stress during the main growing period in Belize, farmers may have to adjust planting time, install efficient irrigation systems, improve soil fertility and plant short-period and heat resistant varieties of Corn and Beans.

2.4.2 Climate Change Impacts on Pests

A pest is any organism (plant, animal, micro-organism) that, left uncontrolled, will cause economic damage to a commodity (host) that is being produced for a specific purpose. Pests, which include insects, mites, other arthropods, pathogens, nematodes, weeds, and vertebrates, are major constraints to agricultural productivity by directly damaging crops, causing illness in livestock, and inducing plant stress that decrease yields. Crop diseases are caused by viruses (which require a vector), fungi, bacteria or higher plants. Globally, pre-harvest and post-harvest losses attributed to insects, weeds, and plant pathogens are estimated at 45% (Pimentel, 1991); additional losses are caused by vertebrate pests.

Climate change is likely to change the physiology of host-pest interactions by altering the rates of development of different stages of pests whilst also modifying resistance of the host to such pests, for example, increased temperature causing change in growth pattern of host and length of growing season can cause asynchrony with insect biological cycle which may reduce or increase risk for pest damage.

Each pest has its optimum meteorological requirements and it is expected that Climate Change will result in a geographical re-distribution of pests at the global level, whereas the incidence and severity of pest outbreaks will be affected by local weather conditions.

Arthropod pests (insects, mites) are likely to be most affected by temperature changes since they are exothermic and cannot self-regulate their internal temperature. Generally, an increase in temperature will increase the rate of development of an arthropod up to its optimum temperature level. Arthropods generally proliferate under decreased precipitation but certain levels of moisture are required for their development. Contrarily, disease pathogens are mostly affected by relative humidity (especially the crop canopy micro-climate) and temperature. Usually increased relative humidity leads to an increased rate of spread of fungal and bacterial pathogens although some species thrive under decreased humidity. Heavy rains causing flooded soils will directly increase spread of disease agents, as well as cause cultivation problems thereby increased risk of root infection. Similarly drought and other stresses reduce plant immunity and capacity to cope with infections.

Weed competition with crop plants will be influenced by all the Climate Change factors of temperature, rainfall amount and distribution, flora and fauna species complement, carbon dioxide levels and soil conditions (salinity, nutrient/mineral availability, microorganisms). Many weeds are C3[7] plants which will be favoured by an increase in CO_2 expected with climate change.

Pest Modelling

Pest models are usually developed using data from classical experiments in population ecology and previous pest models describing the effects of temperature and humidity on pest development, then meteorological data is extrapolated to the Climate Change scenarios proposed by the Intergovernmental panel on Climate Change (IPCC).

Pest models have to be developed individually for specific crop-pest interactions. Due to the various meteorological, biological and agro-ecological variables involved in pest-crop interactions at field level (for example: alternative food source, plant stress or resistance, biomass and pest-predator interactions), models developed for a particular region would not necessarily work in another region. There is also a level of uncertainty in the prediction of pest- host interactions and eventual results because the many factors (biotic and abiotic) that will influence the interaction cannot be predicted based on current knowledge. Viruses need a vector (usually an insect or nematodes) in order to spread. Viral infection is therefore related to the presence of the vector (e.g. the Brown Citrus Aphid in the spread of Tristeza virus (CTV) in citrus and the Asian Citrus Psyllid (*Diaphorina citri*) which is the vector for the devastating citrus disease known as Huanlongbing (HLB). Hence, a knowledge of the biology of the vector in relation with weather parameters or microclimatic conditions (e.g. humidity and temperature) are required to model the vector life cycle and apply effective control when it is most vulnerable.

Species that are affected primarily by climatic conditions (Temperature and Relative Humidity) will respond more predictably to Climate Change than those species that are more limited by other abiotic or biotic factors, for example: competition, host plants, natural enemies or soil conditions. Models for arthropod pests may be less complex and data may be easier to obtain (pest numbers) than that of disease pathogens e.g. infection sites without symptoms, inoculum build up over time and seasons, and overlap of infections on same host that make it difficult to determine the occurrence of new infections. The data required for pest and disease forecast includes rainfall, temperature, relative humidity, solar radiation, dew point, wind speed, height and direction, leaf area index, crop variety, crop phenology, growth stages of pest and pathogen, pest population and intensity.

In connection with the Caribbean Agro-meteorological Initiative started in 2010, technical personnel of CARDI and the Caribbean Institute of Meteorology and Hydrology (CIMH) were trained in the use of pest and disease simulation models by two crop model experts from the University of Florence, Italy.

[7] C3 Plants refer to crops such as rice, wheat, soybeans, fine grains, legumes, and most trees, which have a lower rate of photosynthetic efficiency

Part of the training included the development of simulation models for some pests and diseases of economic importance in the Caribbean. Selected for modeling were: 1) Black Sigatoka (*Mycospharella fijiensis*) which affects bananas and plantains (*Musa spp.*), Soyabean Rust (*Phakopspora pachyrhizi*), and an arthropod pest, the Asian Citrus Psyllid (*Diaphorina citri*) which is the vector of the devastating citrus disease known as Huanlongbing (HLB) or citrus greening as it is locally called. These pests were selected after consultations with the national Crop Protection Specialist of the Caribbean Region (Rasheeda, et al., 2012). The calibration phase of the models is underway.

Black Sigatoka disease model

Common name pathogen: Black Sigatoka
Kingdom: *Fungi*
Division*: Ascomycota*
Class: *Dothideomycetes*
Order: *Mycosphaerellales*
Scientific names: *Mycosphaerella fijiensis*
Host Banana (*Musa sapientum*)

The model describes the infection caused by ascospores produced by the pathogen.

The fungus is haploid through most of its life cycle and reproduces both asexually and sexually, via conidia and ascospores, respectively. Because *M. fijiensis* produces relatively few conidia, ascospores are considered to be more important in the spread of black Sigatoka (Fig. 1) (Gauhl, 1994; Stover, 1980; 1983). According Jacome et al. (1991), conidia become more important during dry periods when disease development is delayed because of the presence of less conducive climatic conditions. Ascospores are the primary means of dispersal over longer distances within plantations and into new areas, and are the usual means of spread during extended periods of wet weather (Fullerton, 1994; Gauhl, 1994; Gauhl et al., 2000; Jeger et al., 1995; Meredith et al., 1973).

Figure 2.25 a: Black Sigatoka disease cycle. Source: Gauhl, 1994

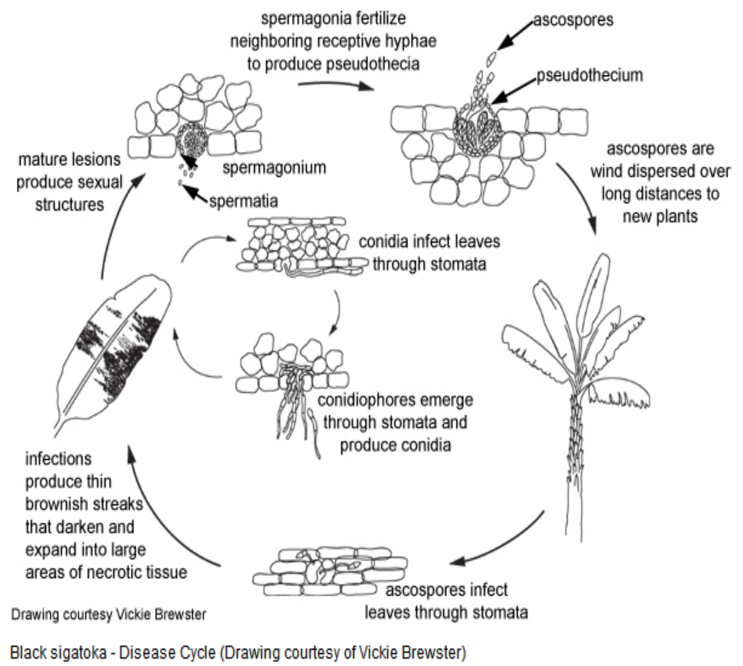
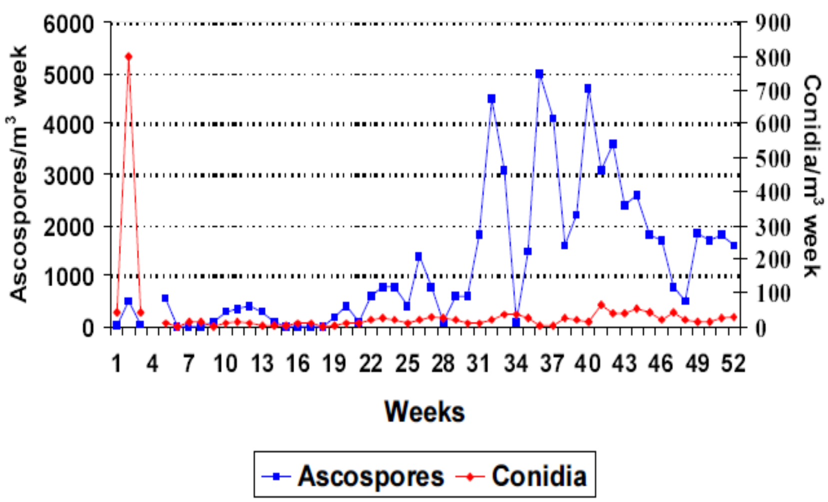


Figure 2.25 b: Seasonal variation of ascospores and conidi in the Caribbean zone of Costa Rica.



Source: Gauhl, 1994

Ascospores are produced in pseudothecia in mature lesions, which are common on both sides of the leaf surface. The ascospore release requires the presence of a film of water from rain or dew that imbibes the pseudothecia and results in the forcible ejection of the ascospores through the leaf boundary layer, where they are disseminated by air currents. During infection the Germ tubes take approximately 48 to 72 h to penetrate the stomata. Successful infection is promoted by extended periods of high humidity and the presence of free water on the leaves; Maximum germination occurs when free water is available on the host plant tissues.

Model phases

The model has as inputs hourly mean temperature, hourly relativity humidity and daily or hourly precipitation data.

The model considers different phases.

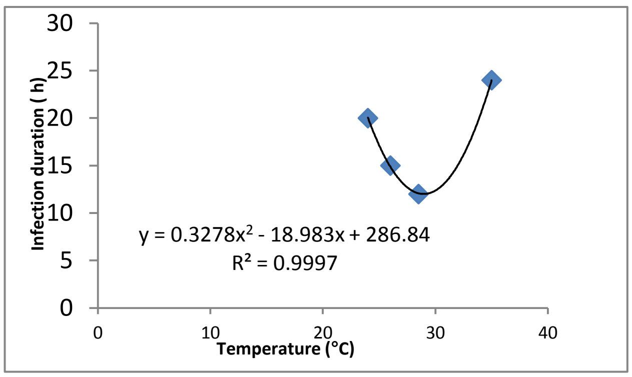
i) Ascospores Formation

ii) Ascospore Discharge

iii) Infection

The **Infection** takes place during periods of leaf wetness. Under optimum temperature (27°<T<30°C) infection is completed in 12 hours of moist conditions. If temperature is not optimal, this phase needs more time following the equation shown in Figure 4 (Jacome and Aschuh, 1992; 1993; Jacome et al., 1991; Chuang and Jeger, 1987; Stover, 1983)

Figure 2.25 c: Infection duration with different levels of temperature



By multiplying the daily infection development determined using the described function and the % of ascospore release, daily level of infection risk was estimated.

iv) The Risk Index

The risk index was obtained by combining the infection level obtained with the described method and the risk level due to meteorological conditions. Two methods can be used, the first based on evapotranspiration and the second considering rainfall.

The first method considers Potential Evapotranspiration. Taking into account available data, Hargreaves-Samani formula (1982) was used, but other methods can be considered in different conditions.

In particular the risk ETP index is based on accumulated ETP during the last 7 days:

Figure 2.25 d: Evapotranspiration Index

ETP	**ETP Index**
40 mm	No Risk = 0
> 30 mm	Low Risk = 1
> 22 mm	Average Risk = 2
< 22 mm	High Risk = 3

The final risk index is calculated with the following equation:
Infection Level * risk ETP index

The second risk evaluation model uses the amount of precipitation during the infection events:

Figure 2.25 e: Risk Evaluation Model

- infection with 0 mm rain:	severity = 1
- infection with < 2.5 and 10 mm of rain:	severity = 2, 3, 4.
- infection with > 10 mm of rain:	severity = 5.

The risk is determined considering the accumulation of this severity values for the last 4 days.

- 0 there is	**no** risk	= 1
- lesser than 4 there is a	risk	= 2
- between 4 and 12 there is a	**moderate** risk	= 3
- higher than 12 there is a	**high** risk	= 4.

The final risk index is calculated with the following equation:
*infection level * risk RAIN index*.

2.4.3 Constraints to Climate Change Pest Models

Apart from the fact that the predictive ability of pest models are questionable with respect to field reality and unknown factors of the future e.g. landscape changes, there are several constraints to CC pest models which must be considered:

- Information must be disseminated therefore users (farmers) must have access to devices or means of dissemination used and some models require purchase and maintenance of expensive equipment/devices.
- The more comprehensive (complex) the model is, the more accurate, but also more difficult to input data. There is need to develop user friendly models with reasonable predictability levels depending on the end user because an unused model is useless.

- Confidence building and trust (ex. in the meteorological service) has to be developed for farmers to use the technology

2.4.4 Impact assessment of Major Commodities

1. General impacts of climate change on agriculture include direct yield decreases of crops as a function of shorter maturation cycles due to the faster accumulation of degree days which control the physiological growth of all living organisms.

2. Increased temperature could adversely affect agriculture through its effect on increased insect activity (including vectors), increased disease rate of development, decrease in crop yield, heat stress on livestock, decreased performance of selected or "improved" pasture grasses and changes in soil micro-organisms.

3. Periods of excessive rainfall lead to flooding which causes direct crop and livestock losses, soil erosion and decreased productivity, faster spread of certain crop diseases (fungal and bacterial), difficulty in cultivation practices, difficulty with harvesting and transportation, and affects application of crop and livestock treatments.

4. Periods of drought cause stress on crops (losses or decreased yields) and livestock (food and water stress), and favours spread of certain fungal diseases (e.g. rust).

5. Rainfall unpredictability adversely affects timing of crop production operations.

6. Increased carbon dioxide could have positive effects on yields of certain C3 crops from carbon dioxide fertilization but may also generally increase growth of C3 weeds leading to increased competition.

7. Sea level rise may affect crop and livestock production by flooding in coastal areas, and cause salt water intrusion hampering irrigation operations on coastal crops.

Table 2 (k): Matrix of Climate Variability and Climate Change Impacts on Agriculture and Water in Belize

Sectors	Risks	Climate Change Impacts
Agriculture	Sugarcane crop and sugar production exposed to recurrent floods in the Orange Walk and Corozal Districts. Also, extended droughts and high temperatures affect yields. High humidity and warmer temperature favor pests such as froghopper. Citrus and banana crops are especially vulnerable to wind and flood damage in the Stann Creek, Toledo and Cayo Districts. Citrus Greening (Huanlongbing, HLB) could become devastating if not contained. Drought and high temperatures stress banana plants. High humidity favours increased incidence	Expected 1–2 °C increase in ambient temperature by mid-21st century and changes in seasonal rainfall of by ± 10% are predicted to lower yields of beans, corn, and rice by some 10%. Crop model results for Belize concur with this finding. Yields of sugar and citrus are predicted to remain stable at first, then diminish with increased rainfall variability and temperature increase after 2050. Banana, citrus and emerging vegetable crops will experience increased stress in a warmer temperature environment and

	of diseases. Intense rainfall results in flooding of banana fields in low-lying areas. Higher temperatures and heat waves stress livestock and poultry resulting in reduced body weight in cattle, and high mortality in poultry. Droughts decrease pasture biomass which reduces livestock production in the Belize River Valley, and western and northern Districts, especially. Livestock farmers in the flood plains of the Rio Hondo, New River, Belize River, and watersheds in the Stann Creek and Toledo District are all vulnerable to recurrent flood events. Pests and disease incidence in exposed vegetable production and other crops will only worsen as conditions become more favorable for increased number of vector generations in a single cropping season	reduction in yields. The negative effects of climate change reduces plant resistance to pests and diseases, resulting in mortality and decrease in yields. The atmospheric water demand will increase in the warmer climate of the 21st century (reduced moisture surplus in the wet season months) putting an added stress to crops grown in northern, western and central Belize. Warmer nighttime temperature increases the respiration rate of certain crops which stunts growth and development, especially at the flowering and grain-filling phenological phase, causing a reduction in yields. Increase in temperature shortens the growth periods of the crops, inhibits grain filling and decreases yields. The gains for C3 crops arising from increased CO_2 fertilization is expected to be offset by other climate factors related to warmer temperatures and water stress (IPCC, 2007)
Aquaculture	Historical hurricanes such as Mitch, Keith and Iris impacted aquaculture farms in southern Belize, hence the high risks of the aquaculture industry in Belize to the effects of future topical cyclones impacts. Warmer ambient temperatures results in warmer sea water temperature, changes in pH and reduced dissolved oxygen, which negatively impacts aquaculture production. The normal oxygen tension in water of 20 ^{o}C at sea level is 9.1 ml/l and at 25 ^{o}C it is 8.2 ml/l. Excessive evaporation results in increased salinity in shrimp ponds. A standard management practice is to replace a minimum of 1% by volume of water in each pond on a regular basis, usually daily. This helps to replace water volume that was lost, improve dissolved oxygen levels, manage the build-up of toxic waste products and maintain recommended salinities Climate Change will favour increased intensity of rainfall.	Increased intensity of tropical cyclone in North Atlantic basin in warm climate (IPCC, 2007). The major impacts from tropical cyclones will continue to be damage to property from (i) storm surge, (ii) wind damage, and (iii) flooding. Projected increased sea temperature ranging from +0.7 °C to +2.7 °C by 2080 across all three scenarios, will change coastal water chemistry and reduce dissolved oxygen Climate Change is projected to caused increased periods of dry, extending into the wet season Projected increased intensity of rainfall in a warmer climatic regime will result in: i) increased volumes of freshwater, ii) more erosion, and iii) flooding. Increased volumes of freshwater will result in lowered salinity in the saline environment, and increased levels of oxygen. Because the species of shrimp being cultured prefers

	Erosion is a constant concern in pond aquaculture; erosion mitigation and control is a standard part of the design and management of pond infrastructure. If pond banks are properly maintained, erosion as a result of increased rainfall is not expected to be a major concern. If properly drained, flooding is not expected to be a major concern on aquaculture farms.	salinity between 10 % - 25% (parts per thousand) increased rainfall will not be a concern until the salinity falls below 10 %. The benefit will be increased volumes of fresh oxygenated water.
Water Resources	Inadequate drainage of many farm lands lead to extensive and devastating water logging and dieback of crops and disease outbreak in livestock in the wet season and during big flood events. Water catchments to harvest water during rainy season are limited, increasing the risk of water shortage in the dry season for livestock and croplands located away from rivers. Water for irrigation is projected to become scarce during extended dry spells in the sugarcane, rice and banana growing areas, which will directly impact yields. Saline intrusion is already problematic in some areas of the coasts, impacting freshwater supply for domestic and industrial use, and water quality for crops.	Sea level rise will favour salt water intrusion particularly in the cayes and over the coastal low lands of Belize, impacting cultivation near coastal northern Belize District and Corozal District. Changes in evaporation rates and rainfall variability is already affecting water resources. Significant reduction in rainfall around and beyond mid-21st century will lead to soil desiccation in some agricultural zones.

Table 2 (l): Risks, Climate Change Impacts and Adaptation Strategy for Crops and Livestock

Crops, Livestock and Aquaculture	Risks	Climate Change Impacts	Adaptation Strategy
1) Sugarcane	a) Saline intrusion due to sea level rise Flood, pests, high winds	Increased extreme weather (i.e. stronger Tropical Cyclone events and extended dry spells in the wet season), increased pests incidence will result in decreasing yields	- Improved drainage and install efficient irrigation systems; - plant heat, pest, and flood resilient varieties, and also early-maturing varieties.
2) Citrus	Floods , drought, pests and diseases	Spread of new pests and diseases, increased extreme events, decreased in yields	- Improved drainage, - plant pest and heat resistant varieties. - Improve sterilization/sanitation of nurseries
3) Banana	Flood, high winds, drought, pests and diseases	Increased extreme events, spread of new pests and diseases, decrease in water resources, decreased in yields	- Upgrade and maintain drainage and irrigation systems. - Conserve water for processing, - - Plant flood, heat and pest / disease resistant varieties Introduce IPM
4) Corn	Excessive rainfall, droughts and high temperature, pests	Increased heat waves, droughts and periodic excessive rainfall, increased pests incidence, decrease in yields	- Plant heat and pest resistant and early maturing varieties, - introduce improved IPM, - adjust planting date to match rainfall pattern, - improve soil fertility

5) Rice	Droughts, pests and diseases	Increased extreme events, spread of new pests, decreased water resources, decreased in yields	- Plant heat and pest resistant varieties, - practice IPM, and conserve water by installing improved irrigation systems, - conserve soils.
6) Beans	High temperature, excessive rainfall, pests and diseases	Increase in extreme events, increased pests incidence, decrease in yields	- Adjust planting date to match rainfall pattern, - improve soil fertility, - practice IPM, - plant heat and pest resistant varieties, - plant higher yielding varieties,
7) Vegetables	High temperature, drought, excessive rainfall, pests	Warmer ambient temperature, periodic excessive rainfall, increased pests incidence	- Erect improved crop cover structure, - fertigation, - practice IPM, - use organic crop technology, - plant heat and pest resistant varieties, and high- yielding varieties
8) Cattle, sheep	High temperature, droughts, diseases,	Heat waves and droughts leading to increased stress, spread of new diseases	- Plant heat and pest resistant and high yielding grass varieties, - upgrade herd with breed that have high resilience to warmer conditions, - improve hay and silage production, - have flood contingency plan to reduce flood risks.
9) Poultry	High temperature, diseases	Heat waves and droughts leading to increased stress and mortality, spread of new diseases	- Have improved aeration for poultry house, - raise heat resistant breed, practice integrated disease management.
10) Aquaculture (Shrimp)	Increase sea surface temperature,	Salinity, Sea Surface Temperature (SST), decreased Dissolved Oxygen (DO), change in pH.	- Efficient aeration systems, - improved pond management

3. ADAPTATION STRATEGIES TO ADDRESS THE ADVERSE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE

There are multitude adaptation strategies to address the adverse effects of Climate Change in agriculture. Many of these were discussed with the key stakeholders to get their input, insights and make use of the collective wisdom of those intimately involved with coping with agricultural challenges on a daily basis. Some of the adaptation measures being recommended for specific impacts of climate change on the agriculture sector include:

***Flooding*:** Site selection, flood management mechanism at community level, cambering, vegetation management to prevent erosion, road infrastructure, drainage schemes with suitable engineering designs, clearing of drainage outlets, wetlands management, weather forecasting promote native adapted pasture species.

Saltwater intrusion: Manage water extraction, water harvesting for irrigation source, site selection, water use efficiency (drip irrigation and fertigation), seasonal location where possible, high technology (infrastructure) systems to combat intrusion, land use allocation, species, breeds and cultivar selection, agroforestry.

Pests and diseases: Pest modelling, ecological refuges for arthropod, bird and mammal pests, forest management, biological control, protective cropping including structures, floating pest covers and fruit protection, communal pest management, seasonal production where possible, soil amendment, intercropping, crop spacing (micro-climate management), germplasm diversity, selective pesticides (preserve beneficials, species, breeds and cultivar selection, vegetation barrier for chemical and genetic overflows, Integrated Pest Management (IPM).

Weeds: Biodegradable mulch, land preparation, timing of cultivation, intercropping, drip irrigation.

Drought: Water harvesting, watershed management, soil amendments, composts, economic cost of water, drip irrigation, water recycling through aquaponics, drought feeding plan for livestock, species, breeds and cultivar selection.

***Increased temperature* stress** Irrigation, improved nutrition management to combat yield losses, species, breeds and cultivar selection, livestock infrastructure design, silvopastoral system for cattle.

Other general remedial measures can include use of appropriate energy sources, research, monitoring changes in weather patterns and commodity responses including pest dynamics, soil microorganism monitoring and management, commodity insurance, storage, germplasm banks for selected tolerant cultivars, marketing efficiency, planning of production, community resilience, training, identification of new product niches, agro-processing and production of technological alternatives e.g. recycling of waste material scheme for overall production efficiencies.

3.1 Summary of Findings from the consultations, survey, interviews and workshops

Figure 3.1 below is a summary of salient issues emerging from the extensive consultation process. (Additional information of the consultations in contained in Annex II)

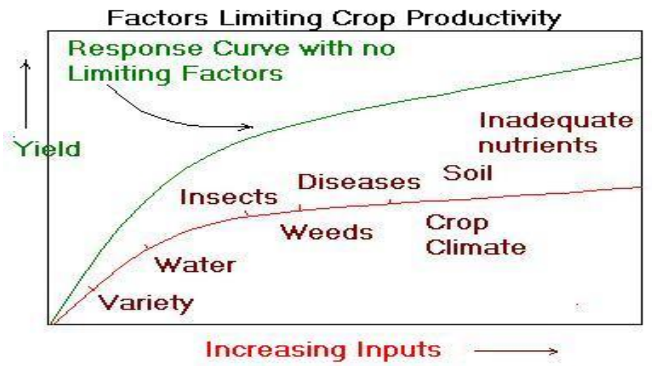
Figure 3.1: Summary of Findings from the Consultations and Survey Process

- Most stakeholders have noted climate change effects on agricultural systems.
- Pest/disease and soil nutrition emerged as the most critical needs for all categories of stakeholders.
- Most farmers use chemical pesticides as the primary method of pest control but most believe that integrated crop/pest management is the better alternative. Farmers are environmentally conscious even if not particularly adhering to best environmental practices.
- Most farmers select their farm site based on good quality agriculture soils. Agriculture is seen as a business even by those that have significant home consumption of agriculture produce, and most farmers consider their enterprise profitable or fairly profitable.
- Organic production is considered an economic opportunity as well as an adaptation measure.
- Commodity tolerance for climate change effects is considered a priority adaptation measure. Suggestion is often to choose commodity type, and systems that are suitable for climate of the area to minimize need for extraneous interventions.
- All vegetable farmers recommend protective crop structures as an adaptation measure for Climate Change.
- Most farmers want commodity insurance and are prepared to pay for effective coverage.
- Most farmers that are not of immigrant origin say there is need for improvement in the way their group or community is organized so as to maximize benefits to all farmers.
- Most stakeholders think that GOB should pay for Climate Change interventions.
- Stakeholders generally think that the department of agriculture should be the lead agency to monitor climate change effects on agriculture with assistance from farmers.
- Half of policy makers are knowledgeable of and support the national biosafety policy, but most producers are unaware of the policy.
- There is no discernible pattern with producers’ practices, experiences, location or age regarding willingness to pay for water or relocate their farms as adaptation measures.
- Producers are not greatly concerned about the possibility of salt water intrusion although technicians note its periodic occurrence in northern Belize.

3.2 Proposed Adaptation Measures

Figure 3.2 shows a schematic of the response curve for crop production. As illustrated, the limiting factors for yields include seed variety, water requirement and availability, pests, crop climate (climate variability), soil and nutrients availability. Under the projected warmer conditions with increasing rainfall variability in Belize and in the region, crop yields will be determined by how effectively adaptation measures are implemented and managed in order to avert detrimental effects of the limiting factors that climate change could, to a larger extent, exacerbate.

Figure 3.2: Schematic of crop response curve with and without limiting factors



Based on current information regarding possible adaptation measures, the status of the agricultural sector including its policy and institutional framework, consultations with stakeholder groups and analyses of responses, and the understanding that the strategy and action plan cannot realistically undertake all possible adaptation measures, the following measures are selected for their practicality, usefulness, interest of stakeholders and relevance to Climate Change issues that will impact Belize's agriculture. Recommendations are made for specific technical and cross-cutting adaptation measures, policy and institutional strengthening and stakeholder education, early warning and awareness programmes.

Technical adaptation measures are categorized according to four direct and indirect effects of Climate Change specifically:

i. Direct effects -rainfall changes: excess, shortage and variability
ii. Direct effects - temperature increase
iii. Indirect effects of rainfall and temperature changes – *greater than* changes in pests and diseases status
iv. Indirect effects of rainfall and temperature changes - *greater than* changes in soil fertility

3.2.1 Rainfall - Effects and Changes

Climate Change may result in less rain overall, but the most detrimental effect is likely to be the change in the distribution pattern of rainfall leading to conditions of periodic drought and flooding, as well as the more frequent occurrence of severe storms. The latter is dealt with under the natural Disaster Risk Reduction (DRR) Strategy for agriculture whereas the Climate Change adaptation strategy considers the impact alleviation remedies for vagaries in rainfall distribution.

3.2.1.1 Drainage

All crops and by extension all farms require good drainage, either natural or constructed, to allow for proper aeration of the root environment and to alleviate waterlogging stress on crops and pastures. Drainage systems should preferably be designed on community or region-wide basis to ensure that water drained from one farm does not adversely affect other farms or sensitive sites. Extreme flood events will occur despite any drainage efforts at farm or community level but the drainage will afford some measure of protection from excessive losses by allowing rapid runoff after the flood subsides. Maintenance of wetlands and vegetation, management of watersheds and clearing of major waterway outlets at the national level are important actions to alleviate large scale flooding. Farms may need to consider relocation if infrastructure needs to minimize losses from flooding.

3.2.1.2 Road infrastructure

Improved designs for road infrastructure (including all-weather resistant road surfaces and high capacity drainage) are important to alleviate adverse effects of excess rainfall over a short time period which invariably damages roads of inferior construction. After a flood, good roads will ensure access to farms for remedial measures as well as the transport of produce thereby minimizing losses after extreme rainfall events. Banana, citrus and sugarcane are more or less fixed in their locations and require good road infrastructure.

3.2.1.3 Relocation

Production of annual crops can be relocated within a farmed area during an annual production cycle based on seasonal rainfall forecast.

In the instance of extreme vulnerability due to farm location the implementation of the appropriate land use policy measures should encourage permanent relocation for the production of important agricultural commodities.

3.2.1.4 Irrigation

In preparation for drought conditions expected with Climate Change, irrigation can be used to supplement the water needs of most of crops. Currently sprinkle irrigation is used extensively in on banana farms, and drip irrigation is largely employed for the production of high value vegetable crops and papayas for export. Some farms utilize flood irrigation for rice production. Irrigation is likely to become necessary to maintain the production of sugarcane as well as other commodities for food security or export. Attention must be paid to water quality for irrigation, especially in drought prone areas susceptible to salt water intrusion, and the possible re-use or recycling of water to offset shortages.

Renewable energy source for powering irrigation systems must be considered. As irrigation needs become more critical for more commodities the cost of pumping water may be prohibitive and renewable energy sources should be explored to reduce cost. Drip irrigation is encouraged to conserve scarce water resources along with the application of appropriate fertilizers (fertigation) to improve efficiency of crop production systems.

3.2.1.5 Watershed management

Watershed management is critical to maintain the country's water resources in the long term. Appropriate land use practices must be adhered to in order to minimize the contamination of soil and water resources, and the maintenance of well and river water resources to allow for proper timing of appropriate agronomic practices. All stakeholders must be aware and engaged in the practice of watershed management to serve the nation's long term needs.

3.2.1.6 Water harvesting

The extreme variations in precipitation expected with CC can be alleviated by harvesting water when it is available for later use under conditions of water shortage. The harvested water can be used for irrigation as well as for livestock. Designs are recommended to gravity feed from water catchments into cattle troughs to replace the current system of pond catchments visited directly by cattle.

3.2.1.7 Weather forecasting and seasonal production

The most effective way to combat the negative effects of the variation in rainfall patterns is to institute climate/weather forecasting systems specifically for agriculture purposes (land preparation, planting, other cultivation practices, harvesting, storage) on a timely basis and as localized as possible. This will allow improved risk management in temporal and spatial cultivation for the production of seasonal and annual crops, as well as timely farm operations for perennial commodities (crop and livestock) where possible.

Crops have different water requirements at certain critical phases of the production cycle. Over years of experience farmers have developed planting schedules to coincide with the water requirement needs of the various annual rain fed crops such as corn, beans, rice, cowpea, sorghum, cucurbits (cucumber, watermelon, squash, pumpkin, zucchini, cantaloupe) , root crops and various vegetables. With the expected variations in seasonal precipitation projected with Climate Change farmers will need to rely on timely agro-meteorology forecast so as to adjust planting dates to coincide with availability of water for productive growth, as well as drier conditions for certain agronomic practices and harvesting.

Timely and localized weather forecasts will also assist farmers to adjust pest management practices, especially as regards prophylactic applications for fungal pathogens in susceptible cropping systems. Such forecasts from regional meteorology stations are currently utilized by the banana industry for the management of the Black Sigatoka disease.

3.2.2 Temperature - Effects and Changes

3.2.2.1 Crop and Livestock Tolerance

There will be need for research/selection and the preparation of technological packages for the production of crop and pasture varieties, and livestock breeds that are better adapted to the changed agro-ecological conditions such as increased temperatures brought about under Climate Change. In this regards it is prudent to maintain the indigenous genetic diversity of Belize's major staple and food security commodities (crops and livestock) as an instrument to combat detrimental effects of climate change on the production landscape. Research/selection of improved cultivars and breeds can be done locally where appropriate but effective use should continue to be made of regional research and development institutions as a practical and efficient system of information exchange for accessing adapted cultivars and breeds. It should be noted that adaptation to increased temperatures may involve not merely change in crop varieties but the adoption of substitutes; for example, sweet potato instead of Irish potato, more reliance on indigenous or better adapted vegetables; for example, spinach, chaya, or scallions. This would require effective liaising with education, health and tourism sectors to promote more utilization of crops that are better suited to Belize's agro-ecological conditions under climate change

The selected crop types should be preserved in germplasm banks to retain availability in the event of field losses due to natural disasters as well as to maintain purity of seed where erosion of purity occurs under natural agro-ecological interactions inherent in farming systems. Germplasm banks will include refrigerated storage of true seed as well as field storage of vegetative propagules.

3.2.2.2 Irrigation

Heat stress on plants can be alleviated by irrigation to supply sufficient water to allow the cooling effect of evapotranspiration, a physiological process which would otherwise lead to dehydration in situations of water deficit. The use of water for irrigation purposes to combat heat stress involves the concept of water use efficiency over the length of the crop growing period and necessitates proper soil management for precise and economic application of a possible scarce resource.

3.2.2.3 Silvopastoral systems

Silvopastoral systems which utilize shade trees of economic value will help to alleviate heat stress on range livestock as well as provide added income to the enterprise by the sustainable extraction and sale of wood from the silvopastoral farming system.

3.2.2.4 Heat alleviating infrastructure

Heat alleviating infrastructure involves appropriately ventilated housing designs especially for poultry, pigs, sheep and goats. Examples of engineering design to allow maximum air flow, hot air extraction, heat reflective materials or other appropriate measures should be recommended by agriculture engineering experts.

3.2.3 Pests and Diseases - Effects and Changes

3.2.3.1 Integrated Crop/Pest Management

Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage utilizing a combination of techniques such as biological control, use of resistant varieties, habitat manipulation, and modification of cultural practices (Strand, 2000). IPM can be defined as the judicious application of various compatible techniques to keep pest populations below economically damaging threshold levels. Monitoring of the crop system, including the use of modern Information Technology (IT) tools, is therefore critical in IPM and pesticides may be used when the need for curative measures to keep pests below the defined economic threshold level is indicated. Pest control materials are selected and deployed in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment. Integrated crop management adds to IPM other components of the crop environment, such as soil, fertility and water management.

3.2.3.2 Protective Cropping Structures (tropical greenhouses)

Protective cropping structures (PCS) constructed of specific pore size screen mesh materials (lumite) and UV protective plastic are used to physically exclude arthropod pests, and minimize disease incidence by excluding rainfall disseminated fungal and bacterial pathogens. By regulating the amount and placement of water through drip irrigation and fertigation powered by solar technology, the protective structure maximizes efficiency of production of high value vegetables, and allows production throughout the year regardless of vagaries of weather conditions. Appropriate designs include reflective aluminium infused materials and air flow vents that help to ameliorate the effects of ambient temperatures inside the structure.

Soil management is of particular importance and care must be taken to not introduce soil borne nematodes, pathogens or insect pests into the tropical greenhouse. To maximize the benefit of re-used soil in this cropping system organic methods can be explored such as the use of beneficial microorganisms and compost for soil health and fertility as well as the use of organic foliar fertilizers and pesticides (if necessary).

Research must be conducted for selection of suitable varieties and production practices for the regular PCS crops like sweet pepper, tomato, cucurbits, cabbage, as well as other suitable vegetables and high value condiments. It must be determined what crops can be grown economically with the protective cropping structures and the least costly mesh pore size which will accommodate the pest management needs of the different crops ex. larger pore size for cabbage and lettuce varieties.

There will be need to develop production and marketing strategies by assessing production capacity of the tropical greenhouses, demand for different products and the training, education and organizing of farmers to some degree so as to produce according to market demands and avoid losses from untenable production surpluses.

Technicians should collect and assess data on agronomic aspects of tropical greenhouse production and internal temperatures to advise on design modifications for future greenhouses, tailoring the design (including movable structures), size and construction materials to suit particular farm situations.

Tropical greenhouses are also useful for production of vegetables on coastal areas vulnerable to saltwater intrusion due to the most efficient use of harvested water for irrigation and decreased water use for pest management.

3.2.3.3 Pest Modelling

IPM is enhanced with the use of system models or other prediction schemes that uses appropriate biological, environmental, economic, or other inputs to analyze the most effective management actions, based on acceptable control, sustainability, and assessment of economic or other risks. Crop system models or simply pest models are developed and used to produce information on the status of the crop, its pests, and its environment under different scenarios, including different management options. The results can be used to assess a range of pest management techniques, and the risks and impacts on yields and profits.

Pest models for major crops of regional importance should be developed with CARICOM or Central American regional cooperation and adapted at country level where applicable. At the local level experts at BAHA, CARDI and the meteorology department should work along with agriculture industries to develop models for one or two major pests of major crops. There will be need to train staff of government and support agencies in Climate Change crop and pest modelling so that this expertise is not limited to just a few personnel. Research, studies and monitoring of pest-host interactions in regional agro-ecological environments will have to be on-going as experts and producers stay on the lookout for new pests or different species of similar pests adapted to change in climatic conditions.

The economics of pest modelling strategies must be considered bearing in mind that CC induced effects of pests on crop and livestock production cannot be precisely predicted.

3.2.3.4 Biological Control

The use of appropriate indigenous or, if necessary, imported biological control agents (BCA) can be the most expedient, cost effective and environmentally sustainable option for management of pests and insect vectors. Ideally the biological control agent (predator, parasitoid or microorganism) would eventually establish within the agro-ecological environment, reproduce and sustain stable population levels that keep the target pest population below its economic threshold. However, effective pest control is often achieved through continuous releases of laboratory produced BCA's within target zones.

3.2.3.5 Biodiversity

Effective pest management necessitates the implementation of measures to preserve or improve the natural resource environment that creates the essential agro-ecological balance for economic sustainability of agriculture production systems.

A healthy forest maintains an ecological balance of pests and beneficial organisms thereby reducing the deleterious effects of pests on proximate agriculture activities. The biodiversity of flora and fauna in forested areas is also important in that wildlife (avian, mammalian, arthropod species) that feed on forests can become pests of cultivated crops when forests are physically or chemically disturbed. Aerial spraying of pesticides in large scale crop cultivations should be strictly regulated to avoid adverse effects on forest health.

3.2.3.6 Research

Research into new pest and disease interactions that will evolve as a result of Climate Change should be undertaken. Research should also include augmentation of crop defence mechanisms against pest e.g. use of effective microorganisms, selection for natural resistance or tolerance and Climate Change effects on the populations of important pollinators.

Range cattle should be encouraged for the production of a more nutritious meat, and being a more Climate Change conscious management system. Along with the use of protected water troughs, there should be research into proper grazing management of selected pasture grass and legume species to promote cattle health and the reduction of parasites that decrease weight gain.

3.2.4 Soil Fertility - Effects and Changes

3.2.4.1 Soil/nutrition management

Although 38% of soils in Belize are considered suitable for agriculture none are universally recognized class 1 agricultural soils. This makes soil/nutrition management in agricultural systems even more critical. There is need to research/implement measures to preserve and improve the physical and chemical properties of soils with particular emphasis on avoiding soil compaction, and maintaining the ecological balance and critical role of beneficial soil organisms and micro-organisms that would be affected by increased temperatures and variation in water regime resulting from Climate Change. Consultant soil experts have often indicated that, due to insufficient understanding of soil nutrition, farmers in the banana industry often use chemical fertilizers inappropriately resulting in wastage, lack of benefit and waste of money.

Pasture maintenance under Climate Change effects will involve research and selection for grasses that can tolerate soils affected by both drought and excessive water but with better nutritional value than the popularly used *B. humidicola*. Examples could include African star grass, guinea grass and other indigenous species. Germplasm of selected grass and legume species should be maintained in field banks where necessary to avail cuttings where no viable seed is available. Grazing management studies to maintain longevity and fertility of pastures is indicated, including supplemental use of indigenous microorganisms as best practice for pasture fertility.

3.2.4.2 Soil Amendment

Soil fertility, which could be adversely impacted by Climate Change, could be improved through the use of soil treatments including various forms of organic matter (e.g. compost, vermiculture, and bokashi), physical and chemical amendments as appropriate, and the study and application of the commercially available Effective Microorganisms, or similar product. Beneficial micro-organisms also include the use of inoculants, (*Rhizobium* nitrogen fixing bacteria) for enhanced legume production of beans and other legumes, as appropriate. The benefits of using organic matter as soil amendment includes improving the soil structure, aeration, drainage, water infiltration, water and nutrient holding capacity as well as providing plant nutrients and energy source for beneficial soil micro-organisms and earthworms. Currently some farmers purchase organic matter from commercial suppliers, some produce compost in their fields for their own use and one small farmer group was assisted with a central group facility.

3.2.4.3 Vegetation Management

It is important to prevent loss of fertility of Belize's generally fragile soils through erosion resulting from excessive rainfall events. Good management practices to prevent exposure of bare soils and its subsequent erosion include maintenance of live vegetative cover during fallow, organic mulches during cultivation periods, observance of the mandatory sixty six feet riparian natural vegetation, and staggered planting on contours when utilizing sloping land for agricultural production.

3.3 Aquaculture Adaptation Measures

The Ministry of Agriculture was recently given the mandate for the management and development of the aquaculture sector, hence the inclusion of aquaculture in the adaptation strategy for agriculture. In order to develop an appropriate response it is necessary to determine the changes that are expected to occur and the possible impacts on the sector. Based on the most recently available information, the following climate change scenarios have been predicted for Belize in no particular order of priority:

a) increased frequency and intensity of tropical cyclones;
b) increase in sea surface temperatures;
c) increased periods of dry;
d) increased intensity and volume of rainfall;
e) increased in the number and types of pests and diseases.

During the consultations with the industry stakeholders it was learned that the operators have introduced a series of best practices for management that, while geared primarily toward efficiency and cost reduction, will go a long way in helping the sector adapt to climate change. Each scenario is looked at below along with the best practice management measure that is currently being practiced:

3.3.1 Increased frequency and intensity of tropical cyclones

The major impact from tropical cyclones has been and will continue to be damage to property from (i) storm surge, (ii) wind damage, and (iii) flooding. Currently the operators have, of necessity, been leaving a buffer of mangrove and riparian vegetation between the ponds and the coastal water bodies as part of the compliance with DoE and Forestry regulations. This buffer has been sufficient in mitigating or completely eliminating the effects of storm surge on coastal aquaculture facilities in the past. Currently wind has little impact on the ponds themselves. The major impacts of wind damage have been on free standing structures such as buildings. Because farm buildings are constructed in open areas where wind is a factor even without the benefit of tropical cyclones, the response has been to (i) reduce the number of free standing structures, (ii) construct wind resistant structures, or (iii) construct buildings that are 'disposable' made of inexpensive and readily available materials. Of singular importance on all farms is the availability of a Hurricane Plan that all members of staff are familiar with. This reduces the time taken and errors made in preparing for a hurricane.

3.3.2 Increase in sea surface temperatures

Warm water carries less oxygen than cold water and the warmer the water the lower the oxygen tension. This is of major importance to a person who is raising animals that obtain oxygen directly from the water. The normal oxygen tension in water of 20^0 C at sea level is 9.1 ml/l and at 25^0 C water of higher oxygen content or use mechanical means (paddle wheels and air pumps) to dissolve more oxygen. This is a management practice that is currently being used.

3.3.3 Increased periods of dry

The effect of increased periods of dry are increased evaporation and a resulting increase in salinity. A standard management practice is to replace a minimum of 1% by volume of water in each pond on a regular basis, usually daily. This helps to replace water volume that was lost, improve dissolved oxygen levels, manage the build-up of toxic waste products and maintain salinities within a preferred range.

3.3.4 Increased intensity and volume of rainfall

The impacts of increased rainfall, particularly in a short period of time, are (i) increased volumes of freshwater, (ii) erosion, and (iii) flooding. Increased volumes of freshwater will result in lowered salinity, in saline environments, and increased levels of oxygen. Because the species of shrimp being cultured prefers salinity between 10‰ (parts per thousand) and 25‰, increased rainfall will not be a concern until the salinity falls below 10‰. There is the benefit of increased volumes of fresh oxygenated water.

Because erosion is a constant concern in pond aquaculture, erosion mitigation and control is a standard part of the design and management of pond infrastructure. If pond banks are properly maintained, erosion as a result of increased rainfall is not expected to be a major concern. Of necessity, aquaculture facilities are properly drained. Flooding is not expected to be a concern.

3.3.5 Increase in the number and types of pests and diseases

Belize has developed and continues to develop disease resistant strains of the species being cultured. As an industry there has been a push to ensure that only animals produced in Belize are cultured here since they have already been exposed and are resistant to the local pathogens. This will need to continue to ensure that there is no contamination or introduction of new pests, new pathogens or new strains of existing pathogens.

The following adaptation measures are proposed to enhance the measures that were already in place:

3.3.6 Improvement in policy and regulatory services that were under the auspices of the Government of Belize

This refers primarily to the strength of the partnership that is needed between the policymakers, regulators and providers of support services such as the Ministry of Natural Resources and the Ministry of Forestry Fisheries and Sustainable Development. Two of the key elements of the best practices efforts are (i) maintenance of a buffer that is free of certain types of development between the farms and the adjacent water bodies, and (ii) regulation of the activities that could threaten the most important resources used in the industry, namely clean water and healthy brood stock. To ensure that the farms, and the industry, remain viable it is important that the policy and regulatory framework provide the necessary safeguards that will allow the industry to continue to operate safely. It is also important that the agencies involved work closely with the private sector. In this regard it will be necessary to also build capacity in certain agencies to ensure that they are able to meet their regulatory obligations.

3.3.7 Access to clean water sources

One of the resources relied on the most in the industry is clean water. It is the quickest and easiest response to a number of management concerns, including temperature, dissolved oxygen and physiological stress problems. In the area where most farms are located there is a growing concern about the quality of the water bodies that are being used for abstraction because of the increase in unregulated human activity in adjacent areas.

3.3.8 Water Storage

To adapt to changes in water quality in the existing water sources farms will need to be able to store and reuse water when necessary. This requires additional land and is dependent on the need to have policy decisions that are favourable to the industry. This has a direct relationship to the need for the public and private sector to work closely together in the interest of the sector.

3.3.9 Information and technology transfer

During the consultation process this was considered to be a vital part of the adaptation measures as it was felt that it is important that the public and private sector be on the same page in terms of technologies that are available, response to unexpected weather situations and long term adaptation policies and strategies that impact the sector.

3.3.10 Reduced energy cost

As the industry moves towards best practices the focus on improved management and the efficient use of resources, the need to conserve water will become increasingly obvious. One of the highest production costs for operators in Belize is the cost of energy. Energy is a key factor in any effort to conserve and/or reuse water as it is required for water quality management.

3.3.11 Renewable sources of energy

During the consultations renewable sources of energy was not considered to be a major adaptation strategy as most of the energy requirements were in the pumping of water, and most solar powered pumps currently available are below the capacity required by the farms.

3.3.12 Research

Research into resistant varieties, improved management systems; improved shrimp growing techniques, etc.

3.3.13 Improved brood stock

This was already being done by the industry as part of the good practice management measures. The three existing hatcheries have been working on improving genetics and disease resistance. The Government needs to play a larger role in policy framework and technical support.

3.3.14 Crop Insurance

If it is available and affordable it will be used. However, private sector stakeholders feel that if the other measures are in place there should be no need for insurance since they have been operating without it since the start of aquaculture in Belize.

3.4 Cross-cutting Adaptation Measures

3.4.1 Insurance

Apart from the technical measures to address specific effects of Climate Change on agriculture, there is the overarching measure of commodity insurance that the vast majority of agricultural producers have identified as critical to maintain levels of production under the predicted Climate Change scenarios. The review of relevant documentation, research on applicable models and consultations on the usefulness of insurance to stakeholders in the agriculture sector pointed to the current need for insurance services to farmers and producers in the sector. This will be substantially increased as some of the impacts that are expected with Climate Change become increasingly evident.

3.4.2 Farmer Group Resilience

It must be recognized that whereas technical and infrastructural remedies are important, the people factor is always the most important element for successful implementation. Solutions must be sought to achieve the effective engagement of the primary stakeholders, the farming community, and to promote group resiliency for responding to the challenges of Climate Change. In this regard it has been recommended that Disaster Risk Management (DRM) and Climate Change be addressed concurrently since community planning, coordination and resilience are key strategies for both CC and DRM. The DRM plan for agriculture has strongly charted institutional requirements and education needs for community empowerment.

It will be necessary to promote group learning systems including observations, data collection, analysis, and assessment for agricultural communities to actively participate in understanding changes and changing needs due to effects of Climate Change. It is recommended that the Cooperative Department re-focus its attention to the promotion of group engagement and organizational needs instead of focusing on the legal structure of cooperatives. Working with informal group structures this department could use its resources to promote resiliency for agriculture producers through group funding models (apart from insurance) and other group food /economic security measures.

3.4.3 Monitoring and Documentation

Effective adaptation to the effects of Climate Change will require continuous monitoring and documentation of crop and livestock responses to the meteorological, agro-ecological and environmental changes experienced over time. Pro-active adaptation strategies are expected to alleviate eventual impact of Climate Change but the effects of any subsequent remedial measures must also be documented so as to inform a continued process of research, education and implementation of appropriate actions to maintain viable and responsive agricultural systems. The major stakeholders in the monitoring and documentation of Climate Change impacts on agriculture and the effectiveness of response measures will be the farmers, farmer associations and the responsible public entity, the Ministry or Department of Agriculture. Agriculture as the lead agency designated to collect and analyse data should be responsible to design data collection instruments for farmers that are easy and simple to understand and operate. Samples of the farming population representing the different categories and commodities should be selected to participate in the data collection process. Data to be collected include commodity types, varieties or breeds, production practices, onset and duration of crop growth stages, type and incidence of pests and yield output. The lead agency will correlate the agriculture data from sample farmers with climatic data from the meteorology department and other agro-ecological factors to analyse needs and effectiveness of adaptation measures.

4. IMPLEMENTATION CAPACITY

4.1 Institutional capacity

The MFFSD is designated as the government agency responsible for the coordination and implementation of Climate Change policies in Belize. The Climate Change office, under the MFFSD, is being strengthened to take on a more expansive role in various technical, educational and liaising aspects of Climate Change.

The NCCC has wide representation from various sectors and is responsible for coordinating climate change actions at the local, regional and international level, and is organized to address the various aspects of Climate Change.

Climate Change focal points have been appointed in key ministries. The MNRA Climate Change focal point is also responsible for coordinating Disaster Risk Management.

BAHA is responsible for averting introductions or establishment of new pests and is being strengthened under the IDB financed Agricultural Services project.

Regional and Producer Research organizations in the country have technical capacity in crop management, integrated pest management and improved irrigation/drainage systems.

Support agencies such as OIRSA, IICA, CARDI and ROTC are capable, cognizant and supportive of the Climate Change adaptation needs for agriculture.

Generally, there are relevant regulatory and policy making mechanisms in place.

Institutional Gaps

Research and Development (R&D) in Agriculture is the vehicle for the advancement of a sustainable and profitable agricultural sector in Belize. The MNRA liaise with local, regional and international agricultural institutions, stakeholders and agriculture enterprise to promote improved agricultural practices; however, much more can be done by stakeholder institutions and the Ministry in the area of Research and Development. The National Coordinating Committee for Research and Development (NCCARD) has been in existence for several years with a mandate to promote and coordinate effective research in agriculture. However, NCCARD has not functioned, effectively, perhaps because members have been too occupied promoting their own individual activities and enterprises, and are not able to sufficiently focus on national efforts. NCCARD could benefit the sector, effectively, if it were deployed to strengthen research institutions through public/private sector liaison, facilitation and advocacy. In the area of Climate Change and Agriculture, NCCARD could further enhance the benefits of national research through undertaking the role of documentation and targeted dissemination of research results relevant to adaptation needs.

Adaptation strategies could be better served if agriculture could firmly institute liaison with the health and education sectors to promote the nutrition and health of agricultural products. The liaison could promote the use, marketing and funding of interventions that support wholesomeness of agriculture products for example decreased pesticide use for coping with pest challenges, improved soil management instead of overuse of chemical fertilizers which kill soils and contaminate water sources, infrastructural assistance and training for vegetable growers and education for consumers.

The Belize Marketing and Development Corporation (BMDC) could be a positive force for strengthening viability of agriculture enterprises if it were to fulfil its mandate. However, it has consistently failed to perform its mandated function of identifying and developing markets for potential products and advancing private sector marketing mechanisms for effective product distribution, growth and export. The BMDC should either be made to perform its supportive role for agriculture producers or be re-organized so as to fulfil its intended purpose or be disbanded.

Agriculture needs to forge a liaison with the coastal zone sector specifically for the management of mangroves which could impact water quality for the aquaculture sector, as well as the influx of salt water into coastal low lying agriculture production plots.

4.2 Policy Environment

The National Land Use policy supports interventions for climate change in agriculture. The World Bank recently started a five-year project on land use management with the intention to implement the land use policy. There is clear dedication among some government policy makers involved in this process and it is expected that the policy will be implemented in the medium term.

A comprehensive Disaster Risk Reduction Action Plan for agriculture has been prepared and accepted by the Department of Agriculture. Organizational and institutional elements of this plan will serve the implementation of CC adaptation measures.

Natural resource management is a recurrent theme in almost all relevant policy documents which underscores the importance and widespread appreciation of the value of natural resources for the sustainability of Belize's productive sector.

Belize's energy policy which promotes the use of renewable energy, including farm residual biomass as a renewable energy source and an alternative economic product of farms, is supportive to the proposed adaptation measures for energy efficiency. However, the policy does not specifically outline fiscal incentives to adopt alternative energy sources and there is need to strengthen this aspect of the policy.

Belize's Biosafety policy supports economic and environmentally sustainable adaptation measures through risk analysis of the use of living modified organisms (LMO's).

The existing environmental laws which prevent clearing of 66 feet vegetation along waterways and clearing/planting on specified degree slopes to prevent erosion, and regulate management of watersheds, form a part of the legal framework for Climate Change adaptation measures. However, these laws all need to be enforced. Policy enforcement and partnerships with NGO's should be effective and decision-making processes should always consider the collective wisdom of stakeholders. Climate Change strategy and policy for the productive sector should be streamlined into the country's short, medium and long term national development strategy to ensure food safety and sustainable development.

Policy Gaps

The Ministry of Agriculture needs to elaborate a rice policy, an effort which has been attempted several times in the past. Currently, the most efficient system of rice production is flood irrigated rice (FAO, 2005), which uses a vast amount of water. The country's major production of irrigated rice is in the northern region, the area which is expected to be most affected by water deficits resulting from Climate Change. A well-defined, comprehensive rice policy will determine how and to what extent supportive adaptation measures should be instituted.

It is expected that all sectors, including the productive and industrial sectors, will prepare Climate Change adaptation strategies which can inform the proposed Growth and Sustainable Development strategy for Belize. The Climate Change office is expected to undertake a leading role in this task.

4.3 Technical Capacity

Selection for Tolerance

Some capacity exists and actions are already ongoing in the following areas that can be utilized for the benefit of climate change adaptation in the agriculture sector:

- A recently implemented basic grain seed selection, purification and storage project for food security (FAO) in southern Belize has introduce farmers to the participatory process of germplasm selection; and
- The University of Belize operates a meristem facility which can mass produce propagules of selected tolerant varieties for quick adoption in the agriculture sector. Sugarcane plantlets are currently being produced by this facility and there are plans for producing selected varieties of banana and plantain in the near future.

Biological control

SIRDI is currently experimenting with the release of a biological control agent (*Metarhizium anisopliae*) for the sugarcane froghopper (*Aeneolamia postica*) and has plans to eventually produce the fungus in Belize for widespread use in the industry. SIRDI's research capacity is being strengthened under the Accompanying Measures for Sugar (AMS) project.

A partnership between OIRSA and BAHA, in a biological control program for the Pink Hibiscus Mealy bug, is very successful and the relevant technical capacity is fully developed.

CREI experimented with an imported biological control agent for the Brown Citrus Aphid, vector of the Tristeza virus and, subsequently, discovered a naturally occurring parasitoid in Belize which effectively controls the aphid. They are currently looking at a biological control option for Asian Citrus Psyllid, the vector of the greening disease Huanglongbing.

Protective Cropping Structures

Protective cropping structures were introduced under the 9th European Development Fund (EDF) financed Agriculture Enterprise Development (AED) Project and was well received by vegetable farmers. Some structures have been properly managed and some farmers have experimented with lower cost design of the original structures.

Irrigation

An ongoing CDB project is developing an investment plan for irrigation and drainage which will pave the way for the development of strategic irrigation and drainage infrastructure. This should help to build technical capacity in the mapping of watershed zones for proper drainage infrastructural development.

There was an Irrigation Unit established in the Ministry of Agriculture which did extensive work in the promotion and development of drip irrigation systems throughout the country. The technical personnel, under this unit, underwent substantial training.

Water Harvesting

The concept of water harvesting catchments was explored under the AED project, whereby two possible catchment designs were prepared for farms in the Cayo District.

Climate Change Modelling

CARDI Belize and CIMH staffs have received training in pest simulation modelling.

There are two agro-meteorologists in Belize and two independent consultants have received training in Climate Change crop modelling under the global project.

Composting

Under a Ministry of Agriculture supported organic production programme, several farmers have been trained in the production of compost, bokashi and the use of vermiculture for improving soil fertility with added organic matter. The use of organic matter in soils is well appreciated by all categories of farmers and request for compost as an adaptation measure was overwhelming.

Gaps

There is a dire need to improve the technical capacity of agricultural personnel in most sub sectors. Also, the ratio of trained and equipped agriculture personnel to farmers is critically small. Hence, there is a need to increase the number of trained personnel in most of the specialized fields of agriculture, livestock and aquaculture.

Specifically, there exists a need for more trained personnel in agriculture engineering, soils and nutrition management, integrated crop/pest management, food processing, climate crop and pest modelling, hydrology, monitoring and documentation, research methods, Information Technology (IT) and Geographic Information Systems (GIS). This expertise must be established in the Ministry of Agriculture, so that these critical services can be available at the national level and for the benefit of all farmers.

Road Construction

There is much public and private sector experience and technical capacity in road construction and several EU funded projects have assisted in improving main and feeder roads for agriculture support. However, perhaps due to financial constraints many roads have not been properly surfaced, cambered or drained to withstand extended rainfall events. It is hoped that longevity becomes a priority factor in the subsequent construction of agricultural road infrastructure so it becomes an effective adaptation measure for Climate Change.

4.4 Stakeholder Attitude, Interest and Awareness

The survey conducted among agriculture stakeholders gaged their perspective and attitude towards agriculture. A summary of the responses is contained in Figure 4.1 below. In general, farmers view agriculture as a business and the majority of the farmers were aware of Climate Change and the effects it can have on crops and livestock.

Figure 4.1 Stakeholder attitude, interest and awareness towards Agriculture

The development of this National Adaptation Strategy and Action Plan was conducted in a fully participatory process which had broad participation from public and private sector organizations and the national farming community. The following is a synopsis of the findings:

Stakeholders generally display much enthusiasm for agriculture development. Most stakeholders rate agriculture as no. 1 for economic and financial benefits to Belize and Belizeans. It is important, however, for top level decision makers to demonstrate greater support for agriculture in order to maintain the confidence of the agriculture sector stakeholders.

The Agriculture Department is encouragingly engaged at the level of middle management and field services. The farmer field schools approach is being promoted which builds group participation and resilience.

Most producers note effects in their agriculture systems which they attribute to Climate Change. Awareness of Climate Change is widespread among producers although there are widely varied levels of knowledge and education of the subject matter.

All categories of stakeholders have a general understanding of the environmental context with respect to adaptation strategies for climate change.

The agriculture enterprise is considered profitable or fairly profitable by vast majority of farmers interviewed; agriculture is seen as a business and farmers demonstrate willingness and enthusiasm to adopt adaptation measures to maintain or improve competitiveness. Thirty-four percent of farmers suggest that farmers should assist in meeting the cost of Climate Change interventions.

A soils/tissue analysis laboratory operated by Central Farm up to the early 1990's was well utilized by farmers across the gamut of agriculture production systems.

Support agencies generally display awareness, engagement, concern and willingness to assist in adaptation measures in their respective capacities.

Gaps

Small farmers generally indicate that there is need for improvement in their producer or community organizations in allocating equitable resources to generate maximum benefits and to take advantage of economic opportunities that require group energies or investments.

Producers submit very variable responses, displaying some stubbornness, regarding farm relocation and the concept of an economic cost of water as adaptation measures.

5. ACTION PLAN

Five (5) major actions have been identified for effectively implementing the proposed adaptation measures and these are categorized as follows:

- **i. Infrastructure and Equipment**
- **ii. Research and Training**
- **iii. Education and Early Warning**
- **iv. Commodity Insurance**
- **v. Monitoring and Documentation**

5.1 Infrastructure

5.1.1 ***Drainage systems*** - There is need for the MNRA to hire a competent agriculture engineer to advise the Belize Government and private agriculture stakeholders on appropriate drainage needs and system design for sugarcane, citrus, pastures, grain and vegetable production areas in the districts. The banana farms have already identified their drainage needs. A Flood Mitigation project in the Belize River Valley is undertaking appropriate measures for that area. Similarly, previous work undertaken by the Ministry of Works has identified drainage needs for the Sarawee production area of the Stann Creek District complete with cost estimates. The drainage construction started under the AED project proved very effective but the system in Sarawee needs to be completed.

5.1.2 ***Laboratory for biological control*** - Sugarcane is the major export crop with the largest number of farmers. The research arm of the industry, SIRDI, is currently experimenting with a biological control agent (BCA), the fungus *Metarhizium* for the control of the major sugarcane pest, the froghopper *Aeneolamia postica*. SIRDI currently imports the BCA from Costa Rica but it is only available to some farmers at this time. They plan to set up facilities to produce the BCA, in country, so that it can be available in sufficient quantities for effective use and control of the pest. It is recommended that the biological control laboratory be constructed at and managed by SIRDI, with appropriate government subventions for financing production of BCA's for the "public good", given the high cost of this program.

5.1.3 ***Soil and tissue analysis laboratory*** - After the demise of the Central Farm soils laboratory, CREI operated a mini lab for soil analysis for some time. Currently, all the major agricultural industries rely on foreign laboratories for their soil and tissue analysis needs. It is recommended that the soil and tissue analysis laboratory be set up under the management of CREI and that government subventions to CREI be re-instated to assist in operationalizing this very critical service to farmers, at large. Another option would be to set up mini soil labs for each major commodity, operated on the same basis as CREI. These mini soil labs could then provide a service to other users in their particular zone for a fee.

5.1.4 ***Protective cropping structures*** - Investments in protective cropping structures for vegetable producers throughout the country should be considered a national priority by both the government and the private sector. Current costs range from roughly \$3,000 to \$20,000 per unit depending on size, design, materials used and irrigation equipment installed. As a follow up to the AED project, the MoA should embark on a thorough and comprehensive exercise in encouraging and supporting the extensive and effective use of covered structures in vegetable production. This will involve reactivating a dedicated unit in the MoA to train vegetable farmers in the design, construction, management and maintenance of the PCS, to identify research needs, to source suitable materials for construction, to collect production and marketing data and to facilitate early warning systems for preserving expensive PCS materials in the event of impending strong winds.

5.1.5 ***Road infrastructure -*** The MoA and the MoW, in collaboration with the major agriculture industries, must assess the road infrastructure needs. This exercise was carried out for the banana industry. District Agriculture Coordinators must advise on priority road infrastructure needs for the informal agriculture sector in all six districts. The latter exercise was undertaken, a few years ago, under the first EU funded Belize Rural Development Programme (BRDP).

5.1.6 ***Electrification or use of solar pumps for irrigation*** - Since drought and heat stress are likely to become big challenges, there is need to decrease the cost of pumping water for irrigation. Based on crop tolerance and projected precipitation, banana, sugarcane, rice and most vegetables are likely to require irrigation. For water use, efficiency drip irrigation is recommended for small and medium sized farms, as well as large farms where practical. Pumping cost can be significantly reduced over the medium to long term using renewable energy for the power sources. Large farms should consider electrification whereas solar pumps may be more practical for smaller acreages. Electrification needs for banana farms have been assessed.

5.1.7 ***Germplasm banks*** - It is recommended that a national germplasm bank be established at the Ministry of Agriculture Research and Development Station at Central Farm for the maintenance of seed and vegetative propagules of cultivars selected for tolerance to the impacts of Climate Change. This involves a cold storage facility for true seed and irrigated field plots for vegetative planting material.

5.1.8 ***Water catchments*** - The Orange Walk, Corozal and Cayo Districts will be most in need of water harvesting structures, the former two due to projected water deficits in the north of Belize and the latter due to hydrological constraints of groundwater access. Three water catchments, one in each district, should be constructed on selected farms, to serve as demonstrations to other farmers in terms of design, water storage and retention capacity.

5.1.9 ***Agro-meteorological forecasting equipment*** - Additional Automatic Weather Stations (AWS) is to be procured for the Meteorology Department that can be deployed in sparely monitored, agriculture zones to improve on the meteorological network's coverage. This will enable the receipt of timely weather data to enable the preparation of seasonal, monthly and weekly agro-meteorological forecasts, specific to the different agricultural zones.

5.1.10 ***Monitoring and documentation software*** - Agriculture technicians and climate specialists will need to be equipped with appropriate equipment such as computers, GPS, printers and software, including Geographic Information Systems (GIS) capability, for the collection, documentation and analysis of data pertinent to Climate Change impacts on the various aspects of agricultural production and the effects of response measures.

5.1.11 ***Research programme and facility*** - Key, leading institutions such as MoA, CARDI, CREI, SIRDI, BAHA, ROTC, OIRSA, IICA and the BGA should be invited to develop a well-planned, coordinated and prioritized national agriculture research programme based at Central Farm. Trained personnel, equipment and materials should be provided to enable a properly functioning national research facility at the Central Farm. Whereas other research bodies will serve specific industry or regional needs, a full-fledged national research system must be established to support overall adaptation actions for agriculture. Materials and equipment will be needed for research into soil fertility management, crop and livestock protection, identification of climate resilient crop varieties and livestock breeds and assessment of performance, agro-processing, supportive infrastructure for irrigation and livestock, components of protective cropping structures and development of new products for emerging niches.

5.1.12 ***Compost facilities*** - Basic compost facilities and equipment should be established by the MoA and managed by farming groups at suitable locations in each district. These facilities should be of easy access to members of all organized agriculture production groups to enable use of the various forms of organic matter for sustained soil fertility. The use of compost was overwhelmingly endorsed by all categories of farmers and group-managed facilities were mostly recommended. Banana farmers have investigated their compost needs and quantified the costs of establishing suitable facilities for their industry.

5.2 Research and Training

Research and training actions will be necessary to support, complement and in some instances actualize the infrastructural and equipment measures elaborated. As adaptation to Climate Change in agriculture is necessarily a dynamic process, research into new agricultural opportunities, development of new niches and tackling of emerging Climate Change issues should be on-going. It is recommended that some existing baccalaureate staff be upgraded to the Masters of Science (MSc.) Degree level in the various disciplines needed to strengthen the research and development capacity of the national institution.

5.2.1 Formal Training

- MSc. Soil agronomist - To conduct research, development and training in the physical, chemical and biological constitutes of soil, appropriate soil cultivation practices and the proper use of organic matter to avoid harmful effects and maximize benefits.

- MSc. Agriculture. engineering - To conduct research, development and training in the construction and use of drainage systems, water catchments, protective cropping structures, heat alleviating infrastructure for livestock, establishment of irrigation systems and advise on remedial measures for salt water intrusion.

- MSc. Entomology - To conduct research, development and training in Integrated Pest Management, biological control and pest modelling.
- MSc. Plant Pathology - To conduct research, development and training in Integrated Pest Management, biological control and pest modelling.
- MSc. Hydrology - To assess quantity, availability and quality of water resources and advise on appropriate use for agriculture production.
- MSc. Food Technology - To conduct research, development and training in food processing to help maintain agriculture competitiveness by adding value or preservation of some crops which might face restricted production or be confined to seasonal production due to unfavourable meteorological conditions.

5.2.2 In-service Training

Apart from degree level training, on-going or periodic training needs for successful implementation of adaptation measures include training of research staff in agricultural statistics and research methods, training of producer groups in preparation and use of organic matter, training of farmers and technicians in monitoring, documentation and analysis of Climate Change impacts, and training of agriculture experts in utilization of models to predict Climate Change impacts on major agriculture commodities. Training in GIS and IT will be needed to support many of these processes. Training can be provided by local and regional institutions.

5.3 Public Education and Early Warning

Three main public education, awareness and early warning activities are required to support the implementation of the adaptation measures:

i. Timely and localized weather forecast must reach the target group directly - either by e-mail to group focal points or by text messaging to farmers at large - on a seasonal, monthly and weekly basis for the information to be used efficiently for timely planning of livestock and crop production activities.

ii. There should be regular television and radio programmes and effective advertising dealing with these various topics on agriculture and climate change. Stakeholders and farmers in particular, need to be continuously alerted and educated on the management of watersheds, vegetation, wetlands and biological refuges to inform their decision-making in such a way that it becomes a normal part of their everyday farming activities. Education on these aspects must start in the short term before irrevocable damage is done to the agricultural environment.

    The regular programming should also be used to educate stakeholders on the content of the GOB's biosafety policy so that they understand the context, possible benefits and potential repercussions of introducing biologically active genetically modified organisms (LMO's) onto Belize's agricultural landscape. The risk analysis for GMO corn in particular should be ventilated since some stakeholders might consider GMO corn as an option for variety tolerance as an adaptation measure for climate change. It needs to be explained how the use of *Bacillus thuringiensis* (Bt) or glyphosate tolerant GMO corn seed conflicts with recommended measures for CC adaptation and the likely negative socio-economic impacts on Belize's agro-ecology that would result from its introduction.

iii. When applicable pest models are developed, an early warning system should be put in place to inform the target stakeholder groups of predicted pest outbreaks. This can be done via television, radio alert messages, e-mail and text messaging to the designated agricultural group or association focal points.

5.4 Insurance

The literature suggests that what would be required is a form of "Multi-Peril Crop Insurance" program to cover the widest range of risks that could impact farmers and producers of livestock and aquaculture commodities.

This insurance would cover the increased losses expected by farmers and producers associated with the increasing frequency and severity of weather related events. These impacts would be associated with storm related wind, flood and drought related damage. The insurance coverage would necessarily require some established minimum standards which insured farms or production units would have to meet. This would ensure that the insured would actively take measures to prevent losses with investments in certain protective infrastructure such as drainage or wind breaks against flooding or wind damage. Also, this could mean that some locations would not be able to secure coverage, if they are located in zones where damage would have a high likelihood to occur such as farms established in flood plains or cattle ranches located in areas subject to flooding or fires.

The ownership structure proposed is one which would have joint participation of the Government of Belize and the private sector. Government's contribution would be a critical incentive for wider participation since its financial input would act to lower premiums and the costs of coverage to the insured. Meanwhile, the private sector's participation would act to guarantee more market driven management approaches and greater focus on efficiency, cost effectiveness and overall accountability.
In the consultation a majority of farmers are prepared to make premium payments according to assessed risk and affordability.

The Summary Tables: **3 (a**) to **3 (d)** below outline the costs, financing mechanisms, implementing entities and time frames for the various actions.

Table 3 (a): Cost, financing and implementation of actions pertaining to infrastructure and equipment [8]

Action	Time-frame	Cost (BZ$)	Financing Sources	Implementing institutions and agencies
1. Design and construct drains in sugar belt	ST	4,000,000	AMS, farmers	Private contractor
- In banana belt	ST	1,600,000	BAMs, farmers,	Private contractor
- In citrus belt	MT	2,000,000	GOB , Partners	Private contractor
- In Sarawee	ST	100,000	GOB	Min. of Works
2. Construct and equip laboratory for biological control	ST	150,000	GOB, association	SIRDI, BAHA
3. Construct and equip laboratory for soils and tissue analysis	MT)	250,000	GOB, association	CREI
4. Construction of Protective cropping structures	ST	400,000	GOB, farmers	Agriculture Department.
5. Road infrastructure: feeder roads	MT - LT	10,000,000	EU and Partners	Ministry of Works
6. Electrification in banana region for irrigation improvements	MT	1,500,000	BAMS	BEL, Farmers
7. Electrification in sugar region for irrigation improvements	MT	2,500,000	AMS	BEL , Farmers
8. Solar powered irrigation pumps	MT	2,000,000	AMS, Farmers/GOB	Farmers
9. Composting plant for banana industry	MT	250,000	BAMS	BGA
10. Compost plant for sugarcane industry	LT	250,000	AMS	Association
11. Compost facilities for 10 small farmer groups	ST	300,000	FAO and Partners	Farmer groups
12. Germplasm bank: Expansion and Upgrade	LT	150,000	GOB, FAO	MoA/CARDI
13. Water harvesting catchments demonstrations	LT	60,000	Partners	Agriculture Department
14. Research equipment for national facility	MT	200,000	MoA, EU and UNDP	Agriculture Department
15. Agro-met forecasting equipment	ST	400,000	GOB	Meteorology Department
16. Monitoring and documentation system - software and training	MT-LT	40,000	Partners	Agriculture Department
TOTAL		**26,150,000**		

[8] Short term (ST) is defined as a period of 1 - 3 years; Medium term (MT) is 4 - 6 years and long term (LT) is any period more than 6 years.

Table 3 (b): Costs, financing and implementation of actions pertaining to research and training (R & T)

Action	Time-frame	Cost (BZE$)	Financing	Implementing institutions and agencies
1. T MSc. soil agronomist	ST	60,000	Partners	CREI and MoA
2. T MSc. agric. engineering	ST	60,000	Partners	MoA
3. T MSc. Entomology	ST	60,000	Partners	MoA
4. T MSc. Pathology	ST	60,000	Partners	MoA
5. T MSc. Hydrology	ST	60,000	Partners	Hydrology Dept.
6. T MSc. food processing	ST	60,000	Partners	MoA
7. T in Geographic Information Systems	ST	30,000	Partners	LIC, GOB
8. T in Information Technology Applications	ST	30,000	Partners	MoA, Producer Groups Associations
9. T Research and statistics (local or agency professionals)	MT	20,000	Partners	CARDI, MoA
10. R & T Climate modelling	MT	30,000	Partners	Meteorology
11. R & T Pest modelling	LT	30,000	Partners	MoA, BAHA
12. T Monitoring and Documentation	MT	40,000	GOB	MoA/ producer groups
13. T composting	ST	20,000	GOB	Producer groups
14. Research in biological control	MT On-going	40,000	GOB and Farmer Associations	GOB , SIRDI, CREI,UB
15. Research and Training in Protective Cropping Structures	ST	120.000	GOB and Farmer Associations	GOB , Farmers
TOTAL		**720,000**		

Table 3 (c): Cost, financing and implementation of actions pertaining to education and early warning

Action	Time-frame	Cost Annually (BZE$)	Financing	Implementing institutions and agencies
1. Weather forecasting Transmission: Texts, e-mail to focal points	ST	10,000	GOB	Meteorology Department
2. Awareness Programmes: TV, Radio programmes -vegetation, watershed, wetlands management	ST	10,000	GOB	Dept. of Environment
3. TV, radio programmes - importance of diversity (refuges)	ST	10,000	GOB	BAHA
4. Radio, texts, e-mail Pest forecasting	LT	5,000	GOB	MoA, BAHA
5. TV, Radio programmes - Climate Change awareness	ST	10,000	GOB	Climate Change 0ffice
6. TV, Radio programmes - GMO, LMO	ST	5,000	GOB	MoA, BAHA
TOTAL		**50,000**		

Table 3 (d): Cost, financing and implementation of action for commodity insurance

Action	Time-frame	Cost (BZE$)	Financing	Implementing institutions and agencies
1. Establishment of a Matching Insurance Fund	MT	5,000,000	GOB	- Government of Belize - Insurance Companies

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ANNEXES

Annex I – Survey Questionnaires

STAKEHOLDER SURVEY

Climate Change is a long term change in global weather patterns caused by rising temperatures (referred to as global warming*). Negative effects of Climate Change will include a rise in sea level and an increase in extreme rainfall events (excessive rains, droughts and major storms) in the near and foreseeable future. Over the last 20 years Belize has already been affected by devastating floods which has caused much losses in the agriculture sector. Agriculture will be further disrupted as average temperatures in Belize are expected to rise by 2 to 4 ^{0}C towards the end of this century, and seasonal and annual rainfall totals will continue to change significantly.

The GOB, along with stakeholders in the agriculture sector, must develop an action plan to enable the agriculture sector to adapt to the negative impacts of Climate Change.

The purpose of this survey is to consult with stakeholders of the agriculture sector to get their inputs which will guide the development of a national agriculture sector adaptation strategy to address climate change in Belize.

(*Global warming results from an increase in carbon dioxide levels in the atmosphere mainly due to the burning of fossil fuels)

Section One: Questions for Agricultural Producers

Name: ______________________________

Location: ______________________________

Organization: ______________________________

Commodity(ies): ______________________________

1. Which of the following best describes your farming system?
   □ Milpa □ Semi-mechanized □ Mechanized □High-input
   □ Low-input

2. What is your age range?
   □ 18 – 29 □ 30 – 41 □ 42 – 53 □ 54 – 65 □ >65

3. Which of the following best describes your farm landscape/topography?
   □ Flat terrain □ Rolling or hilly terrain □ Moderately steep hill side □ Steep hill side

4. How many years have you been farming?
   □ 1 – 10 years □ 11 – 20 years □ 21 – 30 years □ 31 – 40 years

5. Which of the following best describes your farm location?
   □ Flood plain □ Coastal low lying □ Buffer area next to Forest Reserve

6. What is the acreage of your farm?
□ 1 – 10 □ 11 - 20 □ 21 – 40 □ 41 – 60 □ 71 – 100
□ 101 – 200 □ 201 – 300 □ > 300

7. Which of the following best describes the soil type on your farm?
□ Sandy □ Sandy/loam □ Loam □ Clay loam □ Heavy clay

8. Which of the following categories best describes your production practice? (Describe your production practices)
Crop: □ Monoculture □ Intercrop □ Mixed Farming □ Rotation
□ Organic □ Protective cover
Livestock: □ Range □Feedlot □ Cut and carry

9. What percentage of your production is used for family consumption?
□ 0 - 24 □ 25 - 50 □ 51 - 74 □ 75 - 100

10. How do you market your produce?
□ Wholesale □ Retail □ Processed

11. Where do you get your seeds and or your planting material?
□ Self-supply □ Agricultural suppliers □ Other farmers
□ Ministry of Agriculture /CARDI □ Other ________________________________

12. How do you control pests/weeds/disease on your farm?
□ Primarily chemical pesticides □ Organic pesticides □ Integrated pest management
□Cultivation practices □ Other ____________________________________

13. How effective is your current system for the control of pests/weeds/disease?
□ Very effective □ Fairly effective □ Poor

14. Do you have an irrigation system on your farm?
□ Yes □ No

15. If **yes**, which best describes the acreage under irrigation?
□ Less than I acre □ 1 – 5 acres □ 6 – 10 acres □ 11 – 20 acres □ >20 acres

16. What type of irrigation system do you use?
□ Drip □ Sprinkle □ Flood

17. What is the source of water that you use?
□ Surface □ Rain harvest □Well □Recycled water

18. Which of the following best describes the quality of the surface or groundwater on or near your farm?
□ Fresh □ Brackish □ Seasonally salty □ Hard □ Polluted

19. Have you ever experienced shortage of water for irrigation purposes?
□ Yes □ No

20. Would you be willing to pay for a water extraction license for irrigation purposes?
□ Yes □ No

If **No**, would you continue to produce the crop(s) that are irrigated?
□ Yes □ No

21. Have you ever experienced flooding on your farm?
□ Yes □ No

22. How profitable do you consider your farm enterprise?
□ Profitable □ Fairly profitable □ Not profitable

23. What actions or support would improve your profitability?
□ Technical assistance □ Credit □ Infrastructure
□ Technology (describe)________________________________
□ Other ____

24. Where do you get advice or technical support for improving your production system?
□ Ministry of Agriculture Officers □ Non-Governmental Organization □ Other farmers
□ Agro-chemical salespersons □ Research institutions
□ Other _______________________

25. How important is the seasonal rainfall pattern for your farm?
□ Not important □ Fairly Important □ Important □ Highly important

26. From your experience have you detected changes in the seasonal rainfall pattern over the past 15 years?
□ Yes □ No

27. From your experience, have you detected any changes in day time temperatures over the past 15 years?
□ No detectable change □ Getting cooler □ Getting warmer

28. Have you noted any changes in the night-time temperatures over the past 10 to 15 years?
□ No detectable change □ Getting cooler □ Getting warmer

29. Which of the following best describes extreme weather events such as floods and droughts in your area over the past 15 years?
□ No detectable change □Same frequency but weaker □Same frequency but stronger
□ Increased frequency but weaker □ Increased frequency and stronger

30. How knowledgeable are you of the term and implications of "Climate Change"?
□ Not knowledgeable □ Fairly Knowledgeable □ Knowledgeable

31. Through which medium did you learn about Climate Change?
□ Workshops □Television □ Radio □ Internet □ Newspaper
□ Other ____________________________

32. Have you noticed any changes in recent years with your production which you believe is caused by climate change?
□ Yes □ No

33. If **yes**, what are these changes and what are you doing about it?

____

34. What aspect of climate change do you think will seriously affect your enterprise?
□ Drought □ Flood □ Storms □ Saline intrusion □ Pests and diseases
□ Heat stress □ Changes in soil fertility

35. How reliable is the weather information you receive?
□ Unreliable □ Reliable □ Very reliable

How would timely and reliable agricultural weather forecast specific for your area help in your farm operations?
□ Not at all □ Some extent □ Very much

36. Would you use crop/livestock insurance to reduce your risk?
□ Yes □ No

If **yes**, what sort of insurance model would be appropriate?
□ Farmers Cooperative Insurance □ Formal insurance sector
□ Other _________________________

If **yes**, are you prepared to pay an insurance premium?
□ Yes □ No

37. What factors would affect your decision to participate in an insurance program?
□ Cost □ Type of coverage □ Other __________________________________

38. How do you make major decisions regarding your production?

Quantity of production:	□ Individual	□ Group	□ Community
Production system:	□ Individual	□ Group	□ Community
Pest management:	□ Individual	□ Group	□ Community
Marketing of produce:	□ Individual	□ Group	□ Community

39. Do you see a need for improvement in how your farming community or association is organized?
□ Yes □ No

If **yes**, please explain.

____

40. Has your neighbour's farm practices ever negatively affected your production?
□ Yes □ No
If **yes**, please explain.
____

41. Would you relocate your farm if that is recommended due to Climate Change threats to your present location?
□ Yes □ No

42. What factors would affect your decision?
□ Availability of suitable land □ Availability of credit □ Economic infrastructure
□ Access /Logistics □Other ________________________________

43. Who should monitor the effects of Climate Change on agriculture?
□ Farmers/cooperative/association □ Meteorology Department □ Hydrology Department
□ Research institutions □ BAHA □ Agriculture Department
□ Other______________________________

44. Who do you think should finance interventions to address Climate Change needs for farmers?
□ Farmers themselves □Government of Belize □Others ______________________

45. What interventions do you recommend to reduce the negative effects of Climate Change on agriculture?

Flooding: □ farm location □drainage (farm, community, national scheme) □cambering
□ road infrastructure □ wetlands management □ vegetation management to prevent erosion □ other __________________________________

Drought: □ water harvesting □ watershed management □ water recycling (eg. Aquaponics)
□ water policy-priority water use □ economic cost □ cultivar tolerance □ drip irrigation instead of sprinkler or flood □ other ____________________

Weather unpredictability: □ seasonal production where possible □ protective crop structures
□ agro-meteorology forecast □ other ________________________

Increase/changes in pests: □ pest modeling □ biological control □ crop tolerance
□ integrated crop/pest management □ protective cropping
□ manage biodiversity (plant and animal) □ seasonal production where possible
□ other____________________________

Salt water intrusion: □ manage water extraction □ farm location □crop tolerance
□ technology (infrastructure) to combat intrusion □ agroforest systems
□ other________________________________

Changes in soil fertility: □soil amendment □compost □Effective Micro Organisms
□other ____________________________

Heat stress on:

a. (i) **Crops:** □ irrigation □ cultivar tolerance □ improved production and marketing practices to combat yield losses □ other ________________________
b. (ii) **Livestock (cattle, pigs, poultry):** □ breed selection □infrastructure □ silvopastoral systems –shade trees
c. other ____________________________

46. What are the Climate Change issues that will need to be addressed through research?
□ Cultivar/breed selection for tolerance □ Pest/disease management □ Soils/nutrition management □ Irrigation efficiency □ Alternative energy
□ Other ______________________

47. Are you familiar with Government of Belize's Biosafety (GMO) policy?
□ Yes □ No

48. Do you support the Biosafety policy?
□ Yes □ No

49. How important is organic agriculture as an economic opportunity for agriculture?
□ Important □ Fairly important □ Slightly important

50. Is organic agriculture a good system for adaptation to Climate Change?
□ Yes □ No

51. How would you rank these sectors for their contribution to Belize's economic development in order of importance? (1 being the most important and 8 the least important)
□ Wholesale and retail □ Petroleum/ Oil □ Agriculture/agro processing
□ Tourism □ Aquaculture □ Offshore banking □ Forestry and fisheries
□ Manufacturing

52. How would you rank these sectors for their contribution in terms of financial benefits to Belizeans in order of importance? (1 being the most important and 8 the least important)
□ Wholesale and retail □ Petroleum/ Oil □ Agriculture/agro processing
□ Tourism □ Aquaculture □ Offshore banking □ Forestry and fisheries
□ Manufacturing

53. How would you think the Government of Belize ranks these sectors in order of importance? (1 being the most important and 8 the least important)
□ Wholesale and retail □ Petroleum/ Oil □ Agriculture/agro processing
□ Tourism □ Aquaculture □ Offshore banking □ Forestry and fisheries
□ Manufacturing

Section Two: Questions for Policy Makers

Name: ____

Institution: ____

Position: ____

Area of Training: ____

1. How would you rank these sectors for their contribution to Belize's economic development in order of importance? (1 being the most important and 8 the least important)
   □ Wholesale and retail □ Petroleum/ Oil □ Agriculture/agro processing
   □ Tourism □ Aquaculture □ Offshore banking □ Forestry and fisheries
   □ Manufacturing

2. How would you rank these sectors for their contribution in terms of financial benefits to Belizeans in order of importance? (1 being the most important and 8 the least important)
   □ Wholesale and retail □ Petroleum/ Oil □ Agriculture/agro processing
   □ Tourism □ Aquaculture □ Offshore banking □ Forestry and fisheries
   □ Manufacturing

3. What are the priorities of the Ministry of Natural Resources and the Environment?

   ____

   How does the Ministry of Agriculture determine how it allocates its resources?

   ____

4. Where does the Ministry of Agriculture channel most of its human and financial resources?
   □ Small farmers □ Medium farmer s □ Large farmers □ Export farmers
   □ Domestic market farmers

5. What effects are currently being experienced in the Agricultural sector from Climate Change?
   □ Flooding □ Drought □ Weather unpredictability □ Salt water intrusion
   □ Increase/changes in pests □ Heat stress on crops/livestock □ Changes in soil fertility
   □ Other ____________________________

   What effects do your expect in the Agricultural sector from Climate Change?
   □ Flooding □ Drought □ Weather unpredictability □ Salt water intrusion
   □ Increase/changes in pests □ Heat stress on crops/livestock □ Changes in soil fertility
   □ Other ____________________________

6. Who identifies the Ministry of Agriculture's research, development and extension needs?
   □ Policy makers □ Extension agents □ Consensus from farmer groups
   □ Research institutions □ Development partners □Other ____________________

7. What are the problems of land use-related to Climate Change?

____

8. Is Government of Belize committed to implementing the Land Use Policy as it relates to reserving land for agriculture?
□ Yes □ No

If **yes**, when? □ Short term (3 – 12 months) □ Medium term (1 – 5 years) □ Long term (> 5 years) (High level officials only; Head of Department, Minister, Chief Executive Officer)

9. What major sectors must agriculture liaise with to successfully address Climate Change issues in agriculture?
□ Education □ Forestry □ Lands □ Energy □ Meteorology
□ Tourism Environment □ Coastal Zone □ Health □ Non Government Organizations □Other (could be more than one answer) _____________________

10. What sort of coordinating/liaising mechanism would you support or recommend?

____

11. Who should monitor the effects of Climate Change on agriculture?
□ Farmers/cooperative/association □ Meteorology Department □ Hydrology Department
□ Research institutions □ BAHA □ Agriculture Department
□ Other ___________________________

12. Are you familiar with Government of Belize's Biosafety (GMO) policy?
□ Yes □ No

13. Do you support the Biosafety (GMO) Policy?
□ Yes □ No

14. How important is organic agriculture as an economic opportunity for agriculture?
□ Important □ Fairly important □ Slightly important □ Unimportant

15. How important is organic agriculture as an adaptation strategy for Climate Change?
□ Very important □ Fairly important □ Slightly important □ Unimportant

16. What actions need to be strengthened to effectively address Climate Change in agriculture?
□ Land use management □ Research □ Alternative energy
□ Integrated crop/pest management □ Preservation of watersheds and wetlands
□ Marketing □ Infrastructure □ Crop/livestock Insurance □Other ___________________

If **yes** to insurance, what sort of insurance model would be appropriate?
□ Farmers Cooperative Insurance □ Formal Insurance sector
□Other ___________________________

17. Who do you think should finance interventions to address Climate Change needs in agriculture?
□ Farmers themselves □ Government of Belize □ Regional/International partners
□ Other ___________________________

18. What interventions do you recommend to ameliorate negative effects of Climate Change on agriculture?
Flooding: □ farm location □drainage (farm, community, national scheme) □cambering
□ road infrastructure □ wetlands management □ vegetation management to prevent erosion □ other ______________________
***Drought*:** □ water harvesting □ watershed management □ water recycling (eg. Aquaponics)
□ water policy-priority water use □ economic cost □ cultivar tolerance □ drip irrigation instead of sprinkler or flood □ other _____________________

Weather unpredictability: □seasonal production where possible □protective crop structures □ agro-meteorology forecast □ other _________________________

Increase/changes in pests: □ pest modeling □biological control □crop tolerance
□ integrated crop/pest management □ protective cropping □manage biodiversity (plant and animal) □ seasonal production where possible □ research
□other _______________________

Salt water intrusion: □ manage water extraction □ farm location □crop tolerance
□ technology (infrastructure) to combat intrusion □ other ____________________

Changes in soil fertility: □soil amendment □compost □Effective Micro Organisms
□other ___________________________

Heat stress on:

a. (i) **Crops:** □ irrigation □ cultivar tolerance □ improved production and marketing practices to combat yield losses □ other _________________________
a. (ii) **Livestock (cattle, pigs, poultry):** □ breed selection □infrastructure □ silvopastoral systems □ other____________________

19. What are the Climate Change issues that will need to be addressed through research?
□ Cultivar/breed selection for tolerance □ Pest/disease management
□ Soils/nutrition management □ Irrigation efficiency □ Alternative energy
□ Other __________________________

20. Who should be responsible for Climate Change research for adaptation in agriculture?
□ CARDI □ Central Farm □ NCCARD □ Individual Farmers' organizations □ Other ___________________________

21. On a scale of 1 to 5 (1 being most effective) how would you rate the effectiveness of the major agriculture research organizations to date?

a.	CARDI	□ 1	□ 2	□ 3	□ 4	□ 5
b.	Central Farm	□ 1	□ 2	□ 3	□ 4	□ 5
c.	NCCARD	□ 1	□ 2	□ 3	□ 4	□ 5
d.	CREI	□ 1	□ 2	□ 3	□ 4	□ 5
e.	SIRDI	□ 1	□ 2	□ 3	□ 4	□ 5

22. How do you view the importance of Climate Change models for agriculture?
□ Not important □ Important □ Very important

23. Who should decide which models should be developed?
□ Meteorology Department □ Farmers/producers □ Research institutions □ Agriculture Department

24. Who should implement and manage these models?
□ Meteorology Department □ Farmers/producers □ Research institutions □ Agriculture Department

Section Three: Questions for support agencies

Name: ____

Institution: ____

Position: ____

Area of Training: ____

1. How would you rank these sectors for their contribution to Belize's economic development in order of importance? (1 being the most important and 8 the least important)
   □ Wholesale and retail □ Petroleum/ Oil □ Agriculture/agro processing
   □ Tourism □ Aquaculture □ Offshore banking □ Forestry and fisheries
   □ Manufacturing

2. How would you rank these sectors for their contribution in terms of financial benefits to Belizeans in order of importance? (1 being the most important and 8 the least important)
   □ Wholesale and retail □ Petroleum/ Oil □ Agriculture/agro processing □
   Tourism □ Aquaculture □ Offshore banking □ Forestry and fisheries
   □ Manufacturing

3. How are you involved with the agriculture sector?
   □ Advisory □ Partnering in implementation □ Project development □ Funding
   □ Research

4. How do you view your role in regards to Climate Change actions for agriculture?
   □ Advisory □ Partnering in implementation □ Project development □ Funding
   □ Research

5. What actions need to be strengthened to effectively address Climate Change in agriculture?
   □ Land use management □ Research □ Alternative energy □ Integrated crop/pest management □ Preservation of watersheds and wetlands □ Marketing
   □ Infrastructure □ Commodity Insurance □Other ___________________________

6. What major sectors must agriculture liaise with to successfully address Climate Change issues in agriculture?
   □ Education □ Forestry □ Lands □ Energy □ Meteorology
   □ Tourism □ Environment □ Coastal Zone □ Health
   □ Non-Governmental Organizations □ Other ____________________________

7. How well do you think these sectors liaise at present?
   □ Very well □ Fairly well □ Somewhat □ Not at all

8. What sort of coordinating/liaising mechanism would you support or recommend?

____

9. Who should monitor the effects of Climate Change on agriculture?
□ Farmers/cooperative/association □ Meteorology Department □ Hydrology Department □ Research institutions □ BAHA □ Agriculture Department
□ Other _________________________

10. Are you familiar with Government of Belize's Biosafety (GMO) policy?
□ Yes □ No

11. Do you support the Biosafety Policy?
□ Yes □ No

12. How important is organic agriculture as an economic opportunity for agriculture?
□ Very important □ Fairly important □ Slightly important □ Unimportant

13. How important is organic agriculture as an adaptation strategy for Climate Change?
□ Very important □ Fairly important □ Slightly important □ Unimportant

14. What interventions do you recommend to ameliorate negative effects of Climate Change on agriculture?

Flooding: □ farm location □drainage (farm, community, national scheme) □cambering □ road infrastructure □ wetlands management □ vegetation management to prevent erosion □ other ____________________

***Drought*:** □ water harvesting □ watershed management □ water recycling (eg. Aquaponics) □ water policy-priority water use □ economic cost □ cultivar tolerance □ drip irrigation instead of sprinkler or flood □ other ___________________

Weather unpredictability: □seasonal production where possible □protective crop structures □ agro-meteorology forecast □ other _______________________

Increase/changes in pests: □ pest modeling □biological control □crop tolerance □ integrated crop/pest management □ protective cropping □manage biodiversity (plant and animal) □ seasonal production where possible □ research □other _____________________

Salt water intrusion: □ manage water extraction □ farm location □crop tolerance □ technology (infrastructure) to combat intrusion □ other __________________

Changes in soil fertility: □soil amendment □compost □Effective Micro Organisms □other _________________________

Heat stress on:

a. (i) **Crops:** □ irrigation □ cultivar tolerance □ improved production and marketing practices to combat yield losses □ other ________________________

b. (ii) **Livestock (cattle, pigs, poultry):** □ breed selection □ infrastructure □ silvopastoral systems □ other_______________________

15. What major climate change issues need to be addressed through research?
□ Cultivar/breed selection for tolerance □ Pest/disease management
□ Soils/nutrition management □ Irrigation efficiency □ Alternative energy
□ Other __________________________

16. Who do you think should finance interventions to address climate change needs for farmers?
□ Farmers themselves □ Government of Belize □ Regional/International partners
□ Others _____________________________

17. Are you prepared to finance the actions relating to Climate Change adaptation for agriculture?
□ Yes □ No

If **yes**, through what means or modus?
____

18. CARDI, BAHA, OIRSA, SIRDI, CREI – (Research Institutions)

How do you view the importance of pest modelling for Climate Change in agriculture?
□ Very important □ Somewhat important □ Unimportant

19. Who should decide what models should be developed?
□ Meteorology Department □ Farmers/producers □Research institutions □ Agriculture Department

20. Who should be responsible for implementing and managing these models?
□ Meteorology Department □ Farmers/producers □Research institutions □ Agriculture Department

Annex II – Database of responses

Stakeholder	Policy makers		Support agencies		Producers	
# Respondents	**25**		**17**		**83**	
Issue	**Responses**	**%**	**Responses**	**%**	**Responses**	**%**
Agriculture considered most important sector for Belize's economic development	16	64%	9	53%	45	54%
Agriculture considered most important sector for financial benefit to Belizeans	20	80%	10	59%	42	51%
Agriculture ranked as second most important sector for economic development	6	24%	3	18%	14	17%
Agriculture ranked as second most important sector for financial benefit to Belizeans	3	12%	3	18%	9	11%
CC effects on agriculture noted	21	84%	X		64	77%
Knowledge of GMO policy	13	52%	12	71%	9	11%
Supports GMO policy	10	40%	12	71%	6	7%
Does not support GMO policy	1	4%	0	0%	3	4%
Organic agriculture as an economic opportunity	18	72%	10	59%	67	81%
Organic as an option for CC adaptation	19	76%	10	59%	66	80%
Actions to strengthen						
Land use management	22	88%	14	82%	x	
Research	20	80%	8	47%	x	
Alternative energy	12	48%	4	24%	x	
Integrated crop management	17	68%	11	65%	x	
Watershed/wetlands	22	88%	11	65%	x	
Marketing	7	28%	3	18%	x	
Infrastructure	12	48%	9	53%	x	
Insurance	15	60%	7	41%	66	80%
Farmers/Assoc. insurance	10	40%	X		46	55%
Formal insurance sector	2	8%	X		15	18%
Hybrid GOB/farmers	3	12%	X		2	2%
Liaising needs –Sectors		0%				
Education	16	64%	14	82%	x	
Forestry	17	68%	10	59%	x	
Lands	16	64%	10	59%	x	
Energy	11	44%	7	41%	x	
Meteorology	19	76%	12	71%	x	
Tourism	4	16%	5	29%	x	
Environment	12	48%	12	71%	x	
Coastal Zone	12	48%	8	47%	x	
Health	7	28%	2	12%	x	
NGOs	13	52%	7	41%	x	

Stakeholder	**Policy makers**		**Support agencies**		**Producer**
# respondents	**25**		**17**		**83**
Issue	**Responses**	**%**	**Responses**	**%**	**Responses**
Monitoring CC effects on agric.					
Farmers/Associations	12	48%	8	47%	34
Meteorology department	13	52%	12	71%	30
Hydrology department	8	32%	8	47%	13
Research institutions	11	44%	9	53%	27
BAHA	2	8%	4	24%	13
Agriculture department	21	84%	12	71%	46
Financing of CC interventions					
Farmers	12	48%	7	41%	28
GOB	19	76%	14	82%	67
Int/Reg partners	19	76%	9	53%	6
Research needs					
Selection for tolerance	19	76%	10	59%	37
Pest/disease management	21	84%	12	71%	51
Soils/nutrition	18	72%	11	65%	40
Irrigation efficiency	18	72%	12	71%	32
Alternative energy	11	44%	5	29%	15
CC Interventions recommended					
Farm location	15	60%			**30**
Drainage	20	80%			**50**
Cambering	6	24%			**8**
Road infrastructure	10	40%			**17**
Wetlands management	16	64%			**4**
Vegetation management	16	64%			**33**
Water harvesting	14	56%			**24**
Watershed management	18	72%			**23**
Water recycling	11	44%			**14**
Water Policy-priority use	14	56%			**9**
Economic cost of water	3	12%			**3**
Cultivar/Breed tolerance	20	80%			**41**
Drip irrigation	16	64%			**29**
Seasonal production	15	60%			**41**
Protective cropping	15	60%			**27**
Agro-met forecast	18	72%			**35**
Pest modelling	7	28%			**11**
Integrated crop management	18	72%			**38**
Biological control	17	68%			**23**

Biodiversity	13	52%			**9**
Research	12	48%			**1**
Manage water extraction	8	32%			**9**
Saltwater combat technology	11	44%			**8**
Soil amendment	11	44%			**26**
Compost	18	72%			**51**
Micro-organisms	13	52%			**32**
Irrigation	21	84%			**44**
Improved production	14	56%			**31**
Heat stress infrastructure	9	36%			**11**
Silvopastoral systems	15	60%			**24**
Agroforestry	1	4%			**12**

Producer Issues					
Total respondents = 83	**# Responses**	**%**		**# Responses**	**%**
Age - under 42	43	52%	**Pest control practices**		
Age- Under 54	25	30%	Chemical pesticides	**57**	69%
Age - over 65	7	8%	Organic pesticides	**7**	8%
Landscape			Integrated pest management	**19**	23%
Flat	48	58%	Cultivation practices	**16**	19%
Rolling	26	31%	Very effective pest control	**30**	36%
Steep	6	7%	Fairly effective pest control	**48**	58%
Years in farming			Poor pest control	**3**	4%
1 to 10 years	18	22%	Irrigation used	**31**	37%
11 to 20 years	28	34%	No irrigation used	**48**	58%
21 years and more	37	45%	Prepared to pay for water	**31**	37%
Farm location			Enterprise profitable	**75**	90%
Flood plain	35	42%	**Support/advice needed**		
Coastal low lying	15	18%	Technical assistance	**46**	55%
Close to forest	32	39%	Credit	**29**	35%
Soil type			Infrastructure	**27**	33%
Sandy	3	4%	Technology	**30**	36%
Sandy loam	24	29%	Market	**2**	2%
Loam	16	19%	**Imp. of weather forecast**		
Clay loam	28	34%	Not important	**2**	2%
Heavy clay	8	10%	Some extent	**26**	31%
Home consumption > 24%	18	22%	Very much	**52**	63%
Seed source			**Prepared to pay for insurance**	**59**	71%
Self supply	**29**	35%	**Would relocate farm**	**40**	48%
Agric. Suppliers	**42**	51%			
Farmers	**12**	14%			
Min/CARDI	**6**	7%			

Annex III – Climate Change and Agriculture in Belize

ANNEX III A: IPCC Fifth Assessment Report Indicators

Summary of some of the main indicators captured in the IPCC AR-5 Report

Increase in greenhouse gas (GHG) concentrations: The concentration of greenhouse gases (GHG) in the atmosphere continues to increase. In 2011, the concentration of carbon dioxide (CO_2)—the most significant GHG emitted into the atmosphere—reached 390.5 ppm or 40 percent higher than concentrations measured prior to the industrial revolution (280 pm). In April 2014, global CO_2 concentrations hit 402 ppm, the highest levels in over 800,000 years. There is near universal consensus in the scientific community that this increase in GHG and CO_2 concentrations, due to human activity, has triggered a series of dynamic changes in the Earth's climate system.

Increasing Ocean and Air Temperatures: As a result of increasing GHG concentrations, global mean surface temperature (both land and oceans) has increased by 0.85°C since the late 19th century. More specifically, the last three decades have been the warmest period of the past 1400 years. The number of warm days and nights has increased on a global scale, resulting in fewer cold days and nights. And because of better data collection since the Fourth Assessment, the IPCC is also certain that global average sea surface temperatures (SST) have increased as well.

Changes in Extreme Weather: In the United States, the impacts of extreme weather events like Superstorm Sandy and Hurricane Katrina are beginning to leave a lasting impression of climate change. And while economic and population growth also play a significant role in the overall impact of extreme weather events, the IPCC states that heat waves, heavy precipitation events, tropical cyclones, and drought have increased in many regions across the world. With only a few exceptions, wet regions are becoming wetter, and dry regions are becoming drier, exacerbating impacts of both floods and droughts around the world.

Loss in Ice Sheets, Glaciers, Sea Ice Extent, and Snow Cover: With the rise in air and ocean temperatures, it's no surprise that the planet's ice and snow has begun to melt. In the past 20 years, ice sheets in both Greenland and Antarctica have been losing mass. The rate of ice loss in the most recent decade was eight-times faster in Greenland, and nearly five-times faster in Antarctica, compared to the prior decade. Similarly, glaciers, Arctic sea ice, and snow cover in the Northern Hemisphere have also decreased substantially.

Rise in Sea Level: Accounting for ocean currents, wind, and geography, global sea levels have risen, largely due to the loss of glacier mass, sea ice, and ice sheets, as well as ocean expansion due to warmer temperatures. According to the IPCC, sea levels have risen by 1.7 mm/year since 1901, a faster rate since the mid-19th century compared to the previous two millennia. In the last 20 years, the rate of sea level rise has nearly doubled. (IPCC, 2014)

IPCC SRES Climate Scenarios

The schematic below is an IPCC illustration of the Special Report on Emission Scenarios (SRES) (IPCC, 2007). Climate Scenario A2 describes a very heterogeneous world with strong population growth, slow economic development and slow technological change.

Climate Scenario B2 describes a world with a medium population and medium economic growth, more oriented toward local solutions to reach economic, social and environmental sustainability.

Climate Scenario B1 describes a convergent world with the same global population that peaks by mid-century and declines thereafter, as in A1, with emphasis on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

Climate Scenario A1 describes a future world of very rapid economic growth, global population peaks by mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. Three A1 groups are: A1F1 - fossil intensive; A1T - non-fossil energy sources; and, A1B - a balance across all sources.

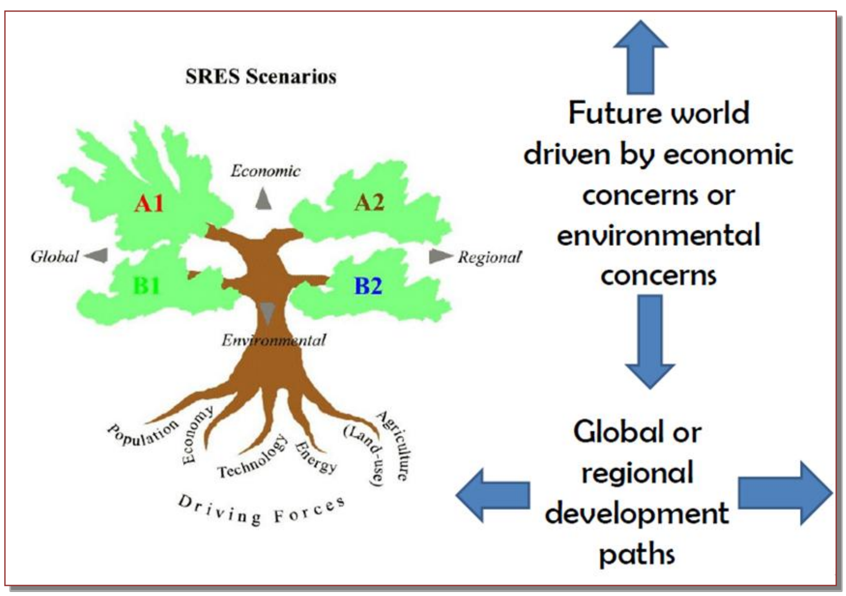


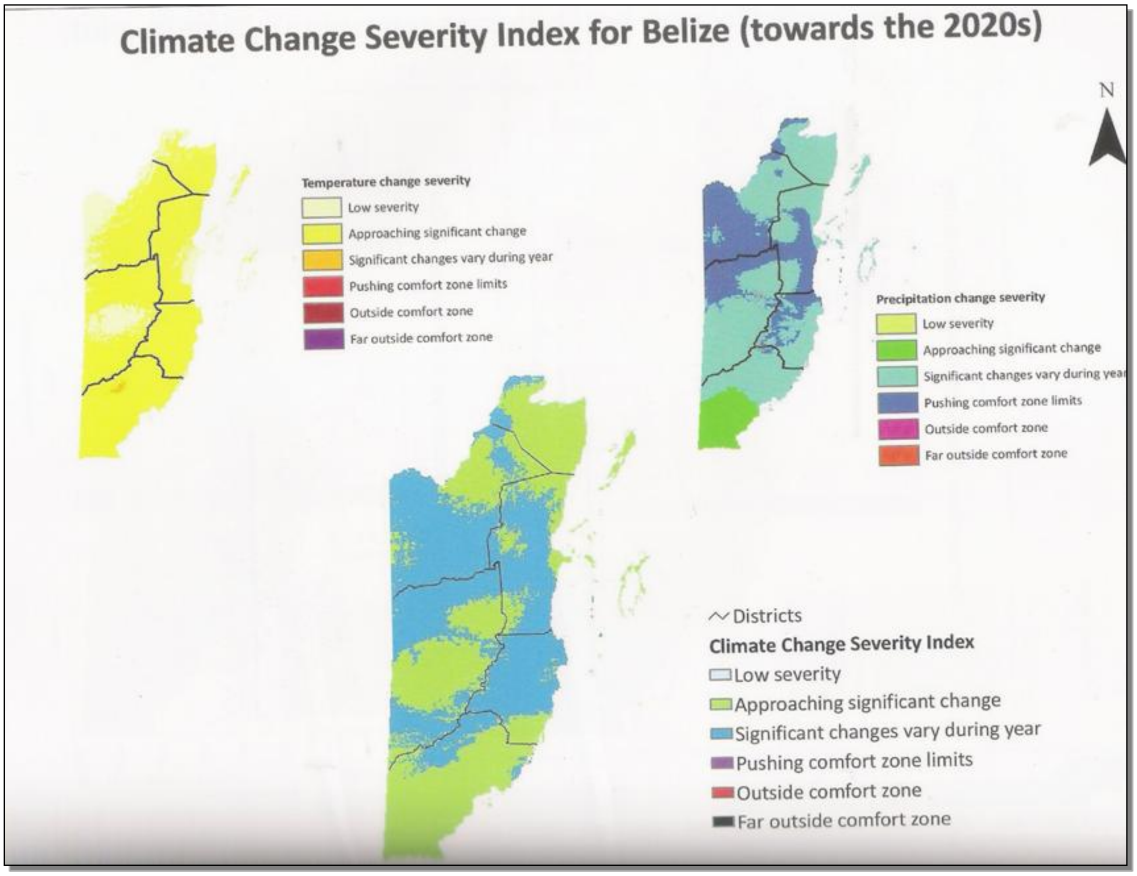
Illustration of IPCC Special Report on Emission Scenarios (SRES)

ANNEX III B: Optimum Temperature and Growing Periods for some of Belize's major crops

Crop	Sugar	Orange	Banana	Rice	Maize (Corn)	Common Beans	Perennial Soybean	Potato
Scientific Name	*Saccharum Officinarum L.*	*Citrus Sinensis L. Osbeck*	*Musa cuminata cola*	*Oryza Sativa L. s. japonica*	*Zea Mays L. s. mays*	*Phaseoilus vulgaris L.*	*Glycine wightii Arn.*	*Solanum Tuberosum L.*
GMin (days) Minimum length growing season	365 days	180 days	180 days	90 days	65 days	60 days	210 days	90 days
GMax Maximum length of growing season	365 days	365 days	365 days	180 days	365 days	100 days	365 days	160 days
Tkill °C Killing temperature	-5 °C	-10 °C	1 °C	0 °C	0 °C	4 °C	-10 °C	-1 °C
Tmin °C Minimum temperature	16°C	13°C	12 °C	8 °C	10 °C	9 °C	13 °C	7 °C
Topmin °C Minimum **optimum temperature**	27 °C	20 °C	23 °C	25 °C	18 °C	14 °C	20 °C	15 °C
Topmax °C Maximum **optimum temperature**	32 °C	30 °C	33 °C	35 °C	33 °C	24 °C	30 °C	25 °C
Tmax °C Maximum temperature	45 °C	38 °C	42 °C	42 °C	47 °C	28 °C	32 °C	30 °C
Rmin Minimum precipitation	700 mm	450 mm	650 mm	700 mm	400 mm	220 mm	550 mm	250 mm
Ropmin Minimum optimum precipitation	1050 mm	1200 mm	1200 mm	1000 mm	600 mm	350 mm	800 mm	500 mm
Ropmax Maximum optimum precipitation	1300 mm	2000 mm	3600 mm	2000 mm	1200 mm	1400 mm	1800 mm	800 mm
Rmax Maximum precipitation	2500 mm	2700 mm	5000 mm	3000 mm	1800 mm	1800 mm	4000 mm	2000 mm
District crop mostly grown	Orange Walk & Corozal District	Stann Creek & Cayo District	South Stann Creek District	Toledo, Orange Walk & Cayo District	Cayo, Bze, Orange Walk, Toledo	Corozal, Orange Walk, Cayo Stann Creek & Toledo	Orange Walk & Cayo	Cayo

(Source: CGIAR 2013)

ANNEX III C: Climate Change Severity Index



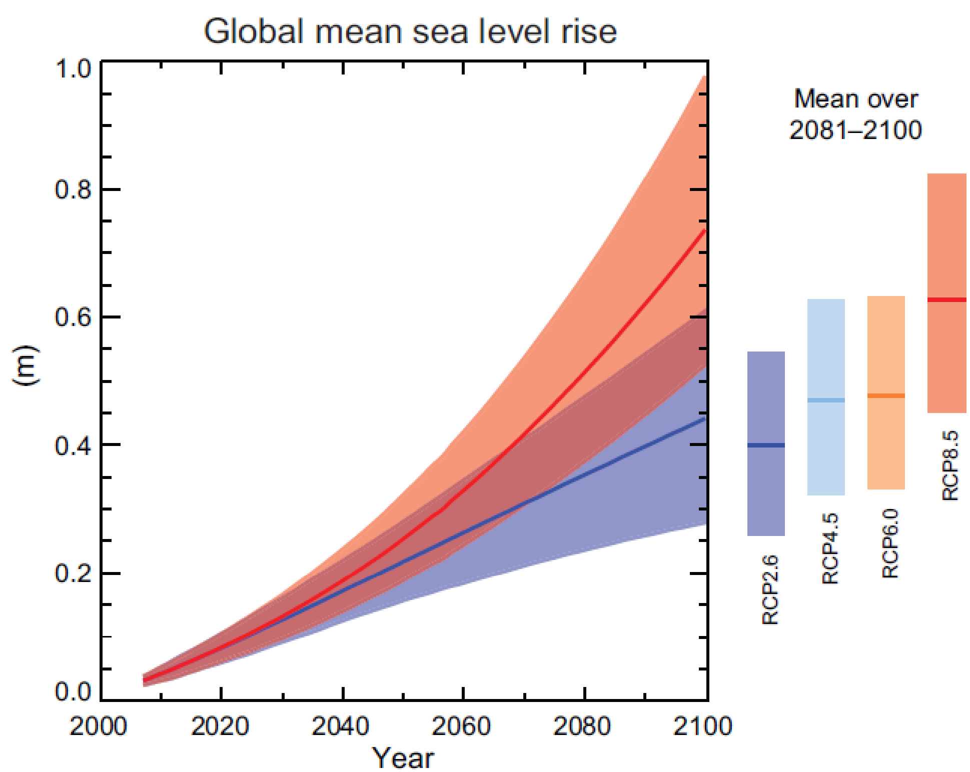
(Source: Anderson *et. al.*, 2008)

ANNEX III D: Sea Level Rise

The Inter Governmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5, 2013) indicate that:

*"Global mean sea level will continue to rise during the 21st century. Under all RCP scenarios, the rate of sea level rise will **very likely** exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets."*

The confidence in projections of global mean sea level (MSL) rise has increased since AR4. Model projections indicate that global MSL rise for 2081-2100 will ***likely*** be in the range of 0.26 to 0.55 m for RCP 2.6, 0.32 to 0.63 m for RCP 4.5, 0.33 to 0.63 m for RCP6.0, and 0.45 to 0.82 m for RCP8.5 (***medium confidence***). The Figure below shows CMIP5 models global MSL projections under the high, medium and low RCPs scenarios.



Projections of global mean sea level rise over the 21st century relative to 1986-2005 from a combination of the CMIP5 ensemble with process-based models (RCP2.6 – RCP8.5) (SPM WGI, IPCC 2013)

ANNEX III E - IPCC Fifth Assessment Report (AR5) Climate Projections for Central America and the Caribbean

Temperature and rainfall change projections from CMIP5 Global Models for the RCP 4.5 scenario for the Central America and the Caribbean (SPM WGI - AR5, IPCC 2013).

RCP4.5			Temperature (°C)					Precipitaion (%)				
REGION	MONTH[a]	Year	min	25%	50%	75%	max	min	25%	50%	75%	max
Central America												
Central America	DJF	2035	0.3	0.6	0.8	0.9	1.3	−8	−3	−1	2	10
		2065	0.7	1.2	1.5	1.7	2.1	−15	−4	−2	3	10
		2100	1.0	1.6	1.8	2.4	2.7	−22	−5	0	2	11
	JJA	2035	0.5	0.7	0.8	1.0	1.4	−8	−3	−1	2	7
		2065	1.1	1.3	1.6	1.9	2.5	−15	−6	−2	1	6
		2100	1.1	1.6	2.0	2.5	3.2	−17	−6	−2	1	12
	Annual	2035	0.4	0.7	0.9	0.9	1.3	−8	−3	−1	1	6
		2065	1.0	1.3	1.5	1.8	2.4	−14	−6	−2	1	6
		2100	1.2	1.6	1.9	2.5	3.0	−17	−5	−2	1	9
Caribbean (land and sea)	DJF	2035	0.3	0.5	0.6	0.7	1.0	−13	−4	0	3	8
		2065	0.6	1.0	1.2	1.4	1.8	−14	−6	−1	3	16
		2100	0.7	1.2	1.4	1.9	2.4	−22	−6	0	5	15
	JJA	2035	0.3	0.5	0.6	0.7	1.1	−17	−9	−6	0	11
		2065	0.7	0.9	1.1	1.4	2.0	−25	−16	−11	−4	16
		2100	0.7	1.1	1.3	1.8	2.5	−36	−18	−10	−3	13
	Annual	2035	0.3	0.5	0.6	0.7	1.1	−12	−5	−3	1	8
		2065	0.6	0.9	1.1	1.4	1.9	−19	−11	−5	−2	17
		2100	0.7	1.2	1.4	1.9	2.4	−29	−10	−5	−1	14

The CMIP5 Global Model projections under the RCP4.5 scenario projects annual temperature increase of 1.2 °C at the low end to 3.0 °C for the high end for Central America by 2100. Precipitation change is projected to range from - 17% to +9 % by the end of the century. The model projections for the Caribbean are less but significant. An increase of 2.4°C is projected at the high end by 2100, and percent precipitation change is projected between - 10% to 14%.

ANNEX III F

Effects of changes in temperature and precipitation on agricultural and crop production losses as a percent of Belize's 2007 GDP (Source: Ramirez *et al.* 2013)

Year	Scenario A2 (ECHAM, GFDL, HADGEM) Discount rate (r)				Scenario B2 (ECHAM, GFDL, HADGEM) Discount rate (r)			
	Agricultural production		Crop production		Agricultural production		Crop production	
	0.02	0.04	0.02	0.04	0.02	0.04	0.02	0.04
Changes in temperature and precipitation								
2020	6.42	5.79	5.02	4.49	1.13	0.94	1.21	1.03
2030	12.25	9.71	9.37	7.42	5.20	3.84	4.20	3.15
2050	16.78	12.02	13.80	9.69	7.41	4.93	6.37	4.23
2070	21.40	13.60	18.32	11.23	10.80	6.09	9.62	5.35
2100	34.50	16.33	29.94	13.67	15.92	7.20	14.57	6.43
Changes in temperature								
2020	0.08	0.06	0.31	0.26	-0.10	-0.09	0.10	0.09
2030	0.15	0.11	0.53	0.40	-0.01	-0.04	0.34	0.25
2050	1.03	0.54	1.63	0.95	0.69	0.32	1.29	0.73
2070	3.66	1.43	4.20	1.83	2.87	1.07	3.46	1.48
2100	11.85	3.14	**11.42**	3.34	6.67	1.89	7.01	2.25
Changes in precipitation								
2020	6.32	5.71	4.67	4.20	1.23	1.03	1.12	0.96
2030	12.09	9.58	8.81	6.98	5.27	3.91	3.92	2.95
2050	15.68	11.44	12.08	8.67	6.80	4.66	5.16	3.56
2070	17.47	12.05	13.86	9.28	8.15	5.12	6.37	3.97
2100	22.04	13.00	**17.98**	10.14	9.45	5.41	7.75	4.28

Source: Prepared by report authors.

Annex IV – List of Stakeholders

No.	Name	Position	Organization	Contact Information
1.	Wendel Parham	Chief Executive Officer	Ministry of Forestry, Fisheries and Sustainable Development	Tel. No.: 822-0810 E-mail: ceo@ffsd.gov.bz
2.	Ann Gordon	Climate Change Coordinator	Ministry of Forestry, Fisheries and Sustainable Development	Tel. No.: 822-0401 Cell No.: 632-1926 E-mail: coord.cc@ffsd.gov.bz
3.	Emily Waight-Aldana	Principal Climate Change Officer	Ministry of Forestry, Fisheries and Sustainable Development	Tel. No: 822-0401 E-mail: pcco.cc@ffsd.gov.bz
4.	Colin Mattis	Climate Change Officer	Ministry of Forestry, Fisheries and Sustainable Development	Tel. No.: 822-0401 E-mail: cco.cc@ffsd.gov.bz
5.	Wilber Sabido	Chief Forest Officer	Ministry of Forestry, Fisheries and Sustainable Development	Tel. No.: 822-1524 E-mail: cfo@ffsd.gov.bz
6.	Beverly Wade	Fisheries Administrator	Fisheries Department	Tel. No.: 224-4552/ 223-2187 E-mail: bawade@yahoo.com
7.	George Myvett	Senior Fisheries Officer	Fisheries Department	Tel. No.: 224-4552/ 223-2187/ 667-8463 E-mail: georgermyvett@yahoo.com
8.	Roberto Quintana	Fisheries Officer	Fisheries Department	Tel. No.: 224-4552/ 223-2187 E-mail: bertoquintana@gmail.com bertoquintana@yahoo.com
9.	Martin Alegria	Chief Environmental Officer	Department of the Environment	Tel. No.: 224-4552/ 223-2187 E-mail: envirodept@btl.com
10.	Gaspar Vega	Minister of Agriculture	Ministry of Agriculture	Tel. No.: 822-2330 E-mail: minister@mnra.gov.bz
11.	Hugo Patt	Minister of State	Ministry of Agriculture	Tel. No.: 822-2330 E-mail: hugopatt@yahoo.com
12.	Jose Alpuche	Chief Executive Officer	Ministry of Agriculture	Tel. No.: 822-2243 E-mail: ceo@agriculture.gov.bz
13.	Roberto Harrison	Chief Agriculture Officer	Ministry of Agriculture	Tel. No.: 822-2332 Cell No.: 622-7911 E-mail: roberto.harrison@agriculture.gov.bz
14.	Fulton Barry Palacio	Agriculture Officer	Ministry of Agriculture	Tel. No.: 822-2332 E-mail:

No.	Name	Position	Organization	Contact Information
15.	Ricardo Thompson	Principal Agriculture Officer	Ministry of Agriculture	Tel. No.:822-2332 Cell No.: 621-5628 E-mail: ricardo.thompson@agriculture.gov.bz
16.	Phillip Tate	Policy Analyst	Ministry of Agriculture	Tel. No.: 802-2241 Cell No.: 623-3253 E-mail: phillip.tate@agriculture.gov.bz
17.	Jose Novelo	Project Officer	Ministry of Agriculture	Tel. No.: 822-2332 E-mail: jenovelo@yahoo.com
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Annex V – Workshop Participants

List of participants – Presentation of Draft Strategy
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