BELIZE TECHNOLOGY NEEDS ASSESSMENT: ADAPTATION

FINAL REPORT

Identification and Prioritization of

Adaptation Technologies for Belize

June 23, 2017

Technology Needs Assessment Climate Change Adaptation Report

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BELIZE

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ACRONYMS

BNCCC	Belize National Climate Change Committee
CCD	Climate Change Department
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
COP	Conference of the Parties
CZMAI	Coastal Zone Management Authority and Institute
DTU	Technical University of Denmark
EST	Environmentally Sound Technology
EU-GCCA	European Union- Global Climate Change Alliance
GEF	Global Environment Facility
Gg	Gigagram
GCM	Global Climate Models
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPRS	Growth and Poverty Reduction Strategy
GSDS	Growth and Sustainable Development Strategy
INDC	Interested National Development Contribution
IPCC	Inter-Governmental Panel on Climate Change
LCDS	Low Carbon Development Strategy
LULUCF	Land Use, Land Use Change and Forestry
MCDA	Multi Criteria Decision Analysis
MDG	Millennium Development Goal
MESTPU	Ministry of Energy, Science and Technology, and Public Utilities
MAFFESD	Ministry of Agriculture, Fisheries, Forestry, Environment and Sustainable Development
MNRA	Ministry of Natural Resources and Agriculture
MRV	Monitoring, reporting, and Verification
N_2O	Nitrous oxide
NCCC	National Climate Change Committee
NCCO	National Climate Change Office
NCCPSAP	National Climate Change Policy, Strategy, and Action Plan
NEPF	National Energy Policy Framework
NMVOC	Non-Methane Volatile Organic Compound
NO_2	Nitrogen dioxide
NPSC	National Project Steering Committee
NSDS	National Sustainable Development Strategy
NSTMP	National Sustainable Tourism Master Plan
PV	Photo Voltaic
RCM	Regional Climate Models

REDD	Reducing Emissions from Deforestation and Degradation
SDG	Sustainable Development Goal
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TNC	Third National Communication
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

EXECUTIVE SUMMARY

Belize is one of 26 participating countries in Phase II of the Technology Needs Assessment (TNA) project, which has its origin in the Strategic Programme on Technology Transfer approved by the Global Environment Facility (GEF) in 2008. The aim is to assist developing country parties to the United Nations Framework Convention on Climate Change (UNFCCC) to determine their technology priorities, for mitigation of greenhouse gas emissions and adaptation to climate change. The TNA project is being implemented by the United Nations Environmental Programme (UNEP), and executed by the UNEP-Technical University of Denmark (UNEP-DTU) Partnership, on behalf of the GEF.

The National Climate Change Office (NCCO) of Belize is coordinating the TNA Project and a National TNA Committee has been set-up within the Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development, to oversee implementation of the project. A National Consultant has been recruited to provide technical assistance to the Belize TNA process.

Adaptation to new climatic regimes must be a part of the regional and national response profile to climate change in the Caribbean (Taylor, et al. 2012). It is unequivocal that, regardless if global emission-reduction targets were to be met, the present concentrations of greenhouse gases commit the world to climate change through the 21st century, and perhaps beyond. The region's inherent climate sensitivity and elevated vulnerability to climate change makes adaptation a priority and a necessity for securing the livelihood of communities and the sustainable development of Caribbean Countries.

In the Caribbean including Belize, a number of programmes aimed at mainstreaming of climate change adaptation into national policy and development plans have already been undertaken with varying degrees of success (Taylor, et.al., 2012; CCCCC, 2012). As the time progresses, common features that must characterize the regional adaptation strategy are as follows:

- Firstly, there is need to target all spheres of Caribbean life and existence because of the pervasive nature of climate change impacts. This means a sectoral approach to adaptation (e.g. water, agriculture, tourism, coastal zone etc.).
- Secondly, if sectoral adaptation is to be effective it must hinge on more specific knowledge of the threats within each sector; beyond what is currently available. Hence, coordinated data gathering and research is critical; particularly research which refines the climate-sectoral linkages. (E.g. Sector vulnerability studies for the National Communications).
- Thirdly, the responsibility for adaptation lies at all levels—individual, community and national levels.
- Finally, since adaptation inevitably demands some knowledge, and change in behavior and attitude, adaptation strategies must of necessity include public education and awareness.

As indicated in Belize's Nationally Determined Contribution (NDC) under the UNFCCC, Adaptation and Mitigation to climate change are high priority issues for the Government of Belize (GOB/NCCO, 2016). In fulfilling some of its obligations as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), Belize has moved to develop policies, strategies, and plans that address climate change in the development sectors. These policies, strategies, and plans have been designed to address both mitigation and adaptation to climate change. Some of the instruments relevant to adaptation to climate change are the National Adaptation Strategy and Action Plan to address Climate Change in the Water Sector in Belize (2010); the National Integrated Water Resource Management Policy (including Climate Change) for Belize (2008); the National Integrated Water Resources Act (2010); the National Sustainable Tourism Master Plan 2030 (2012); the National Climate Change Policy, Strategy and Action Plan 2015 - 2020; the Growth and Sustainable Development Strategy (2015); the National Agenda for Sustainable Development (2015); Belize's Third National Communication to the United Nations Framework Convention on Climate Change (2016); Belize Nationally Determined Contribution under the UNFCCC (2016); and regionally, "Delivering Transformational Change 2011-2021: Implementing the CARICOM 'Regional Framework for Achieving Development Resilient to Climate Change'" (2012), among others.

Belize's First, Second, and Third National Communication to the UNFCCC assessed the vulnerability of certain productive sectors to the impacts of climate change. These sectors were considered as potential areas for technology interventions. These included: Energy, Transport, Agriculture, Land Use Change and Forestry, Water, Coastal and Marine Ecosystems, Human Settlements, Human Health, Tourism, Forestry, and Terrestrial Ecosystems. During the preparation of the Belize TNA, both adaptation and mitigation technologies were considered, but this report focuses on 'adaptation technologies' only. The National Climate Change Policy, Strategy and Action Plan 2015–2020 (CCCCC, 2015) addresses eleven sectors vulnerable to climate change and climate variability, namely: Agriculture, Forestry, Fisheries & Aquaculture, Coastal & Marines Resources, Water Resources, Land use and Human Settlements, Human Health, Energy, Tourism, Transportation and Solid Waste.

Vulnerability assessment for grain crops such as rice, corn and beans was conducted for the First National Communications project, under climate change scenarios of 1 and 2 °C increase in temperature and ±20% change in precipitation. The baseline level of CO_2 was kept at current level for the simulation and adaptation measures by farmers to prevent losses were not considered. The results showed that projected climate change caused simulated crop yields to decrease. Percentage decrease in yields for dry beans, from the 1995 baseline, were in the order of -19% for -20% change in rainfall, to -14% for a +20% change in rainfall. For rice, the yields varied from -14% for -20% change in rainfall to -10% for a corresponding +20% change in rainfall. While for corn, the decreased in yields varied from -17% for -20% change in rainfall to -22% drop in yields for a +20% change in rainfall (Frutos and Tzul, 1995).

Vulnerability assessment studies were conducted for some key sectors in the preparation of the Second National Communication. These included the Coastal Zone, Agriculture, Aquaculture, Health and Tourism. While assessments were not done for areas like Coral Reefs, Mangroves, Ecosystems, Biodiversity and Human Settlements, they were considered from the perspective of the impacts climate change would have. All of them are important components of Belize's development, either economically, socially or environmentally.

Agriculture has been identified as one of the key sectors vulnerable to changing climate. Generally, higher temperatures and lower precipitation are expected to be amongst the major changes associated with climate change projections for Belize. Crops that favor warmer temperatures, such as rice, will thrive under climate change conditions. However, for more economically important crops such as sugar cane, citrus and banana, less rainfall during the critical development phase will increase stress, inhibit grain and fruit formation, and lower yields which will consequently lead to decrease in export earnings.

The choice of crops studied for the Second National Communication (SNC) was based on the availability of data. It was decided that sugarcane and citrus, with longer records of cultivation in Belize, would be the focus crops for the assessment. Mathematical simulation models were used under various climate change scenarios, to assess the expected climate change impacts in the Agricultural sector as it pertains to changes in yields for Sugarcane and Citrus.

Future climate model scenarios project temperature increases between 1° and 2.5° Celsius with changes in precipitation ranging between ±12% and ±20% by 2050. The crop simulation models forecast some 12% and 17% reduction in yields for sugarcane. The temperature increase shortened the growing period of the crops, lowering their yields. Changes in precipitation also affected the yields.

The model used to simulate the yields of citrus predicted a reduction of 3% in yields by 2028, and 5% by 2050 (Santos and Garcia, 2008) for different scenarios. The research indicated that rise in temperature shortens the growing period of many crops, inhibiting grain filling and fruit formation, thus decreasing yields.

Santos and Garcia (2008), simulated crop yields under different climate scenarios using DSSAT-4 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. Additionally, a potential increase in temperature can cause a decrease in yields arising from a reduction in the duration of the crop cycle. The research showed that climate change could favor corn production only if the amount of rainfall increases during the summer, and nitrogen deficiency can be managed effectively.

The vulnerability and adaptation component of the Third National Communication (TNC) gave more detailed assessments of the priority development sectors and areas such as Coastal Development, Water, Agriculture, Tourism, Human Health and Fisheries. These new assessments were analysed with increasing accuracy using scenarios, such as those of ECHAM5 and HadCM311 with assistance from Cuba's Institute of Meteorology (INSMET) via the Caribbean Community Climate Change Centre (CCCCC) and the Climate Research Unit (CRU) at the Universities of East Anglia and Oxford, in the United Kingdom.

The vulnerability and adaptation assessments conducted for the Third National Communication (TNC) revealed that climate change and climate-driven sea level rise and storm surges will have impacts on coastal ecosystems and economic activities in the coastal zone of Belize (Singh et al., 2014). The area most susceptible to the effects of climate change is the coastal ecosystem. Anticipated increases in sea surface temperatures, salinity, pH, sea level, and intensity of tropical cyclone events and storm surge have direct implications on the future state of the coastal zone, and the ability of the Belizean people to sustainably utilize the resources it provides.

Belize is some country rich in surface water sources including streams and rivers as well as many groundwater aquifers found in calcareous rock. The main source of freshwater in rural areas is predominantly groundwater, where approximately 95% of freshwater is extracted from groundwater supplies. Freshwater supplies are sufficient for the current population, though there is an increased stress on these supplies due to population growth, increases in economic and agricultural activities, as well as an increase in droughts (BEST, 2009; CaribSave, 2012).

Despite its water abundance, recent issues with water scarcity in some areas and water quality have become more commonplace as various stresses on water resources increase. A key issue with water vulnerability in Belize is the uneven distribution of water resources. The southern region (Toledo District) has the lowest population, with the highest amount of freshwater availability, whereas the northern region, comprising of the Orange Walk and Corozal districts, have much larger populations, with more land under intensive cultivation, but much less water resources (CaribSave, 2012). Rudimentary Water Systems (RWS), with groundwater as a source, is the main water provision service for rural communities in Belize. These systems are operated by Community Water Boards under the auspices of the Rural Development Department that provides the civil works for well perforation and the construction of ferro-concrete, elevated water tanks. The water quality testing is carried out by the Public Health Bureau in the Ministry of Health. The problem with a number of these RWS is the maladministration to operate the system and ensuring that the water is of potable quality. Consequently, a number of the RWSs experience breakdown for extended periods. The lack of a reliable RWSs forces villagers to harvest rainwater or return to the nearby rivers or stream for their water supply,

The coastal zone of Belize, where a significant percentage of the population is located and where significant agricultural/aquaculture production is carried out, is for the most part below the high tide level. This puts the coastal zone in a very precarious position with regards to climate-driven sea level rise, especially when augmented by storm surges. The cross-cutting linkages between the Coastal Zone, Fisheries and Agriculture, and by extension Tourism and Human Health, are thus very strong and evident; hence adaptation measures designed to assess the risks and protect the coast will also address these inter-linkages between these productive and social sectors.

After extensive stakeholder consultation coordinated by the National Climate Change Office in Belize, the sectors selected for adaptation in connection with the TNA project were: Agriculture, Water Resources, and Coastal and Marine Ecosystems.

After a review of the initial adaptation and mitigation TNA Reports in early 2016, it was recommended by UNEP/DTU that Belize, through the TNA coordination group, revisit the factsheets, conduct more public consultations to redraft new factsheets, and conduct the Multi Criteria Analysis (MCA) process for the selected/approved adaptation and mitigation factsheets. Having successfully completed this stakeholder-driven exercise, the newly recruited consultants were asked to review the TNA Reports with the revised and prioritized adaptation and mitigation factsheets. In connection with this development, the list of adaptation technology factsheets and prioritized technologies are hereby incorporated into this TNA Adaptation Report.

A total of ten adaptation technology factsheets were drafted and presented to small working groups of key stakeholders per sector. These adaptation technology factsheets as per sector are:

Agriculture:

1) *Improved drip irrigation systems for five farming groups using rainwater harvesting and fertigation for crop nutrient requirement*
2) *Rehabilitation of Seven Covered Structure Cooling Systems*
3) *Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties*
4) *Heat and Drought Resistant variety of open-pollinating corn and beans seeds for reproduction and marketing for four farmers' cooperatives*
5) *Micro climate monitoring system for sustainable soil and land management in Agriculture and Agroforestry in Six Training and Demonstration Sites*

Water:

6) *Drought Monitoring System for Northern Belize with Specific Focus on Groundwater Resources*
7) *Water Efficient Fixtures and Appliances*
8) *An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize*

Coastal and Marine Ecosystems

9) *Soft Engineering and Ecosystem Restoration (SEER) Technologies to Address Shoreline Erosion in Three Threatened Coastal Communities in Southern Belize*
10) *Improved Environmental Monitoring Network and Early Warning System for Belize's Coastal Zone to Increase Resilience to Climate Change*

The Lead Consultant, in coordination with the National Climate Change Office, facilitated consultative meetings and work sessions with key sector stakeholders, for the Multi Criteria Analysis (MCA) process for the Agriculture, Water and Coastal and Marine Ecosystems sectors. The results of the MCA exercise along with the adaptation factsheet technologies were later forwarded to the TNA Country Coordinator.

The prioritized technologies per sector are summarized below.

Agriculture Sector:

i. Heat and Drought Resistant variety of open-pollinating corn and beans seeds for reproduction and marketing for four farmers' cooperatives.
ii. Improved drip irrigation systems for five farming groups using rainwater harvesting and fertigation for crop nutrient requirement
iii. Rehabilitation of Seven Covered Structure Cooling Systems
iv. Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties.

Coastal & Marine Ecosystems:

v. Improved environmental monitoring network and Early Warning System for Belize's Coastal Zone to increase resilience to climate change.

Water

vi. Integrated Management Strategy for water safety in eight Rural Water Supply Systems in Belize.

Three technologies out of five were prioritized for the Agriculture sector. After further consultation with key stakeholders in the Agriculture sector, it was recommended that technology No. 4 which scored fourth in the MCA process, namely: *'Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties'*, be considered for further evaluation and analysis in the Barrier Analysis and Enabling Framework stage of the TNA process. The reason being that drought resistant potato seed propagation in Belize is viable and a priority in the food security strategy, in the light of pressing climate change stress in crop production. Meanwhile, one technology was prioritized for the Coastal and Marine Ecosystem sector, and one out of three technologies was prioritized for the Water sector, respectively.

The prioritized technologies in Agriculture, Water, and Coastal and Marine Ecosystems were unanimously supported by key stakeholders in these sectors. A total of six climate change technologies have been prioritized for the Barrier Analysis and Enabling Framework stage of the TNA process. The ultimate goal is to take these technologies to the Technology Action Plan phase (Step III) of the process, and procure funding for all six adaptation technologies.

CHAPTER 1: INTRODUCTION

1.1 The Belize Technology Needs Assessment Project

A Technology Needs Assessment (TNA) is a country-driven set of activities directed mainly at the identification and prioritization of climate change mitigation and adaptation technologies. Since 2001, a number of developing countries which are Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have conducted TNAs within the framework of their national development plans and strategies. However, the revisions of these early TNA processes revealed significant operational and methodological constraints that compromised the quality, comprehensiveness and utility of the resulting country's TNA reports.

A new project has been designed to assist countries in carrying out improved TNAs supported by the Global Environment Facility (GEF) grant financing. Project activities include in-depth analysis and prioritization of technologies, analysis of potential barriers hindering the transfer of prioritized technologies and analysis of potential market opportunities at the national level. All activities were organized around three main components, namely: i) support for the development or strengthening of TNAs; ii) development of tools and provision of methodological information to support the TNA and Technology Action Plan (TAP) processes; and iii) establishment of a cooperation mechanism that aids preparation and refinement of the TNA and TAP implementation and dissemination.

This project is intended to assist countries, like Belize, to complete a TAP on the basis of strong consensus amongst stakeholders on prioritized technologies, including relevant actions in order to accelerate the transfer and deployment of clean and feasible technologies.

The purpose of the TNA project is to assist participant developing country Parties to identify and analyze priority technology needs, which can form the basis for a portfolio of environmentally sound technology (EST) projects and programmes to facilitate the transfer of, and access to, ESTs and know-how in the implementation of Article 4.5 of the UNFCCC Convention. Hence, TNAs are central to the work of Parties to the Convention on technology transfer and present an opportunity to track an evolving need for new equipment, techniques, practical knowledge and skills, which are necessary to mitigate greenhouse gas (GHG) emissions and/or reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change. The main objectives of the Project are:

1. To identify and prioritize through country-driven participatory processes, technologies that can contribute to adaptation and mitigation goals of the participant countries, while meeting their national sustainable development goals and priorities.

2. To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies.

3. To develop Technology Action Plans (TAPs) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies in the participant countries.

UN Environment (also known as UNEP) is responsible for the implementation of the Project and provides overall project oversight and strategic coordination. The TNA Project is executed by the UNEP DTU Partnership (UDP), a long-standing partnership between UN Environment and the Technical University of Denmark, based in Copenhagen, Denmark.

The Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development (MAFFESD) through the National Climate Change Office (NCCO), is responsible for the implementation of the TNA Phase II Project in Belize, and this is facilitated under the terms of a Memorandum of Understanding (MOU) crafted for this purpose. The UDP and the Ministry have signed the MOU. The National Climate Change Coordinator was designated as the National TNA Coordinator, and while the climate change officer was designated as the Assistant National Coordinator in order to provide managerial and technical support to the project.

A National TNA Committee has been set-up within the Ministry of Agriculture, Forestry, Fisheries and Sustainable Development to oversee implementation of the project. The National Consultant supports and facilitates the implementation of the TNA process and all related activities.

1.2 Policies and Regional Initiative on Climate Change and Development Priorities

The variety of national climate change policies and strategies to address adaptation to climate change stretches across many key development sectors and areas including Water, Agriculture, Energy, Coastal Zone, and Human Well-being.

1.2.1 National Adaptation Strategy to address Climate Change: Water Sector

The Government of Belize (GOB), with support from the Mainstreaming Adaptation to Climate Change Project (MACC) executed by the Caribbean Community Climate Change Centre (CCCCC), undertook the preparation of a National Adaptation Strategy to Address Climate Change in Belize's Water Sector. This National Adaptation Strategy (NAS) was prepared by the Belize Enterprise for Sustainable Technology (BEST) in 2009

That exercise noted that deleterious climate change impacts within the Water sector will affect Belize's economic development. The document indicated that temperature increase, changes in precipitation leading to floods and drought, sea level rise causing saline intrusion, and biodiversity stress will all affect the economy, due to increased water acquisition and processing costs. Reduced availability of freshwater will result in increased procurement and distribution costs.

In 2005 the demand for freshwater resources in Belize was from three (3) broad sectors, namely: agriculture, industry and domestic/residential. In that year the water use was: 43.7 % in agriculture, 36.5% in industry and 19.7% for domestic/residential users (SIB, 2005). In 2009 the freshwater demand was partitioned as follow: Agriculture and Industry >80% of the total demand; Domestic/Residential including Tourism < 20% (CCCCC/BEST, 2009).

Five key adaptation actions were recommended. These include: i) the establishment of an agency to execute integrated water resources management, ii) strengthening the existing institutional and human resources capacities in the water sector for improved management practice, iii) formalizing the legal mandate and operations of the National Climate Change Committee, iv) strengthening the trans-boundary relationships to cover the impacts of climate change on the water sector, and v) increasing public awareness and education in water culture and climate change.

1.2.2 National Integrated Water Resource Management Policy

The aforementioned national water policy for Belize was reviewed as part of the exercise to develop the National Integrated Water Resource Management Policy (including Climate Change) for Belize 2009. Climate change is predicted to severely impact water resources (IPCC, 2007; IPCC, 2008) and was the main issue influencing all stages of preparation of the research through, stakeholder interviews and policy finalization.

The policy formulation methodology employed identification of guidelines for good water resources management which were then used as reference in the preparation of an over-arching core policy statement. This policy statement represents the essential socio/political mission and vision statement of water resources management.

The organization of all the inputs to the policy development process, especially issues, opportunities and constraints, contributed to identification of broad themes and critical areas. These policy areas cover: ownership, vestment and rights; assessment by quantification and qualification; institutional capacity and planning; valuation and economic considerations; allocations and prioritization; conservation, efficient use and pollution prevention; need for a water culture; water industry and trans-boundary water issues.

The resulting policy serves as the principal guidance in managing the nation's water resources. This guidance will be necessary for consequential actions such as the preparations of strategies, action plans and adaptation mechanisms in view of the predicted deleterious effects of the impact of "Global Climate Change" in the topical or thematic areas. The National Integrated Water Resource Management Policy (including Climate Change) for Belize was adopted by government in 2009.

1.2.3 National Integrated Water Resources Act 2010

This piece of legislation follows from the preceding Water Resources Management Policy and Strategy. It is a comprehensive legislation that provides for the establishment of a Water Resources Management Authority. It introduces control and regulations for the abstraction of water and the pollution of water through discharge of effluents. In relation to the Authority, the Act describes its functions, powers, composition, etc. The Act also incorporates a Master Plan for the management of the country's water resources. Unregulated use of water had been described as a contributing factor to vulnerability of Belize's water resources.

1.2.4 The National Agriculture and Food Policy for Belize: 2015-2030

The Agriculture and Food sector is one of the main pillars of the Belizean economy, contributing significantly to Gross Domestic Product (GDP) (13.06%)[1], employment (17.9%), income generation and food and nutrition security. The sector is also important to macroeconomic growth and development as a major earner/saver of foreign exchange. In mid-2014, the Government of Belize adopted the National Agriculture and Food Policy 2015-2030.

The Policy framework

1. The overall goal of the policy:

The overall goal of the policy is to engender a conducive environment for the development of an agriculture and food sector that is competitive, diversified and sustainable, that enhances food security and nutrition, and contributes to the achievement of the socio-economic development goals of Belize**.**

2. National Targets:

- Increase the agriculture and food sector average annual growth rate from the current average of 2.8 percent to 4.0 percent.
- Increase agriculture and food sector contribution to GDP in real terms from approximately 13.0 percent of GDP to 20 percent of GDP.
- Increase current average annual growth rate in agricultural exports from 4.2 percent to 5.5 percent.
- Reduce the current average rate of growth in imports from 5.8 percent to 3.5 percent with a heavy focus on import replacement commodities.
- Increase direct employment in the food and agriculture sector to 25 percent of total employed labour force.
- Increase real income of producer by 2.5 percent per year.
- Impact poverty, food and nutrition security and malnutrition.

1.2.5 National Sustainable Tourism Master Plan of Belize 2011

The National Sustainable Tourism Master Plan (NSTMP) of Belize 2030 (draft) aims to achieve a set of quantitative and qualitative specific objectives by 2030. This draft Plan sets out the strategy and action plan which is expected to take Belize into the future with a dynamic, competitive, and sustainable tourism industry. The Master Plan defines the NSTMP structures and programs, and the strategic approaches that should guide the implementation of the plan. The plan also outlines a framework to organize activities to attract funding from different sources (NSTMP, 2011).

[1] World Bank, 2011

The NSTMP lists of objectives are as follows:

- To increase tourism arrivals and tourism movement within the region and the country.
- To reduce health hazards and visual and environmental pollution.
- To reduce consumption of scarce resources.
- To improve application green technologies recycling and energy conservation.
- To enhance transportation capacity by meeting increasing tourist arrivals and flows
- To enhance transport safety and reliability.
- To enhance the tourism destination's competitiveness.
- To increase the tourism satisfaction level.

The National Sustainable Tourism Master Plan (NSTMP) describes Belize as a tourism destination characterized by its excellent natural resources and strong cultural heritage that make it possible for eco-tourism, adventure and cultural tourism to flourish as its main tourism motivations (NSTMP 2030, 2011). The NSTMP also describes Belize as host to four "unique tourism assets" which are accredited with international recognition. These assets are the Belize Barrier Reef Reserve System, the Blue Hole Natural Monument, the Caracol Mayan site, and the Chiquibul Caves System.

The NSTMP comments on the constraints affecting tourism development, which include a few that are described as follows: poor accessibility on land, mainly due to few paved roads leading to the tourism assets; poor level of accessibility by air, mainly due to few international flight connections from tourist origins like Europe; scarce Belizean made handicrafts; inadequate (natural & heritage) asset management, mainly due to lack of awareness; insufficient waste disposal and sewage systems, resulting in unhealthy conditions and visual pollution; and lack of urban land planning and land use regulation, resulting in haphazard and inadequate urban development, beach erosion, and land use conflict; among others.

To address these issues, the NSTMP recommends the upgrading of basic infrastructure and development of support services, and the development of national connectivity.

1.2.6 Growth and Sustainable Development Strategy 2014 – 2017

The Growth and Sustainable Development Strategy (GSDS) is the guiding development plan for the period 2015–2018. It adopts an integrated, systemic approach and encompasses medium-term economic development, poverty reduction and longer-term sustainable development issues. The GSDS builds on previous documents especially Horizon 2030: National Development Framework for Belize 2010 – 2030. The GSDS is Belize's primary planning document, providing detailed guidance on priorities and on specific actions to be taken during the planning period.

The GSDS 2013-2014 is the product of the merger between the National Sustainable Development Strategy (NSDS) 2012 and the Growth and Poverty Reduction Strategy (Catzim-Sanchez, 2015). This Growth and Sustainable Development Strategy adopts an integrated, systemic approach based on the principles of sustainable development, and on three notable drivers that are common to successful developing countries: a proactive role for the state, tapping into global markets, and innovative social policy.

At the core of the GSDS is a commitment to achieve a single overriding goal: to improve quality of life for all Belizeans, living now and in the future. To achieve that goal, GSDS provides a strategic framework, a set of clear policy aims, a considered mix of highlighted and prioritized action areas, and guidance on the necessary institutional arrangements and procedures. Specifically, the GSDS identifies four "Critical Success Factors" (CSFs), subsidiary goals that also provide organizing framework for the objectives and actions grouped underneath them (under the headings of "Necessary Conditions" or "NCs", and "Actions"). Each CSF is also linked to a set of measurable targets.

1.2.7 National Climate Change Policy, Strategy and Action Plan 2015

The National Climate Change Policy, Strategy, and Action Plan (NCCPSAP) to address Climate Change in Belize was prepared for the Caribbean Community Climate Change Centre (CCCCC) and the Government of Belize with financing from the European Union Global Climate Change Alliance (EU-GCCA) Caribbean Support Project, and the Third National Communication Project which was supported by the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF).

The goal of the National Climate Change Policy is to provide guidance for the short, medium and long-term processes of adaptation and mitigation to Climate Change in accordance with national objectives for sustainable development and regional and international commitments.

Its objectives are to:

1. Integrate Climate Change adaptation and mitigation into key national development plans, strategies and budgets;
2. Build Climate Change resilience to prevent, reduce or adapt to the negative impacts of Climate Change on key sectors, economic activity, society and the environment through policies and strategic processes;
3. Promote capacity building and networking across all implementing/involved agencies;
4. Source and secure adequate financing over the short, medium and long-term periods for effective and timely adaptation and mitigation responses; and
5. Capitalize on opportunities currently available through Climate Change negotiation processes that can enhance the economic and social development prospects of the nation.

In coordinating the implementation of the NCCPSAP, the NCCO considers the need to:

a) Facilitate the provision of adequate support on mitigation and adaptation measures to all stakeholders;

b) Monitor the impact of the strategy against the goals and objectives that have been set, and;

c) Make appropriate adjustments to the policy and strategy in light of intended or unintended changes in the general environment.

The Climate Change Action Plan is a five-year programme (2015-2020), which is intended to provide the foundation for the country's capacity and resilience to meet the challenges of Climate Change. The Action Plan is divided into two thematic areas namely adaptation and mitigation. The sectors for which adaptation and mitigation strategy and action plans will be addressed are:

- Agriculture
- Forestry
- Fisheries and Aquaculture
- Coastal and Marine Resources
- Water Resources
- Land use and Human Settlements
- Human Health
- Energy
- Tourism
- Transportation
- Solid Waste

The list above includes all the sectors selected for attention under the TNA Phase II project in Belize.

1.2.8 Horizon 2030

Horizon 2030 is a national long-term development planning framework that embraces all sectors for Belize. It was developed through a national consultation process that occurred across the country and it envisions Belize as a "country of peace and tranquillity where citizens live in harmony with the natural environment and enjoy a high quality of life. Belizeans are energetic, resources and independent people looking after their own development in a sustainable way" (GOB, 2009). The Horizon 2030 framework addresses national development planning through several thematic areas covered under four main headings or "pillars", but this report will only describe two of the pillars that appear to be most relevant to national planning and sustainable development.

Pillar 1: Democratic Governance for effective public Administration and Sustainable Development.

The consultations held during the preparation of Horizon 2030 took stakeholders' opinions and perspectives into consideration. The national consultations indicated that there was much evidence of breakdown in the governance structure and the social fabric, but the majority of citizens felt that that the situation can be fixed. The goals for democratic governance include:

- Strong "watchdog" groups in the non-government sector hold politicians accountable.
- Persons in public life demonstrate the highest ethical standards.
- Government departments are free of corruption, modernized and focused on providing quality service to the public.

- Party politics is in its proper place so that it is less intrusive and divisive in the daily lives of citizens.
- Critical aspects of the political reform process are completed.

Pillar 3: Economic Resilience: Generating Resources for long-term development.

The key economic goals for 2030 under this "Pillar" are building economic resilience, promoting productivity and competitiveness and ensuring the environmental sustainability of economic activity by:

- Increasing agricultural production in a sustainable way and increase local value - added through the development of agro-processing.
- Ensuring a sustainable and profitable tourism sector.
- Developing a strong small business sector, a strong work force and a strong corps of entrepreneurs.
- Ensuring that government is able to make timely investments in key economic infrastructure.

Strategies to realize the goals under this heading include promoting and developing the domestic market through better regulation of illegal imports; make key public investments in economic infrastructure - especially the road network and transportation system; promote investment in agriculture, local manufacturing, agro-processing and other productive activities; support reforestation and sustainable logging by local communities to create jobs and reduce poverty; foster entrepreneurship among young people and invest in science and technology education to promote innovation; and, reduce the costs of access to technology.

This is an overarching vision for sustainable development across all sectors in Belize, and indirectly justifies the selection of technologies suggested in this report.

1.2.9 National Energy Policy Framework 2011-2012

A first draft of this document was produced in 2011, and updated in 2012. It was the result of the effort of the Ministry of Energy, Science and Technology, and Public Utilities to develop a National Energy Policy. The document entitled "National Energy Policy Framework, 2011 – Towards Efficiency, Sustainability, and Resilience for Belize in the 21st Century" was developed to chart a course for Belize to achieve energy efficiency, sustainability and resilience over the next 30 years. It provides policy recommendations to policy-makers and decision-makers, and discusses the pros and cons of various policy instruments that can be used to achieve policy objectives. It is therefore a proposed roadmap of what and where the goal is, how to reach that goal, and what it will take to achieve that goal.

While the National Energy Policy Framework (NEPF) outlines mitigation measures in the Energy sector to reduce GHG emissions, the recommended technologies also allow adaptation to the situation in which fossil fuels become scarce. Technologies which utilize renewable energy from national resources are ideal. Resources such as hydro, biomass, solar, and wind are probably not fully explored yet, so opportunities to apply technologies still exist in these fields. The National

Energy Policy Framework proposes actions to develop other means of producing and utilizing energy to build resilience within this sector in Belize.

The National Energy Policy Framework recommended the following:

(i) Establish a National Energy and Electricity Planning Institute with responsibility for formulating energy plans and policies in coordination with selected stakeholders, for disseminating these policies and plans to relevant stakeholders, and for monitoring and enforcing adherence to the plans and policies by the bodies charged with administering them.

(ii) Create an Energy Sector Planning Framework to guide the process of formulating a least-cost long-term plan for future development of the Belize energy sector along the path of sustainability and resilience (National Energy Policy Framework, 2011).

The Energy sector in Belize offers opportunities to invest in mitigation and adaptation technologies.

1.2.10 National Adaptation Strategy to Address Climate Change in Agriculture

Agriculture is critical to Belize's development for foreign exchange earnings and savings, employment, and food and nutrition security. Belize is considered food secured 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 bouts of excessive rainfall and flooding in late 2013 and early 2014.

The main export commodities, namely: bananas, citrus, sugar and aquaculture, plus commodities accessing emerging market and 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 CCCCC, with the Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development (MAFFESD) 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. 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.

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.

1.2.11 The National Climate Resilience Investment Plan (2013)

The National Climate Resilience Investment Plan (NCRIP) promotes a well-coordinated approach to national development by integrating planning processes across all sectors of the economy through participation among a broad spectrum of stakeholders. It therefore provides the framework for an efficient, productive and strategic approach to building economic, social resilience and development. The plan is designed to build climate resilience into national planning and national development actions. Special importance is given to building climate resilience and improving disaster risk management capacities across all sectors.

The NCRIP was formulated by the Ministry of Finance and Economic Development and bodies a transformational process that seeks to integrate climate change adaptation, climate variability and comprehensive disaster management into national development planning processes and actions. It seeks to build on past efforts using knowledge and lessons learnt from the Climate Investment Funds (CIF), through its Pilot Program for Climate Resilience (PPCR) and from the pilot countries currently in the PPCR.

The NCRIP is led by the Ministry of Finance and Economic Development with support from other ministries. NCRIP will contribute to the pursuit of Vision 2030 and the sustainable development of Belize. The implementation of the NCRIP is expected to utilize the partnerships forged during its development, for an outcome of a climate resilient Belize where its women and have expanded development options.

1.2.12 Integrated Coastal Zone Management Plan 2013

The Plan outlines a vision and implementation plan for sustainable use of coastal resources and supports an integrated approach to development planning and adapting to climate change. The Plan contains critical measures for climate change adaptation relevant to this sector, which includes the identification of short, medium and long-term strategies to address the threats of climate change on coastal communities as well as coastal and marine resources. The management plan also takes into consideration the necessary adaptive measures to mitigate projected climate change impacts and recommends that all developments within the coastal areas of Belize include an adaptation strategy to mitigate the effects of climate change. It also recommends the prioritization of ecosystem-based adaptation as it builds resilience and reduces the vulnerability of local communities to climate change.

1.2.13 Belize's Nationally Determined Contribution (NDC) 2016

On April 20, 2016, Belize submitted its Nationally Determined Contribution (NDC) to the UNFCCC, with the intention to utilize existing frameworks, policies, projects and activities that provide mitigation and sustainable development co-benefits to realize its NDC objectives. Belize's NDC highlights key sectors in which adaptation and mitigation strategy and action plans will be implemented. These include: Agriculture, Forestry, Fisheries and Aquaculture, Coastal and Marine Resources, Water Resources, Land use and Human Settlements, Human Health, Energy, Tourism, Transportation, Solid Waste, and Infrastructure.

Agriculture

Agriculture is key to the country's development. It is vitally important in terms of food security and employment, and is one of Belize's major export commodity and foreign exchange earner. Recommendations from the National Agriculture Sector Adaptation Strategy to Address Climate Change include both short and long-term measures to address critical gaps in technological developments relevant to crop production, improved soil management practices, diversification into drought resistant crops and livestock, and adaptation in farm production systems, including but not limited to land use, high resolution topographic mapping, and the increasing use of low-water irrigation systems.

Water Resources

Belize has an adequate supply of freshwater due to its geographic location, relatively high level of forest cover and forest reserves, and 18 major water catchment areas, with many smaller sub-catchments. However, the country's water resources face increasing threats arising from anthropogenic sources such as expansion in the agricultural, industrial and tourism sectors, a growing population, water pollution and watershed degradation, and the added stress associated with climate change. The overall goal with respect to the water sector is to enhance the protection and restoration of forest ecosystems, and build resilience of water catchment areas which is vital for their environmental services, including the provision of safe and abundant ground and surface water.

Coastal and Marine Resources and Ecosystems

The adoption and implementation of the Belize Integrated Coastal Zone Management Plan is critical for the sustainable use of coastal and marine resources. Belize's coastal zone is intrinsically linked to the viability of the fisheries and tourism sectors that are dependent on the organisms and ecosystems present in coastal zone to sustain these sectors. Other sectors such as agriculture, aquaculture and petroleum use the coastal waters for transportation of goods and overseas trade. Rapid economic development such as in the tourism industry and population growth, has led to increasing pressures on coastal and marine resources, which directly or indirectly affects the livelihoods of those who depend on them. These threats are exacerbated by natural hazards, global warming, and sea level rise, and vulnerability of sensitive marine ecosystems to climate change. The overall objective in connection with Belize's NDC is to promote the adoption and implementation of the Belize Integrated Coastal Zone Management Plan, to ensure the sustainable use and management of the coastal and marine resources of the country, in the face of impending climate change.

Forestry and Biodiversity

Similar to other natural resource sectors, Belize's forests and its biodiversity are expected to be impacted by Climate Change. Proposed interventions in the revised National Forest Plan, aims to mainstream adaptation and mitigation to Climate Change through the provision of guidance for actions that concerns the direct and indirect threats arising from global Climate Change on forests and forest dependent people, in order to reduce their vulnerability, and increase their resilience and adaptation to Climate Change.

The Government of Belize (GOB), through its National Climate Resilience Investment Plan (NCRIP), seeks to improve Belize's climate resilience to support the country's economic growth and the safety of Belizeans. This cross-sectoral plan identifies both physical and non-physical actions that consider current and future risks posed by climate variability and climate change. The NCRIP is integrated into GOB's Growth and Sustainable Development Strategy and is aligned with Horizon 2010-2030 (GOB, 2009).

1.2.14 The CARICOM "Regional Framework for Achieving Development Resilient to Climate Change

At the regional level, Caribbean states (SIDS), including Belize have formulated and agreed on a number of declarations and strategy for transformational change in light of the imminent threats posed by climate change on the regions socio-economic development (CCCCC, 2012). The declarations and strategy contained in the seminal report, "***Delivering Transformational Change 2011-21: Implementing the CARICOM 'Regional Framework for Achieving Development Resilient to Climate Change'"*** propose the following strategic elements to significantly increase the resilience of CARICOM member states' social, economic and environmental systems:

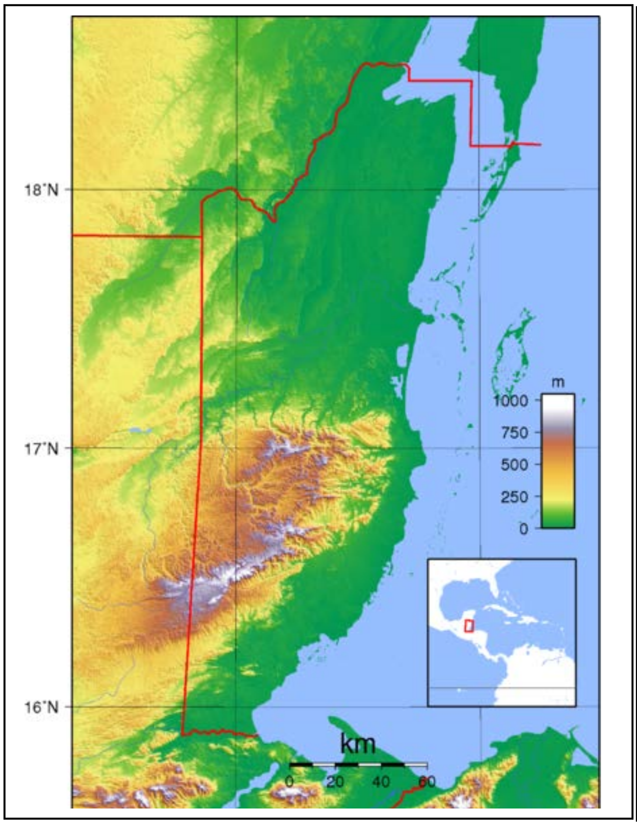
- Mainstream climate change adaptation strategies in the sustainable development agendas of member states;
- Promote the implementation of specific adaptation measures to address key vulnerabilities in the region;
- Promote actions to reduce greenhouse gas emissions though fossil fuel reduction and conservation, and changing over to renewable and cleaner energy;
- Encourage actions to reduce the vulnerability of natural and human systems to the impacts of changing climate; and
- Promote actions to derive social, economic, and environmental benefits through the prudent management of standing forest in CARICOM countries.

1.3 National Circumstances

Belize (formerly British Honduras until the name of the country was changed in 1973), is a relatively new nation, having gained independence only since September 21, 1981. It is located in northern Central America, bordered by Mexico on the north, Guatemala to the west and south, and the Caribbean Sea on the east. Including its territorial waters in the Caribbean Sea, Belize's geographic coordinates are 15˚ 53' to 18˚ 30' north latitude and 87˚ 15' to 89˚ 15' west longitude. Using an offshore territorial limit of 20 km (12 miles), the national territory covers about 46,620 km^2 (18,000 $miles^2$), of which 49% is land.

1.3.1 Physical Features

Belize's land mass includes more than 1,060 tiny islands, known as 'cayes', totaling about 690 km^2. However, there are about 1,540 km^2 of lagoons on the mainland, reducing the effective national land area to some 22,966 km^2 including the cayes. The country's greatest length from north to south is 280 kilometers (174 miles) and its greatest width is 109 kilometers (68 miles). Figures 1 (a) and 1 (b) show the physical and political maps of Belize.



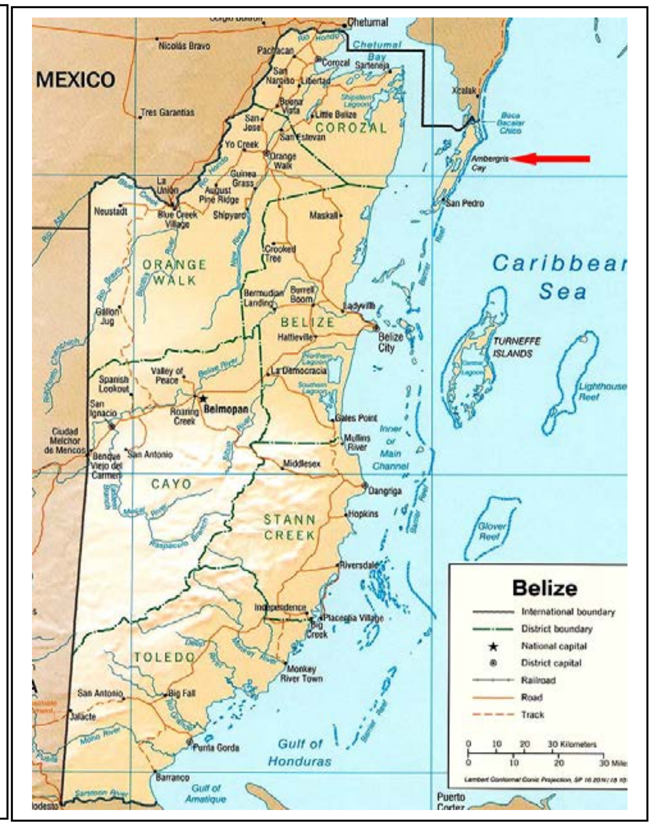


Figure 1 (a): Physical Map of Belize **Figure 1 (b): Political Map of Belize**

The inner coastal waters are shallow and are sheltered by a line of coral reefs, dotted with small coral islands or cayes, extending almost the entire length of the country. The prominent feature in the offshore marine environment is an extensive barrier reef along it's approximately 386 km of coast, which comprises the single largest portion of the Mesoamerican Barrier Reef, a system that extends for approximately 1000 km (Burke and Sugg, 2006) across several countries, and is the largest reef system in the Western Hemisphere.

There is a low coastal plain, much of it covered with mangrove swamp, but the land rises gradually towards the interior. The Maya Mountains and the Cockscomb Range form the backbone of the southern half of the country, the highest point being Doyle's Delight (1124 meters above sea level) in the Cockscomb Range. The Cayo District in the west includes the Mountain Pine Ridge, ranging from 305 to around 914 metres above sea level. The northern districts contain considerable areas of tableland. There are many rivers, some of them navigable for short distances by shallow-draught vessels. A large part of the mainland is forest.

Although the country of Belize is relatively small compared with its Central American neighbors, it boasts a wealth of natural resources in flora and fauna of at least 1,014 native species of vertebrates and 3,411 native species of plants, approximately 70.0 percent of forested land area**,** 18 major river catchments (CSO, 2004 a), and 94 protected areas covering 36 % of the country's mainland area, while the marine protected areas represent 13% of the country's total sea area (Land Information Center, LIC, 2009). In total, some 1,069,426 hectares of the country's 4,078,065 hectares or 26.2 percent of the Country's national territory is under some form of protection (Romero, 2010). The recent discovery of oil in commercial quantities has also added non-renewable sources of energy to Belize’s vast list of resources. In addition to this wealth of physical and biological resources the country is populated by a diversity of people from more than six different ethnic groups, each with unique customs, and languages.

1.3.2 Vegetative cover

The flora of Belize is highly diverse considering the small geographical area. The south contains the low mountain range of the Maya Mountains. The highest point as mentioned earlier is Doyle's Delight at 1,124 m (3,690 ft.). Figure 2 is a land cover map of Belize showing 15 land cover and land use categories around the country.

According to the most recent vegetation surveys, about sixty percent (60%) of Belize is forested, with only about twenty percent (20%) of the country's land subject to human uses (such as agricultural land and human settlements). Savanna, scrubland and wetland constitute extensive parts of the land. As a result, Belize's biodiversity is rich, both marine and terrestrial, with a host of flora and fauna. About twenty-six percent (26%) of Belize's land territory falls under some form of official protected status (Romero, 2010). Although a number of economically important minerals exist in Belize, none has been found in quantities large enough to warrant their mining. These minerals include dolomite, barite (source of barium), bauxite (source of aluminum), cassiterite (source of tin), and gold. In 1990 limestone, used in road-building, was the only mineral resource being exploited for either domestic or export use.

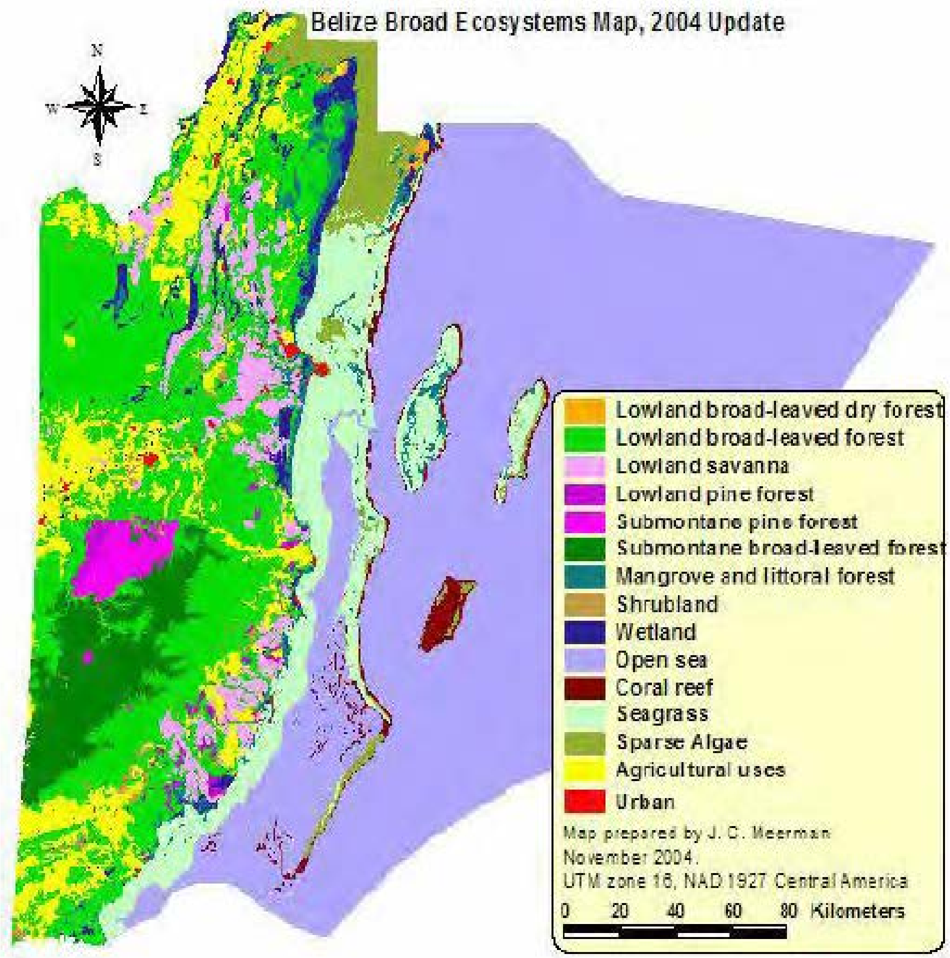


Figure 2: Land cover map of Belize (LIC, 2004)

Agriculture currently provides some 71% of the country's total foreign exchange earnings, and employs approximately 29% of the total labor force. Although about 1,998,230 acres or 38% of the total land area are considered potentially suitable for agricultural use, only perhaps 10 to 15% is in use in any one year. About half of this is under pasture, with the remainder in a variety of permanent and annual crops.

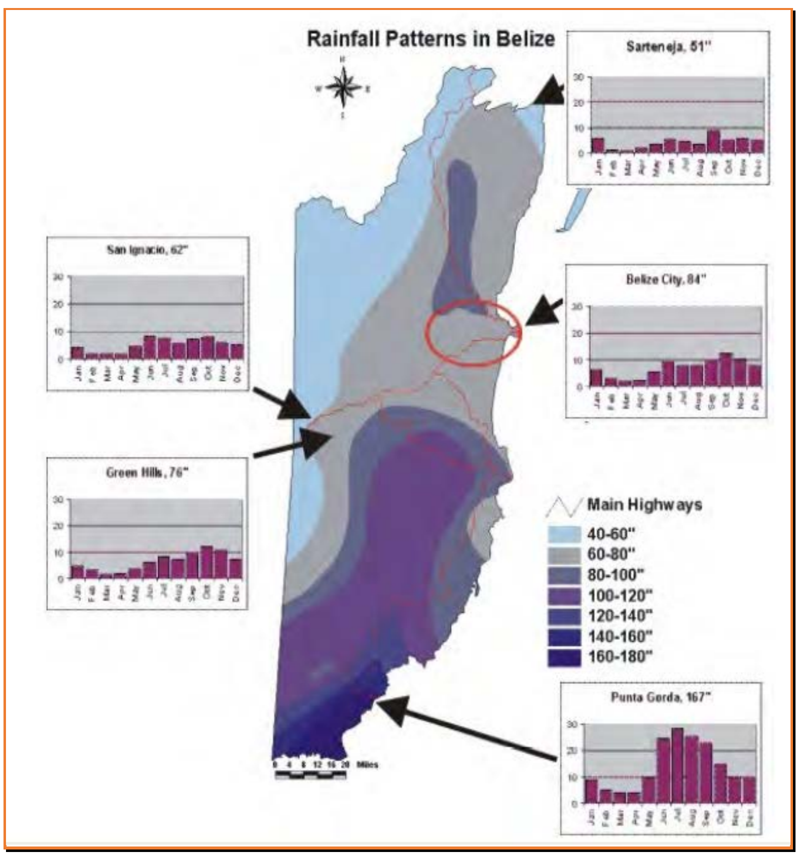
The traditional system of "milpa" (shifting cultivation) involves the annual clearing of new land for crop production; however, there are an increasing number of farmers making permanent use of cleared land by mechanical means. A tax is levied on the unimproved "value" of the land. The expansion and improvement of agriculture is one of the principal aims of national development planning. The Department of Agriculture of the Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development maintains an Extension Service with officers posted in all districts.

Agricultural research is conducted at the Central Farm Research Station into a variety of tropical crops, livestock and pasture. Agricultural research is also done by other non-governmental bodies, such as the Caribbean Agricultural Research and Development Institute (CARDI) and the

Taiwanese Mission, within the country. The Ministry provides mechanical, veterinary and quarantine services to farmers and an agricultural training college at Central Farm. Other government services include the Belize Marketing Board, which operates in the buying and selling of producers' rice from the Toledo District, and the Development Finance Corporation, which offers credit to farmers, among others.

1.3.3 Climate

The country experiences a tropical - sub-tropical climate with a pronounced wet and dry season. The rainy season from June to November and brings between 60 inches (1524 mm) of rain in the north to 160 inches (4064 mm) in the south. The dry season occurs from March to May. A cool, moist transition period extends from December to February, marked by northerly winds associated with the frequent incursions of arctic air masses from continental USA and Canada, and diffused frontal systems migrating equatorward. The cool transition period rainfall (DJF) contributes about 16% to the annual total rainfall. The night-time minimum temperature can drop to 10 C or less in the higher elevation of the Mountain Pine Ridge in extreme cold spell events (CCCCC, 2014). Figure 3 shows the historical, mean annual rainfall distribution across Belize.



Mean temperature in Belize ranges from 27 °C along the coast to 21 °C in the interior, with the coldest month being January and the warmest temperatures experienced in May.

The country is also affected by tropical cyclones and hurricanes that move westward through the Caribbean during the period June to November. On average, Belize is affected by a hurricane or tropical storm every 3 years, usually occurring between the months of September and October. The maximum probability of a tropical storm hitting somewhere along the coast of Belize is ≤ 23% annually, while the annual probability of a hurricane strike in Belize is ≤ 8% (NOAA, 2007).

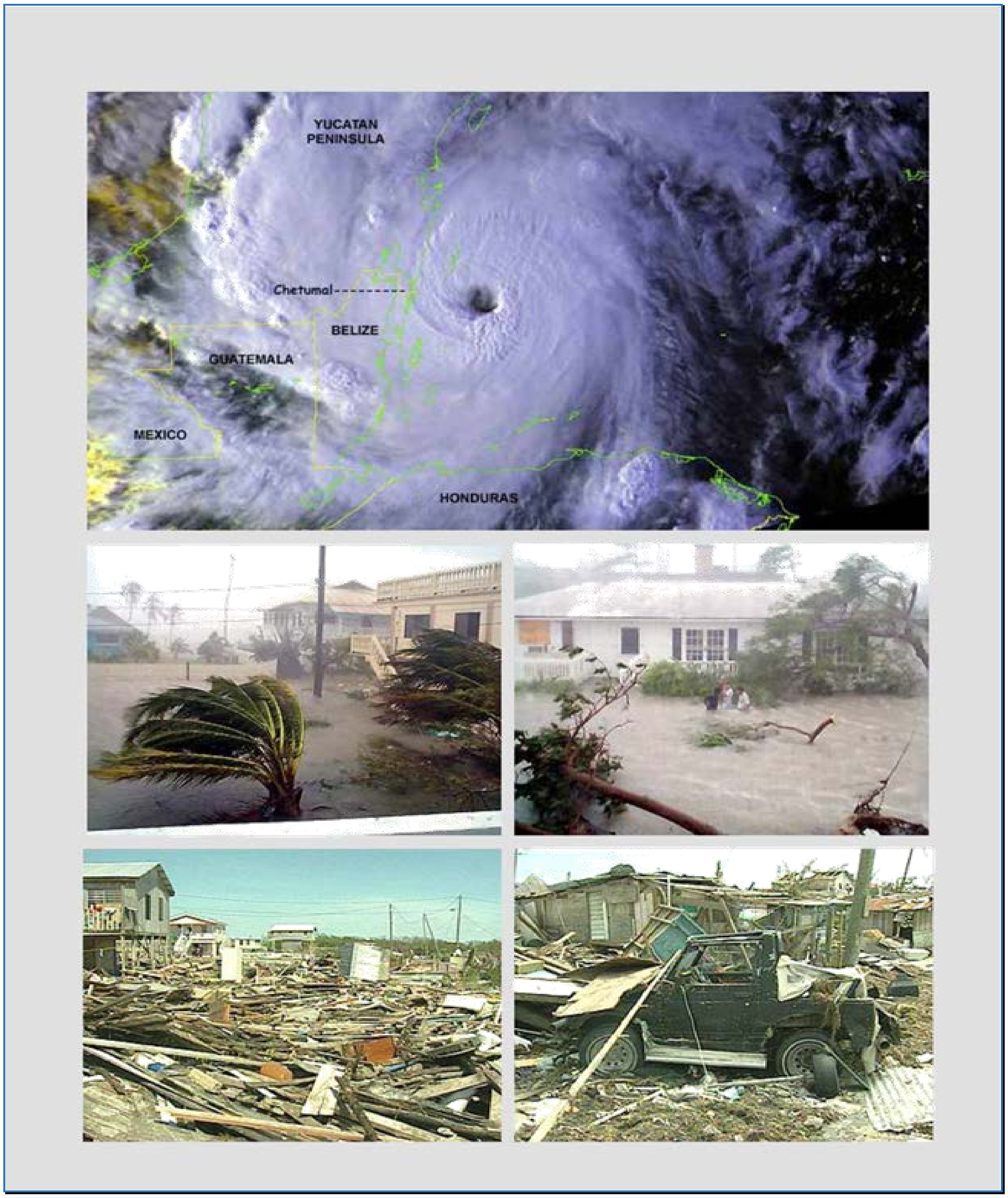


Figure 4: Hurricane Keith impacts in northern Belize in October 2000

In late October 2000, Category IV hurricane Keith underwent explosive cyclogenesis in the north-western Caribbean on its approach to Belize. Hurricane Keith severely impacted the northern cayes and coastal communities of northern Belize, with losses to infrastructures and the productive sector in the range of US $204.8 Million. Figure 4 is an illustration of hurricane Keith (October 1, 2000) and its impacts in Belize. Table 1 is a summary of the estimated losses in U.S. dollars caused by historic tropical cyclones in Belize since 2000 (NEMO, 2016).

Table 1: Estimated damage arising from land falling tropical cyclones in Belize since 2000

No.	EVENT	Date		Sector	Direct Cost	Indirect Cost	Total Damage
				Impacted	**US $**	**US $**	**US $**
1	Hurr. Keith	Oct 1, 2000		All	204,779,630	0	204,779,630
2	TS Chantal	Aug. 22, 2001		All	8,737,005	11,771,000	20,508,005
3	Hurr. Iris	Oct. 8, 2001		All	107,841,500	53,250,925	161,092,425
4	Hurr. Dean	Sep. 21, 2007		All	50,279,000	45,350,000	95,629,000
5	TS Arthur	May 31, 2008		All	42,806,908	0	42,806,908
6	TD 16	Oct. 30, 2008		All	1,390,937	0	1,390,937
7	Hurr. Richard	Oct. 24,2010		All	24,590,000	0	24,590,000
8	Hurr. Earl	Aug. 4, 2016		All	56,750,000	0	56,750,000
						Total	**607,546,905**

(Source: NEMO, 2016. Economic Losses Caused by Hurricanes and Tropical Cyclones in Belize)

1.3.4 Hydrology

Belize's hydrological profile comprises 16 major river watersheds which originate in the Maya mountains in the interior, and discharge into the Caribbean Sea. Figure 5 shows the locations of these watersheds superimposed on a digital elevation map, which includes the transboundary sections of the watersheds in neighbouring Guatemala and southern Mexico. The profile of the watersheds and sub-catchments across the country of Belize is shown in Figure 6.

The interior of Belize has a network of rivers, waterways, lagoons and swamps. Belize also has many wetlands which are mostly found in the northern and coastal areas of the country. The variety of terrestrial, marine, and freshwater ecosystems form part of the tourism attraction of Belize, but are equally important for its economic development. The ecosystems have some degree of protection through the network of protected areas, which includes 26.2% of the total national area.

Belize is rich in surface water sources as well as many groundwater aquifers found in calcareous rock and sandy aquifers in the south of the country. The main source of freshwater in rural areas is predominantly groundwater, where approximately 95% of freshwater is extracted from groundwater supplies (CDB, 2013).

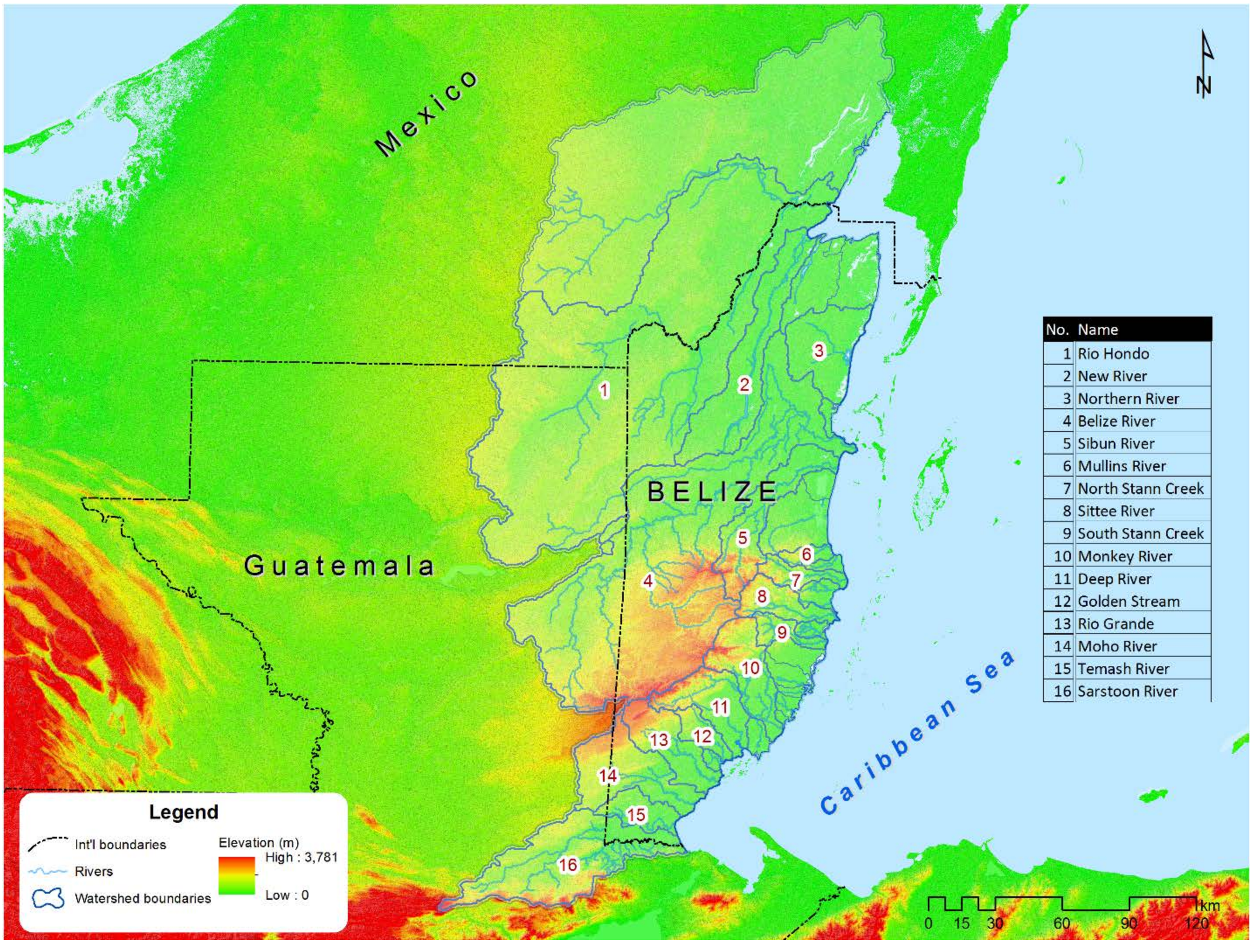


Figure 5: Major and transboundary watersheds in Belize extending into Mexico and Guatemala.

(Source: Cherrington, et. al., 2014)

1.3.4.1 Water availability per capita

The renewable internal freshwater resources per capita (cubic meters) in Belize were 43.39 thousand cubic meters in 2014, according FAO Water Resources report, published in 2015. This is down 9.64% from the 48.02 thousand cubic meters reported in 2009.

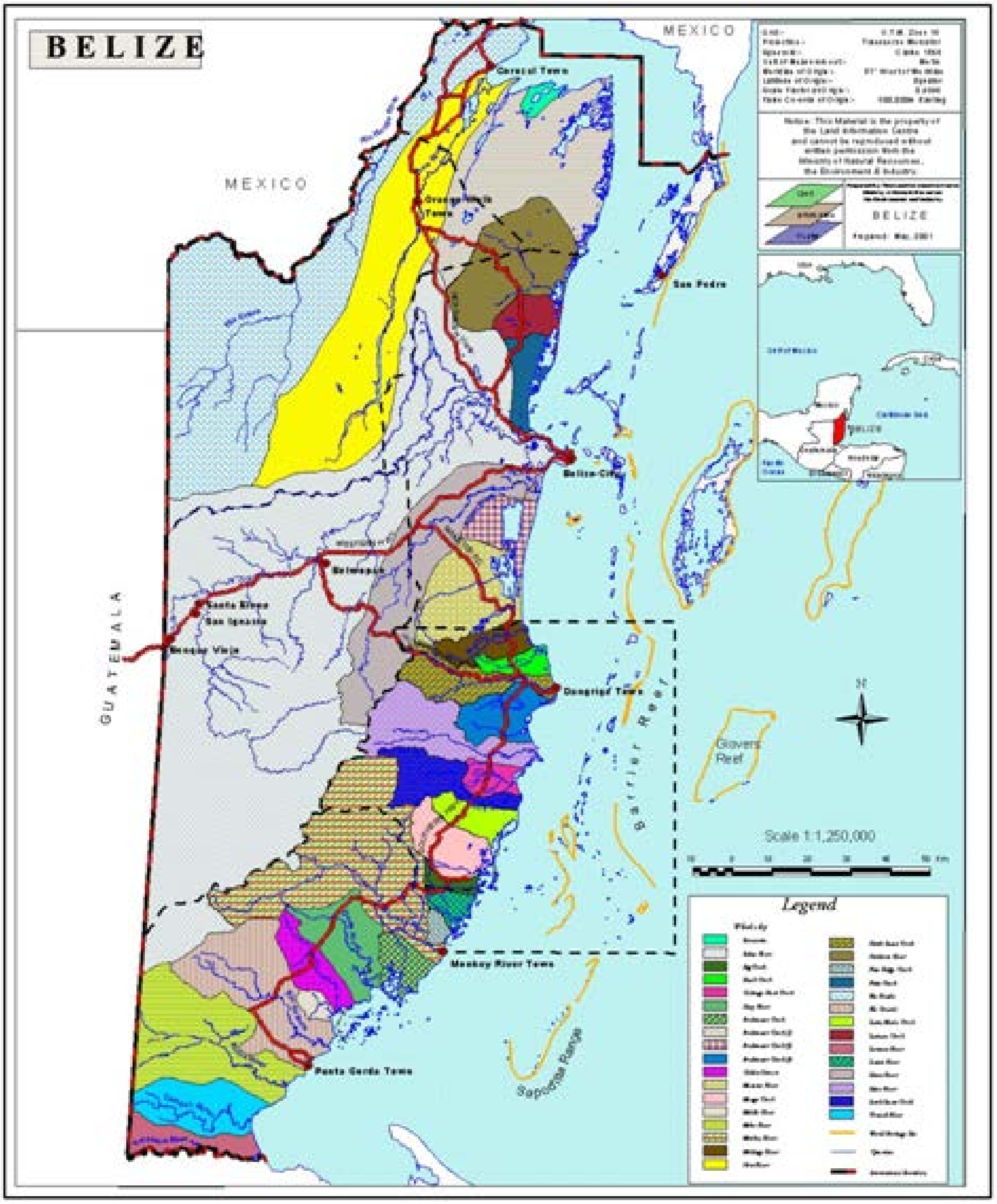


Figure 6: Major Watersheds and Roads in Belize

The total water withdrawal of 101 million m^3/yr is negligible compared to surface water resources. Groundwater as a source, supply the main towns in the Corozal, Orange Walk, Cayo and Toledo districts, and some rural communities of Toledo and Cayo districts. There is need for groundwater resources assessment to determine the current yield and sustainability. Abstraction to service rural areas is carried out by drilling a number of wells until a feasible location is found.

Water demand is rising with the expansion of the agricultural, industrial and tourism sectors, along with a growing population and watershed destruction. This calls for urgent attention be given to the proper management, use and understanding of the freshwater resource. The National Integrated Water Resource Management Policy, 2008, highlights that there is a need to conduct a proper and comprehensive assessment of water resources and develop baseline of water quality for the various uses of water. Figure 7 shows the decline in renewable internal water resources for Belize per capita between 1987 -2009.

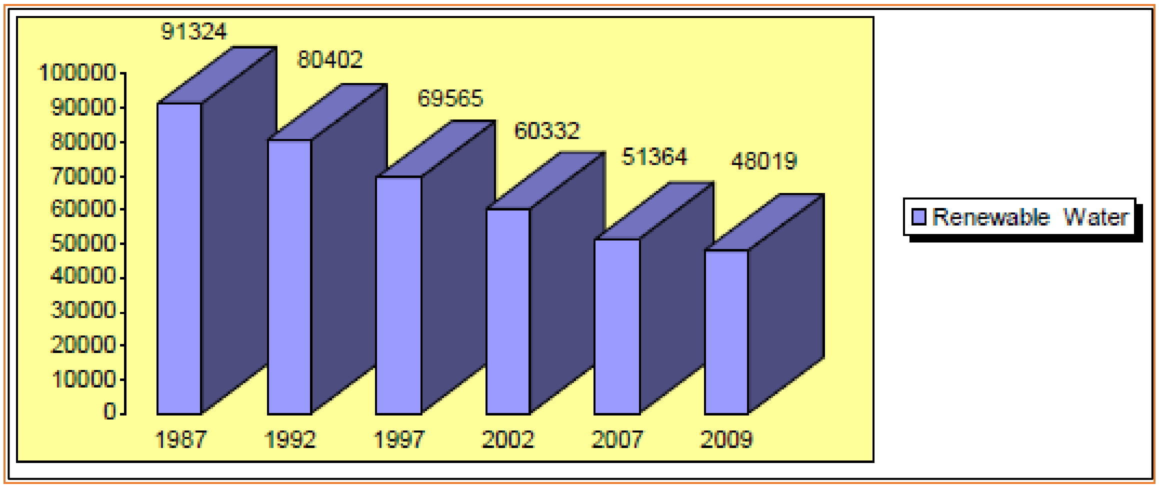


Figure 7: Renewable Internal Water Resources per Capita for Belize (cubic meters)

(Source: Aquastat, FAO, 2010, in CDB, 1013)

1.3.4.2 Water Supply and demands

In the 2014-2015 financial year, the Belize Water Services Limited (BWSL) experience an 8.2 % increase in sales volume since customers consumed 2,278 million US gallons (MUSG) of potable water when compared to 2,105 MUSG in the previous financial year (BWSL, 2015). The total water production was 2,982 million US Gallons, which represented a 7.0% increase compared to the previous year. The increased in production was attributed directly to an increase in consumption.

The BWS water supply and demands does not reflect the production and water use in most rural communities around the country.

1.3.4.3 Rural Water Systems and Water Boards

Belize has two cities, seven towns, and one hundred and ninety-three (193) villages, with ethnic diversity based on geography. The Belize Water Services Limited (BWSL) provides water for the towns and cities. Most villages have Rural Water Systems, providing limited supplies. Rural Water Systems (RWS) are managed by appointed Water Boards. Figure 8 shows a typical Rural Water System infrastructure. The Ministry of Local Government, Labor and Rural Development has the responsibility for these Boards.

Figure 8: Rural Water System infrastructure and water treatment facility

Freshwater supplies are sufficient for the current population, though there is an increased stress on these supplies due to population growth, increases in economic and agricultural activities, as well as an increase in droughts (BEST, 2009). Currently, there are four (4) municipal desalination plants operational in the country. These are located in San Pedro and Caye Caulker Towns, and in the villages of Sarteneja and Chunnox in the Corozal District of northern Belize.

1.3.4.4 Coverage and Services

Village water boards provide a 24 [illegible] to all households and businesses within their respective service areas (provided the household or business formally requests this service, and pays the connection fee). The quality of the ground water in Belize meets the Ministry of Health standards, and therefore most systems operated by village water boards provide potable drinking water to their consumers. However, many village water boards do not consistently follow WHO guidelines for treating all water with chlorine, especially in the manually operated chlorination systems.

As shown in Table 2 below, 62% of the villages and communities in Belize (119 out of 193) have a piped water supply operated by a village water board. Although most village water boards are responsible for water services in a single village, some village water boards serve more than one (1) village or community (in total, 102 village water boards serve 119 villages and communities). 28% of villages and communities (54 out of a total of 193) do not yet have a piped water supply—households in these villages use hand pumps to access ground water supply.

Table 2: Water Supply Coverage in Villages and Communities

District	Total Villages & Community	Total Water Boards	Villages and Communities Served by Water Boards	Villages Served by BWS	Total Served Villages & Communities	Total Unserved
Corozal	28	13	17	7	24	4
Orange Walk	24	18	19	1	20	4
Belize	33	4	7	5	12	21
Cayo	34	23	26	6	32	2
Stann Creek	26	22	22	0	22	4
Toledo	48	22	28	2	30	19
Total	**193**	**102**	**119**	**21**	**140**	**54**
Population (approximate)			**71,820**	**28,440**		**14,844**

(Source: Rural Development Department estimates (2013) 89,000 served by Water Boards representing 159 villages with 35 villages without a water service[2])

1.3.4.5 Projection of Climate and Land Use Change on Water in Belize

A recent study entitled "*Impact of climate and land use change on Belize's water resource*" (Cherrington, Emil; Elma Kay, and Ivanna Waight, 2015; CATHALAC/University of Belize Environmental Research Institute), attempted to determine climate and land use change impacts on the supply and demand of water in Belize. The objectives were:

- *Estimate the cumulative impacts of climate and land use change on the runoff and erosion components of the hydrological cycle in Belize's major watersheds*
- *Estimate the impacts of climate change on runoff and erosion*
- *Estimate the impacts of land use change on runoff and erosion*
- *Estimate changes in demand for human consumption*

The methodology was to conduct hydrological modeling with Non-Point Source Pollution and Erosion Tools (N-SPECT), Land Use Modeling using the Spatial Regression Modeling (IDRISI Selva), and climate modeling utilizing the IPCC AR5 Global Climate Change Models: CNRM-CM5 (France), HadGEM-2 ES (UK), MIROCS (Japan), and the NorESM1-M (Denmark). Use was made of the downscale outputs of all 4 available Representative Concentration Pathways (RCPs) for these models, using only the best and worst-case scenarios (i.e. RCP 2.6 and RCP 8.5). The target area consisted of the 16 major watersheds in Belize, including the sections outside Belize of the 5 transboundary watersheds shared with Guatemala and Mexico (See Figure 5 above). The main conclusions of the study are summarized in Table 3.

[2] Belize Water and Sanitation Strategic Sector Analysis IDB updated by the consultant, 2013

Table 3: Impacts of Climate and Land Use Change on Belize's Water Resources

Estimates of changes in demand for human consumption

- 629,225 people inhabited the project area of interest in 2010, with 48.2% (303,422 persons) inhabiting the mainland Belize segment of the area of interest (See Figure 5 & 6 above).
- For Belize, 2010 population = 303,422 and 2050 = 1.017 million
- For Belize 2010 demand against supply = 0.073% and 2050 = 0.581 % based on worst case CC and land use change scenario (RCP 8.5 NorESM1)
- By 2050, less rainfall is expected across Belize's 16 major watersheds but especially in Northern Belize
- Implications for sugar industry or potential displacement of agriculture to South
- Estimated water demand for human consumption would be 2-8.3 x current demand.
- Estimated supply would be sufficient for human consumption needs but it is imperative to quantify current demand for agriculture

- **Declining rainfall and consequent declines in water yield may in turn increase concentrations of sediments in rivers**

  Rainfall harvesting may be needed if drinking water quality is affected and since it has potential to reduce runoff from flooding

- **Overall, increased deforestation will lead to more erosion, and cause declining water quality**

  Need to decrease deforestation and increase reforestation in Belize, New River and Rio Hondo watersheds especially

- **Simulating changes in the hydrological cycle based solely on climate change scenarios but in absence of land use change, it would appear that a drier climate under stable land use would actually decrease runoff and erosion**

- **Parallel hydrological modeling simulations which take into account land use change but exclude changes in the rainfall regime indicate increases in runoff and erosion (similar to when climate change is also factored in)**

  Both of the above highlight the importance of land management
- **Approximately 53.7% of the surface area of Belize's watersheds lie outside of Belize's national territory, in Mexico and Guatemala**

  Transnational cooperation with national and municipal governments is needed to address high deforestation especially in Guatemala's portion of Belize River watershed
- **Scope of the present study is limited**

  Need to start looking at level of watersheds; quantifying impacts by sector e.g. agriculture, energy etc., assessment of groundwater resources and climate and land use impacts on these.

(Source: Cherrington, et al., 2015)

1.3.5 Irrigation and Drainage

Belize has two (2) major agro-climatic zones. The northern zone is relatively flat, with considerable areas of swampland on the coastal plain. Its average annual rainfall is about 60 inches or 1,524 mm, and its calcareous soils are suitable for cultivation of a wide variety of crops. These soils may, however, change abruptly to acidic soils in certain areas. The southern zone encompasses the central Maya Mountain and a flat to undulating coastal belt, which narrows in sections of eastern Stann Creek District.

The siliceous soils of the Maya Mountain are not suited for agriculture. The high level of soil acidity and poor drainage conditions constitute important constraints to crop production. In total, only 16% of the land is suitable for sustained agricultural production without skilled management. Two (2) main farming systems can be distinguished: Milpa and commercial farming. Both are rain fed dependent. Milpa farming is based on slash-and-burn accommodate small farming practices, but the practice is now confined mostly to the southern Districts. It is the basic system used to produce food for domestic consumption: corn, grown during the wet season, and a variety of other crops (including black beans, vegetables, root crops and plantains). Commercial farming includes export crops such as sugar cane, oranges, grapefruit, banana, cocoa, rice and other grains such as black and pinto beans.

Irrigation in Belize has been marginal because of its climatic and social conditions. Irrigation and drainage information is sparse or non-existent. P existent and only a few private irrigation systems were developed in the 1990s, where surface and sprinkler irrigation is being used for citrus and banana production, surface or flood irrigation for rice and micro-irrigation for papaya production, and drip irrigation for small plots under Crop Cover Structures and open fields of less than five acres for onion cultivation, mostly. It is expected that in the coming years more banana plantations will be irrigated, so that the estimated water withdrawal may be in the order of 240,000 m^3/yr (CDB, 2013; Irrigation Officer, MOA, personal comm. 2016).

1.4 Population Profile

The population estimate according to the Statistical Institute of Belize (SIB) revealed that there were approximately 358,899 persons living within the borders of the country of Belize by mid-2014, with an annual growth rate of around 2.56%. If this growth rate is maintained the population should double in the next forty years. The SIB indicates that this growth rate will be accompanied by a decreasing infant mortality rate and increasing life expectancy. Consequently, the population will be larger and older, with greater demands for food and nutrition. Hence, the growth rate of the agriculture sector must correspond or exceed the rate of population growth, if Belize should remain food secured and productive.

1.5 The Economy

Belize is described as having an economy that is dependent on its natural resources. The economy is diversified with various primary, secondary and tertiary industries contributing to economic development. The value of the country’s Gross Domestic Product (GDP) for 2013 was BZ $2,635.6

Million Dollars (Statistical Institute of Belize, 2014). The primary industries which include agriculture and forestry (10.15%), fishing (3.08%) and mining and quarrying (0.46%) account for the smallest contribution at 13.70% and a total of BZ $381 million dollars. Secondary industries such as Manufacturing (9.90%), construction (2.81%)and electricity and water supply (3.33%) are the second highest income earners; contributing to 16.03% of the GDP with a total of BZ $407.2 Million Dollars. Tertiary industries, which include the tourism and services sector, contributed 60.29% of the GDP and a total of BZ $1,589.1 Million dollars in 2013. This includes wholesale and retail trade and repairs (15.36%), hotels and restaurants (4.72%), transport and communications (11.01%), financial intermediation (6.65%), real estate (10.15%) and community services (4.72%) inter alia.

Belize's GDP has been growing steadily at an average of 4% per year for the past two (2) decades. Future increases in GDP are predicted to result from further diversification of the Belizean economy, which includes the expansion of the tourism, agriculture and oil industries. Specifically, the oil industry had given the economy a boost in 2005/06. Studies have shown a high probability for the existence of more oil deposits, which if located and exploited, could lead to a shift in the economic base of Belize over a relatively short time span. Energy production in Belize comes from sources such as wood (6.13%), petroleum gas (2.77%), hydro (7%), biomass (15.47%) and crude oil (68.63%) (Tillet, 2012). One company, Belize Natural Energy (BNE) is the only agency currently producing oil at about 3,000 barrels a day, with an estimated 20 million barrels of recoverable oil reserves.

The tourism industry is the largest contributing sector to the GDP in Belize. The sector is considered to be the largest earner of foreign exchange and is very important for the sustained wealth of the country. The sector itself was said to contribute to BZD $432.5 million (13.5% of GDP) to the GDP in 2013 and approximately BZD $450.3 million in 2014, rising by 4.1% (GOB, 2015).

1.6 The National Climate Change Office (NCCO)

Belize is one of the many countries that are vulnerable to Climate Change. The Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development is the government agency responsible for climate change. A National Climate Changed Office (NCCO) has been established within this Ministry with the main task of coordinating the country’s climate change program on behalf of the government of Belize. The NCCO is supported by the National Climate Change Committee (BNCCC) which is comprised of eleven members from various government Ministries, non-government organizations and members of the private sector.

1.7 Belize’s Vulnerability to climate change

1.7.1 Vulnerabilities assessment for the Third National Communication (TNC/2015)

The TNC has expanded on the studies and assessments of Climate Change related issues presented in Belize’s Initial National Communications (INC) and Second National Communications (SNC). The TNC highlights the results of the work done to strengthen Belize’s technical and institutional capacity through project implementation in an effort to streamline climate change activities in national development planning. Priority sectors where detailed assessments of climate change impacts and adaptation measures can be instituted included: coastal development, water, agriculture, tourism, human health and fisheries.

The vulnerability assessment was facilitated with regional downscaled Climate Change scenario data (Hadley Centre RCM PRECIS-Echam4, Echam5, & HADCM3). Climate variables included: air temperature, rainfall, solar radiation and evaporation for the period 1961 to 2100 (GOB, 2015). A multi-sectoral team of Consultants analysed the scenarios, and provided an assessment of possible impacts of Climate Change on the natural and human resources of Belize based on projected changes in regional and global climate.

The vulnerability assessment conducted for the TNC indicated that the Agriculture sector will face major challenges connected with climate change by 2050 and beyond. Yields of major crops such as rice, bananas, citrus, beans and sugar cane are expected to decrease because of increased variability of rainfall and increasing surface temperatures. Fisheries and aquaculture industries have also been identified as vulnerable to the impacts of climate change. These impacts will likely be due to habitat degradation and destruction related to heightened storm surge and wave action, increased sea surface temperature, ocean acidification and coral bleaching.

Tourism and the water sector have been identified as highly vulnerable to climate change. It is estimated that Coral Reef-based activities attract more than 80 per cent of foreign tourists to Belize. Ocean acidification and sea level rise is projected to result in further coral dieback, loss of beaches, and damage to coastal property and public infrastructure which directly or indirectly downgrade the country’s tourism product. Freshwater resource is threatened due to increased rainfall variability and instances of saline intrusion into groundwater aquifers, and migration of the saltwater lens farther upriver and into coastal lagoons. This poses a threat to the tourism industry as it is highly water intensive and is the largest consumer of the municipal water supply.

Belize’s Health sector is under threat of increasing vector borne diseases such as malaria and dengue hemorrhagic fever, higher level of air pollution and water borne diseases associated with extreme climate and environmental variability resulting from climate change. Higher incidents of viral and water borne diseases are expected to further burden an already challenged health sector.

The findings in the TNC were critical to inform policies, strategies and actions contained in the National Climate Change Policy, Strategy and Action Plan (NCCPSAP). The outputs of the National Communication are now linked to the decision-making process and development planning and the national and sectoral levels.

The vulnerability and adaptation (V & A) component of the Third National Communication aimed to support more detailed assessments, than for the SNC, within priority development sectors, namely coastal development, water, agriculture, tourism, human health and fisheries. These new assessments were analysed with increasing accuracy using scenarios, such as those of ECHAM5 and HadCM311 with assistance from Cuba’s Institute of Meteorology (INSMET) via the CCCCC and the Climate Research Unit CRU from the Universities of East Anglia and Oxford, UK, to support informed decisions on adaptation action by policy-makers, business, resource managers and the community at large.

1.7.2 Expected Climate Change Impacts on Vulnerable Sectors

Belize's vulnerability to climate change is attributed to its coastal community and development characteristics. A large proportion of the population resides in the coastal zone which is mainly at sea level, and important development activities including agriculture and tourism are conducted in the coastal zone. Changes in average temperatures, rainfall, and sea level rise will affect the coastal zone. According to Belize's Third National Communication to the UNFCCC, the average annual temperature is projected to increase between 0.4° C and 1.7° C by the 2030s depending on which climate change scenario (B1, A2, or A1B) is used in the models (GOB, 2015). Using the same scenarios, the average annual temperature is projected to increase by 0.8 °C to 2.9 °C by the 2060s, and by the 2090s, is expected to increase between by 1.3 °C to 4.6 °C (GOB, 2015).

Global Climate Model projections for mean annual rainfall determine that rainfall levels will decrease towards the 2090s. Rainfall is projected to decrease between one and twenty-six percent over the period. Using the same emissions scenarios as for temperature and rainfall, it is projected that there will be an increase in sea level ranging between 0.18 m to 0.56 m by 2090.

1.7.3 Climate Change and Sea Level Rise Impacts in the Coastal Zone

The vulnerability and adaptation assessments conducted for the TNC revealed that climate change and climate-driven sea level rise and storm surges will have impacts on coastal ecosystems and economic activities in the coastal zone of Belize (Singh et al, 2014). Belize's coastal ecosystems and rich biodiversity will be affected by global climate change. Delicate marine ecosystems such as sea grass beds, mangroves and coral reefs are directly dependent on climatic conditions for distribution, function and growth. Change in climatic conditions can lead to degradation of these already threatened ecosystems (Clarke et al. 2013).

Climate driven sea level rise is expected to have far-reaching consequences on the coastal zone of Belize because of the diverse coastal assets found in this region. These include the major settlements, such as Belize City, San Pedro, Dangriga, Placencia and Punta Gorda that represents close to one half of the population. Flooding events would cause damage to human settlements, infrastructure, mangroves ecosystems that stabilize the coast, purifies runoff water and serve as invaluable habitats for various flora and fauna, and agricultural land and crops.

Other sectors that will be vulnerable to future climate change and sea level rise and storm surges, via direct and indirect impacts are fisheries, tourism and agriculture (Singh et al, 2014). For instance, several coastal areas of Belize, such as Monkey River in Toledo District, are experiencing severe problems of coastal erosion and loss of beaches that is critical for the Tourism sector (Galen, University Applied Research and Development Institute, 2007; CARIBSAVE, 2012). Coastal communities that depend on fishing and agriculture would also be at risk to climate change, sea level rise and storm surges (Singh et al., 2014).

Adaptation options that may warrant immediate short-term consideration include:

1. The formulation and implementation of land-use planning policies to address people and settlements and agricultural lands at risk to inundation deriving from sea level rise and storm surges;
2. Strengthening of sea and river defenses in accordance with sea level rise and storm surges in vulnerable areas;
3. Further implementation of early warning systems in the event of storm surge;
4. The building of more shelters on higher ground either near the coast or inland to house people in the event of inundation due to storm surges;

Longer-term policy changes and adaptation measures to address sea level rise and storm surges include:

1. Adopt more proactive adaptation measures such as the use of building set-backs legislation to limit buildings and other major developmental work on the coast and encourage gradual retreat to higher grounds by making land available in the interior, in an effort to decentralize economic activities and settlement on the coast;
2. Undertake detailed surveys to identify most vulnerable areas along the coast, such as Belize City, San Pedro, Dangriga, Placencia and Punta Gorda, and determine appropriate adaptation strategies;
3. Also undertake evaluation of agricultural lands, coastal aquifers and drainage and irrigation systems (Singh et al, 2014).

However, these adaptation response strategies should also be integrated with economic development policies, disaster mitigation and management plans and integrated coastal zone management plans.

1.7.4 Water Sector

Water supply in Belize comes from underground water, surface water (rivers, lakes and lagoons) and desalinisation of seawater (Ambergris Caye and Caye Caulker). No assessment of the groundwater resources has been carried out, so the knowledge of groundwater quantity and quality is limited (CCCCC, 2008; CCCCC, 2009).

The economic effects of climate variability and extremes on water and agriculture are already noticeable as seen in recent incidents of flooding and drought (Belize Enterprise for Sustainable Technology (BEST: 2008, 2009). Decreasing rainfall amounts and increased variability of rainfall will make it more difficult to plan for agricultural production.

Belize has a stream of three hydropower sites on the Macal River, namely: the Chalillo dam and reservoir which impounds 120 million cubic meters of live storage water and generates 7.3 MW, the Mollejon run-of-river dam and reservoir which supply the nation with 25.2 MW, and the Vaca run-of-river similar to Mollejon in operation, which produces 18 MW of hydroelectricity BECOL, 2010. There is also a small-scale run-of-river hydroelectric plant on the Rio Grande (southern Belize) operated by Hydro Maya Limited, which generates 3.2 MW to the national grid (Tillett, *et al.*, 2012). In 2010, hydropower was contributing approximately 25.8% of primary fuel input into the electricity supply of Belize. (Tillett, *et al.*, 2012). Any significant change in the hydrological cycle will affect hydropower facilities and will threaten the reliability and security of Belize's electric supply. This will cause hydroelectric dams to be less efficient leading to higher costs of electricity as the country becomes increasingly reliant on fossil fuels (Belize Enterprise for Sustainable Technology (BEST, 2009).

Recommended adaptation measures for Belize's water resources include promotion of effective and efficient use of water, establish an agency for water resources management, strengthen the existing human resources in the sector for improved management and increase public awareness and education on water vulnerability and climate change.

1.7.5 Agriculture Sector

1.7.5.1 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 (CCCCC, 2014). 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 4: DSSAT3 Resultant Mean Crop Yields for Corn and Bean in a Warmer Climate

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

(Projection of crop yields for 2 °C increase in temperature and ±20% change in rainfall: for corn ─ average for 30 seasons; for rice ─ average for 10 seasons. Source: Frutos and Tzul, 1995).

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 (Frutos and Tzul, 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 4 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% change in rainfall, to -14% for a change of +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 decreased 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/ USAID, 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.

The choice of crops studied for the vulnerability and capacity assessment of the Third National Communications (TNC) was based on the availability of data. Two cash crops and one important small farmer crop were initially considered in this vulnerability assessment, these being sugarcane, and papayas. Cacao was also considered as this is a small farmer crop grown in southern Belize. However, it was determined that agronomic and meteorological data for papayas and cacao did not cover a sufficiently long period of time for use in the models, so it was decided that sugarcane and citrus, (with longer histories of cultivation in Belize), would be the focus crops for the assessment.

The exercise evaluated, under various climate change scenarios, the expected climate change impacts in the Agricultural sector as it pertains to changes in yields for Sugarcane and Citrus.

The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season. However, it did affect the yield, especially when there were periods of low or high rainfall. With respect to season length it can be concluded that the days for the sugar cane to become mature is shortened.

Another computer model, Crop Wat, was used to simulate the yields of citrus using the average climate data from Melinda Forest Station for control. The model predicted that there are no yield changes in the different scenarios indicating that citrus will not be impacted much. The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season. However, similar to the scenario for sugarcane, it affected the yield during periods of low or high rainfall.

The agriculture sector is key to ensure food security for Belize. Appropriate and timely response measures to the impacts of climate change must be adopted to ensure the sustainability of the sugar and citrus subsector and the overall Agricultural sector. It is recommended that progressive adaptation of cultivars to the new environmental conditions be applied for banana, rice, beans, corn, and vegetables, either through natural or human-induced processes. Varieties could be selected or genetic improvement could be utilized for both sugarcane and citrus. The varieties for sugarcane should be selected to take advantage of the projected increased temperatures. Better management practices for sugarcane will include better drainage infrastructure, and improved harvesting practices to deal with the increased precipitation. Citrus will also require improved drainage, new cultivars with higher resistance to *anaerobiosis*, modified planting dates, and fertilizer applications to compensate for loss of nitrogen due to excess soil water. Improved irrigation with fertigation, and ventilated tropical greenhouse (crop cover structures) will also have to be made available to more farmers for periods of extended drought.

1.7.6 Fisheries Sector

The effect of climate change and sea level rise on the fisheries sector of Belize will be mostly indirect. Fisheries require healthy habitats to survive and reproduce. Essential fisheries habitats in Belize include all types of aquatic habitats, namely wetlands, coral reefs and sea grasses where fish spawn, breed, feed, or grow to maturity (figure 56). Rising sea levels could lead to partial or complete disappearance of these habitats through inundation. On the other hand, rising near-surface water temperature and increasing acidification will continue to cause massive bleaching and dieback of corals.

As reported by Richardson in the Human Development Issues Paper, the IPCC (1997) noted that the reefs of the Caribbean Sea already live near their thresholds of temperature tolerance; thus, *higher sea surface temperatures impair reproductive functions and growth capacity and lead to increased mortality* (Richardson, 2009). With species such as mangroves and corals already stressed from anthropogenic activities, climate change would exacerbate these stresses. As an example, coral bleaching is expected to worsen as a result of climate increase. Ocean acidification is another way in which coral species can be negatively impacted.

1.7.6.1 Recommended Adaptation Measures

The implementation of an appropriate fisheries management policy as a measure to promote reef ecosystem resilience and fisheries sustainability appears to be a sound strategy for Belize.

Adaptive responses to climate change in fisheries could include (Grafton, 2010):

- Management approaches and policies that further strengthen the resource base, recognizing and responding to new opportunities brought about by climate change;
- Monitoring biophysical, social and economic indicators linked to management and policy responses and adoption of multi-sector adaptive strategies to minimize negative impacts such as instituting Government regulations on fishing seasons.

1.7.7 Climate Change and Tourism

A changing climate, along with sea level rise, would result in loss of beaches, properties and public infrastructure and will make Belize less attractive as a tourist destination. The loss of beaches and coastline due to erosion, inundation and coastal flooding and loss of tourism infrastructure, natural and cultural heritage would reduce the amenity value for coastal users (IPCC, 2007; 2013). Belize's tourism sector is largely nature-based and is therefore highly vulnerable to climate change

(Richardson, 2009). Sea level rise pose risks such as flooding, inundation, saltwater intrusion and erosion; threatening water supplies, properties, and coastal areas. Two of Belize's major tourist attractions are the barrier reef and the coastal areas, including the cayes. Richardson determined that the cost of inaction in addressing the vulnerabilities of the tourism would have major negative economic impact. Projected climate change effects on Belize would result in reduced tourism demand, loss of facilities from sea level rise, loss of beaches, and loss of ecosystems (Richardson, 2009). The economic impact of the Belize tourism sector due to the impacts of climate change was estimated at BZ $11 million, by 2025, BZ $27 million by 2050, BZ $43.2 by 2075, and BZ $59.3 by 2100 (Richardson, 2009).

Like many other low-lying coastal nations, Belize is vulnerable to the effects of climate change. Its geographical location leaves the country exposed to the risk of rising sea levels and increasing frequency and intensity of tropical storms. In 2013, the United Nations Intergovernmental Panel on Climate Change (IPCC) issued an assessment based on a consensus of international researchers that stated global sea levels would likely rise from 1 to 3 feet by the end of the century. The third and final economic sector considered in the Vulnerability Assessments is tourism which, for Belize, is vulnerable because of its dependence on natural resources such as coastal beaches, coral reefs, wildlife and forests. Coastal tourism faces particular risks from erosion and flooding, sea level increases, salinization and the threats to physical property. Warmer seawater threatens the coral reefs which attract thousands of tourists for snorkeling and scuba diving activities.

Also, warmer sea surface temperatures are associated with increasing frequency and intensity of tropical cyclones or hurricanes, which threaten coastal settlements and infrastructure. Tourism researchers have projected that climate change may reduce the appeal of tropical destinations because of heat stress, beach erosion, decline in reef quality and increased health risks. The economic impact of climate change for the tourism sector in Belize is estimated $48.3 million Belize and includes the effects of reduced tourism demand, lost facilities from sea level rise, loss of beaches from coastal erosion and loss of reef-based ecotourism. Belize's cayes are prime tourist destinations, accounting for 70% of visitation and 80% undertaking reef-based activities (Richardson, 2009). Therefore, negative impacts of climate on these prime destinations can be devastating from an economic view.

It is reported by the World Tourism Organization and UNEP that the impending changing climate will have both direct and indirect impacts on tourism. These include a shift in attractive climatic conditions for tourism; shifts in the length and quality of suitable tourism seasons (i.e., sun-and-sea or ski holidays); change in seasonal operating costs, such as heating, irrigation and water supply and annual insurance costs; and weather extremes. Weather extremes due to climate change can result in increase in the number of hot days over nearly all land areas, greater tropical storm intensity and peak winds, more intense precipitation events, and longer and more severe droughts. These types of changes will affect the tourism industry through increased infrastructure damage, additional emergency preparedness requirements, higher operating expenses, and business interruptions (UNWTO, 2008).

1.7.7.1 Recommendations for Adaptation to Climate Change in the Tourism Sector

Recommendations for the sector are as follows:

- Proper erection of seawalls around critical areas.
- Introduce adaptation planning which incorporates the expansion and diversification of tourism activities.
- Install soft defenses such as the planting of mangroves.

The Government of Belize should, therefore, urgently pursue finances from the UNFCCC Adaptation Fund to revitalize and upgrade its coastal protection infrastructures, including drainage and irrigation, since these measures will go a long way to promote adaptation in other key sectors such as agriculture, water resources and tourism, and even peoples, settlements and human health and well-being.

1.7.8 Climate Change Impacts on Health

In view of that fact that climate has a significant influence on human health and well-being, climate change may very well further strengthen this relationship. Vector-borne diseases such as dengue and malaria, respiratory diseases such as asthma and water-borne diseases such as cholera and dysentery may become more acute and prevalent in the future with climate change. Important determinants of vector-borne disease transmission include: vector survival and reproduction; the vector's biting rate and the pathogen's incubation rate within the vector organism. Vectors, pathogens and hosts each survive and reproduce within a range of optimal climatic conditions: temperature and precipitation are the most important, while sea level elevation, wind, and daylight duration are also important (Lindsay and Birley, 1996; Martens, 1996).

Belize, under the direction of the Ministry of Health, prepared the Belize Health Sector Strategic Plan (HSSP) 2014 – 2024. The HSSP was developed with the collaboration of social partners and stakeholders, including but not limited to Government Ministries, Professional Organizations, United Nations Agencies, NGOs and the private sector, and the Pan American Health Organization (PAHO/WHO) which provided resources for the development of the Health Sector Strategic Plan.

The HSSP reiterated that since half of Belize's population lives in coastal areas, the vulnerability to natural disasters is extremely high. In addition to the recent hurricanes impacting Belize, a major threat continues to be flooding due to heavy rainfall, which increases the risk for infectious diseases, thus impacting negatively on social life and affecting the country's productive sector.

Furthermore, Belize's Second National Communication Report included a risk based hazard assessment of the vulnerability and adaptation to dengue and dengue hemorrhagic fever. While it was not possible to use modeling in this assessment, it was determined that There is a strong correlation between dengue seasonal variation and monthly average rainfall. The temperature, humidity, rainfall, and altitude above sea level in Belize are within the values, conducive to the sustainable transmission of dengue. Taking into consideration the status of the environmental, biological and socioeconomic factors in Belize, and also the present adaptation capacity, the country has been categorized as having a "medium level vulnerability". Following the risk management process, risk scenarios were developed depicting ways in which dengue (the hazard) could affect different sectors of society, in order to identify dengue risk events. Using standardized Direct Impact Rating tables, Frequency/Probability Rating tables and the Risk Assessment Matrix table, each dengue risk event was ranked as follows:

- Increased cost of health care delivery- extreme risk
- Increased cost of outbreak control- extreme risk
- Work absenteeism- high risk
- Personal income loss- high risk
- Reduced national production- moderate risk
- School absenteeism- moderate risk
- Cancelled tourist visits- moderate risk

1.7.9 Conclusions and Recommendations

The results of the National Communications have now become extremely important to inform national policies and strategies to adapt to climate change, and reduce Belize's carbon emissions. The agriculture, tourism, water, health and energy sectors are highly vulnerable to the impacts of climate change. The National Climate Change Office in the Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development is now the national lead agency on Climate Change, with a mandate to address the cross-sectoral challenges of climate change adaptation and mitigation efforts, and coordinate and manage the national response to the impacts of climate change. The National Climate Change Policy, Strategy and Action Plan is an important policy mechanism to enable the country of Belize to effectively respond to the challenges of current and future climate change for the sustainable development of Belize and the safety of its people.

1.8 Process and Results of Sector Selection and Technologies

Technology requirements can change with changes in policy, development objectives and changes in the technologies themselves (UNDP, 2010). It should therefore be cautioned that the technology needs identified may only have a limited timeframe of application. Any choice of technology should at least satisfy a set of basic requirements and criteria which are determined at the national level, including consideration of sustainable development criteria. However, as a general requirement the following criteria should be taken into account:

- Longevity of the technology;
- Technical support requirements of the technology at the time of availability;
- Cost;
- Social acceptance/environmental impact;
- Contribution to sustainable development objectives as identified.

Identified links among and across the sectors can also aid in maximizing technology choices and are illustrated in the Table 5 below. As can be observed, the matrix (Table 5) attempts to illustrate the possible synergy and inter-linkages among sectors. The table should be read across only to avoid confusion among the relationships between the sectors. The purpose of the table is to aid in prioritizing technologies that can have multiple or collateral benefits in other sectors. It should be noted that the identified inter-linkages are based on the possible applicable technologies only.

Table 5: Inter-sectoral Linkages and Synergies

SECTOR	Energy	Road Transport	Forestry & Terrestrial Ecosystems	Coastal Ecosystems	Water Resources	Agriculture & Aquaculture	Human Settlements	Human Health	Tourism
Energy		√				√	√		√
Road Transport	√							√	
Forestry & Terrestrial Ecosystems				√	√	√			√
Coastal Ecosystems			√		√	√	√		√
Water Resources			√	√		√		√	√
Agriculture & Aquaculture	√		√	√	√			√	√
Human Settlements	√			√				√	√
Human Health		√			√	√			√
Tourism	√		√	√	√	√	√	√	

The process to prioritize the sectors and technologies was formally started on the first day of the TNA Inception Mission to Belize, 23rd March 2015. However, on 19th March 2015, the National Climate Change office had initiated discussions with key government stakeholders on the matter of priority sectors. The Inception Mission then marked the official start of the Phase II project in Belize, with one of the first tasks being to introduce the project to national stakeholders. During the first day of the Inception Mission, one of the presentations evolved into general discussions related to prioritization of sectors and technologies. This produced the preliminary prioritization of the sectors and technologies.

The sectors chosen for mitigation were: energy, transport, agriculture and land use, land use change and forestry. For adaptation, participants decided that it was important for the mission to consider water, coastal and marine ecosystems, human settlements, human health, agriculture, tourism, forestry and terrestrial ecosystems for this phase. Sectors chosen by stakeholders for Mitigation and Adaptation were based primarily from Country-driven priority sectors that required the vulnerability studies for the three National Communications.

The next event which occurred under the project was the National Inception Workshop held on 23rd June at the Best Western Biltmore Plaza Hotel in Belize City. The purpose of this meeting was the verification of the sectors selected for mitigation and adaptation technologies, and the updating of the Work Plan. The output of that meeting was selection of the Mitigation sectors, namely: Land Use, Land Use Change and Forestry; Transport; and Energy for technological interventions.

The Adaptation sectors were still fairly broad with recommendations made for water, coastal and marine ecosystems, human settlements, human health, agriculture, tourism, forestry and terrestrial ecosystems to be addressed during this phase. During a follow-up consultation meeting with the Assistant National Coordinator at the National Climate Change Office (NCCO), the adaptation sectors were narrowed down to the Water sector, Agriculture and Coastal and Marine Ecosystems sectors. These sectors were chosen based on the adaptation priorities of the country as stated in various policy documents and recommendations from Vulnerability Studies for Belize's Second and Third National Communications to the UNFCCC.

The national consultants were tasked with developing a minimum of three factsheets for each of the sectors identified by the national stakeholders in the Inception Mission. These factsheets would provide information on viable technologies that could later be prioritized and implemented locally in sectors such as Energy, Transport, Agriculture, Water, Coastal and Marine Ecosystems, and Land Use Change and Forestry. Twenty-five (25) factsheets were submitted by the National TNA Consultant on September 28th, 2015.

Technologies initially recommended for the various sectors included the following:

- Energy: Advanced Bio-hydrocarbon Fuels, Bio-methane CNG Hybrid Fuel, Improving Private Vehicle Operating Standards, Solar PV
- Land Use Change and Forestry: Agro-forestry, Cropland Management, Land Claim, Forest User groups, Wetland Restoration.
- Transport: Intelligent transport systems, Non-Motorized Transport, Transport and its infrastructure
- Water: Water reclamation and reuse, Desalination, Water-efficient fixtures and appliances, water safety plans
- Coastal and Marine ecosystems: Beach Nourishment, Land claim, coastal setbacks.
- Agriculture: Agro-forestry, Crop Diversification and New Varieties, Index-based climate insurance.

For each factsheet, the Assistant National TNA Coordinator carried out a detailed review. The fact sheet for forest "user groups" was recommended for exclusion since "user groups" are not considered to be "technologies". Some other factsheets were excluded from the list because the documents were not of sufficient quality to be presented to stakeholders. A total of 20 fact sheets were determined to be feasible for consideration by stakeholders at the technology working group meeting where 8 to 10 factsheets were to be chosen for further analysis.

Invitations requesting the participation of sector stakeholders in technology working group meetings were sent out on September 28th, 2015. Their participation was requested for the first technology working group meeting to be held on October 6th, 2015. Twenty-six (26) stakeholders from various public and private organizations were appointed to the working groups for the various sectors.

In preparation for the working group session, stakeholders were provided with the factsheets on October 1st, 2015, for their review and comments. The detailed instructions given to stakeholders were as follows:

- Review the content of the factsheets (Background notes, implementation barriers, reduction in emissions, impact on country priorities, cost, lifetime, etc.).
- Provide critical feedback about the feasibility of the technologies for implementation in Belize.
- Suggest other technologies that should be considered within the sector.

Stakeholders were asked to provide comments and feedback which should be presented at the technology working group session.

The working group session was held at the George Price Centre in Belmopan, on 6th October 2015. The main output of that workshop was a revised list of Fact Sheets that would be further analyzed and prioritized at a follow-up workshop by a broader group of stakeholders.

Additionally, the Working Group session was considered a pre-screening for the Prioritization process which used the Multi Criteria Decision Analysis tool. Some criteria for evaluation were presented to participants, and after some discussion, the list of criteria was finalized to include the following:

- **Capital cost:** Cost in dollars to transfer and establish the technology during the project cycle;
- **Maintenance cost:** Cost in dollars to cover incidentals and maintenance of equipment;
- **Operating cost:** Cost in dollars incurred during operational phase of project;
- **Job creation:** An indicator to assess the benefits of the technology transfer;
- **GHG emissions reduction:** a measure of the carbon reduction potential of the technology during its life-time;
- **Air and water quality:** Improved air and water quality are measurable and can be used as indicators of the effectiveness of the technology transfer;
- **Energy security:** Increased energy security is measurable and can be used as an indicator of the effectiveness of the technology;
- **Technology replication:** the ability or ease of applying or using the technology in other location;
- **Life of the technology:** the timeframe or longevity of usefulness of the technology;
- **Implementation time:** the period in months or years of the technology transfer project cycle.
- **Adaptation potential:** the means by which knowledge, technology and best practice can help reduce the negative impacts of climate change. The 'status of resilience' can be a measure of adaptation potential. For example, ecological indicators show that ecosystem management opens the way to greater potential for adaptation to climate change (Natural Resources Canada: https://cfs.nrcan.gc..ca/).

As a result of the Working Group debate, recommendations were made that the following technologies be further reviewed, and the factsheets prepared for the prioritization process.

1. Coastal and Marine Ecosystems: Four Technologies were selected: Coastal Setbacks, Beach Nourishment, Land Claim and Managed Realignment.
2. Water sector: reclamation and reuse, water safety plans and efficient fixtures and appliances.
3. Agriculture: agroforestry, crop diversification and new varieties and mixed farming.

4. Transportation: Improving private vehicle operating standards, non-motorized transport and bio-methane CNG Hybrid fuel.
5. Land Use, Land Use Change and Forestry: Agroforestry.
6. Energy: solar energy and advanced bio fuels.

A follow-up two-day Technology Prioritization workshop was held on 14th and 15th October 2015 at the Black Orchid Resort in Burrell Boom Village, Belize District. This workshop had the participation of the members of the Working Group as well as other representatives of the TNA project management team. Shortly before the Technology Prioritization workshop, a planning meeting was held between the Assistant National Coordinator and the national consultants' team leader in order to finalize the stakeholders' recommendations on the study sectors. Eleven Fact Sheets were eventually prepared and circulated for consideration.

Thirty-one persons attended the first day of the Technology Prioritization Workshop and twenty-two attended on the second day. After background presentations, and introductions, the participants were instructed on the procedures for the workshop. They were then separated into two groups in order to review the factsheets by categories; one group dealt with mitigation technologies while the other evaluated the adaptation technology factsheets. The two groups reconvened in plenary at the end of the first day to present their findings and make recommendations for the next day's work.

During the closing session at the end of the first day, the participants expressed concerns about the incomplete condition of some of the factsheets. Data and information were missing, the information and costs were irrelevant to Belize, and some had outdated information.

The second day of the workshop began with a review of the previous day's work and outcomes. The use of the Multi Criteria Decision Analysis (MCDA) tool was reviewed, and although it was a smaller group of participants, they again separated according to categories. A few revised factsheets were circulated electronically to enable data to be extracted and inserted to the MCDA tool. The selected criteria were applied to the tool, and weighted, with the participants providing input to the weighting of each criterion. At the end of the analysis, four remaining mitigation technologies were ranked in order of priority derived through the use of the MCDA tool.

1.9 Revised Adaptation Technology Selection and the MCA Process

In February 2016, the National TNA Coordinator requested a change in Consultants due to inefficient work being carried out by the National TNA consultant. As such, a new TNA consultant was appointed on February 15th, 2016. Upon appointment to the post, the new TNA consultant was tasked with procuring a mitigation expert/consultant to facilitate the prioritization of mitigation technologies.

Following a request to revise the TNA climate change adaptation and mitigation technologies, conduct a Multi-Criteria Analysis, and proceed to complete the Barrier Analysis and Enabling Framework process of the prioritized technology factsheets, the new Consultants, after consultation with the TNA Coordinator, proceeded to begin consultative meetings with small stakeholder groups in the selected productive Sectors in March through June, 2016. As indicated earlier, the selected sectors were: Agriculture, Water, and Marine and Coastal Ecosystems for the adaptation technologies, and Energy, Transport and Land Use Land Use Change and Agroforestry for the mitigation technologies.

A major drawback occurred around mid-June, 2016, when the Mitigation Consultant had not delivered on the proposed mitigation technology factsheets and another Consultant had to be procured who could continue with the consultations for re-selection of the mitigation technologies, and drafting of the corresponding technology factsheets.

1.10 Adaptation Technologies

1.10.1 Consultation Process

The consultation process for the selection of the new Climate Change adaptation technologies in Agriculture, Water and Coastal and Marine Ecosystems included face-to-face visits and discussions with stakeholders in focus groups. Visits to individual stakeholders to select, discuss and review the draft technology factsheets were carried out on a weekly basis, except during the four to five-week emergency period to respond to the impacts of Hurricane Earl in June and July, 2016; when many departments and agencies were busy with recovery efforts. Also, the month of September is often a time when many Government Departments and other stakeholder agencies are busy with the two national day celebrations. Thus, stakeholder small group meetings to revised the draft adaptation technology factsheets and develop the set of criteria by sector for the MCA process were resumed in October, 2016.

Table 6 below is a list of the selected adaptation technology factsheets. The updated technology selections were based primarily on feedback from the stakeholders and with guidance from policy documents such as Belize's Nationally Determined Contributions (NDC), Belize's Third National Communication to the UNFCCC, and the National Climate Change Policy, Strategy and Action Plan. From the inception of the deliberations, the selected technologies were related to activities or programs already being considered or implemented in the public and private sectors.

Table 6: Selected Sectors and Technology Applications

Sector	Sub-sector/ Technology Option	Technology Application	Remarks
		1) *Improved drip irrigation systems for crop water requirement, fertigation and water harvesting for five small farming groups*	**Objective:** To extend cropping season and increase income for farming groups. **Scope:** Applicable for farming groups countrywide. **Target Group:** Five farming groups plus training station at Central Farm for other farmers from the districts.

Agriculture	Crop Diversification and New Varieties		**Time Horizon:** Three years Rainwater harvesting incorporated in the irrigation systems, as well as renewable energy for pumping water where required.
		2) *Refurbish Seven Covered Structure Cooling Systems*	**Objective**: Provide a more conducive covered structure micro-climate favorable for increased crop yields **Scope:** Initially 10 covered structures will be refurbished, then technology will be replicated for other covered structures in the near future **Target Group:** Experimental Crop Covered Structures in each Ministry of Agriculture (MOA) district stations and four farmer's groups. **Time Horizon:** 3 years Use of renewable energy technology (e.g. Solar PV) to run cooling system recommended.
		3) *Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties better suited to Belize's current and future climate*	**Objective:** To provide quality, heat/drought -resistance potato seed-tuber planting material for farmers in the Cayo and Orange Walk districts, initially. **Scope:** Initially the technology transfer will be at the level of two districts. **Target Group:** Potato farmers in the Cayo and Orange Walk Districts. Other target groups/stakeholders: University of Belize Micro-Propagation Laboratory Service; Belize Agriculture Health Authority; Nursery workers in the Seed Production Unit of MOA, CARDI, San Carlos Farmers Cooperatives etc. **Time Horizon:** Five years Solar power energy will be used for storage cooling system. Complete production chain considered from purchase of clean stock, lab propagation of quality seed tubers, nursery seed production, selling to farmers, planting quality seed for market, harvesting, storage, supply to

			market, and back to seed reproduction by specialized farmers groups.
		4) *Heat and Drought Resistant variety of open-pollinating corn and beans seeds for reproduction and marketing among small farmers in Belize*	**Objective:** To improve the grain seed stocks and planting material for grain farmers in Belize. **Scope:** Seed for reproduction will be available for seed production cooperatives, and harvested grain for country-wide market and for export. **Target Group:** Four stock seed production groups and farmers cultivating for the local/export markets **Time Horizon:** Four years First crops in the priority list of agriculture crops targeted for development by the MoA/GOB. Production chain will include seed acquisition to storage and marketing.
		5) *Micro climate monitoring system for sustainable soil and land management in Agriculture and Agroforestry*	**Objective:** To improve soil fertility and efficient, irrigation scheduling. **Scope:** The initial intervention will be in six agriculture training and demonstration sites. May be replicated in other sites in the future. **Target Group:** Farmers in each district interested in soil conservation and irrigation scheduling. **Time Horizon:** Three years of training, monitoring and evaluation. Initial cost will include set of soil monitoring equipment and training of field technicians initially, then selected farmer's groups. Monitoring will be done daily and training of farmers and farming groups twice per year for three years.
		6) *Drought Monitoring System for Northern Belize with Specific*	**Objective:** To assess and monitor groundwater resources in the northern districts of Belize.

Water	Drought Early Warning and Water Safety Plans	*Focus on Groundwater Resources*	**Scope:** The intervention will cover the Corozal and Orange Walk Districts **Target Group:** Water consumers for domestic, agriculture and industrial use. **Time Horizon:** Three years Feasibility study critical. Co-financing may have to be accessed via local or international donors (IICA, FAO, EU, GEF, GOB, others). Monitoring will feed into Drought Early Warning and the National Water Plan (IWRM Act, 2010)
		7) *Water Efficient fixtures and appliances*	**Objective:** To conserve water and reduce cost to water consumers **Scope:** Households and businesses countrywide **Target Group:** Water consumers across the country **Time Horizon:** Three years Development of standards and training component for builders
		8) *An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize*	**Objective:** To improve the potable water supply services of eight RWS **Scope:** The pilot project will target eight rural communities. The technology transfer may be replicable for other RWS. **Target Group:** Families in eight rural communities that have inadequate RWS **Time Horizon:** Three years Eight Rudimentary Water Systems with history of community water service mis-management will be targeted in the first instance. An effective Water Safety Plan developed and implemented by middle of first year of project cycle. Community participation critical for success, especially that of Village Water Board members.
		9) *Soft Engineering and*	**Objective:** To contribute to efforts in coastline

Coastal and Marine Ecosystems	Habitat Restoration	*Ecosystem Restoration (SEER) Technologies to Address Shoreline Erosion in Three Threatened Coastal Communities in Southern Belize*	protection and restoration **Scope:** Three threatened coastal communities **Target Group:** Property owners and families in threatened communities. **Time Horizon:** Five years Technology recommended will be a mix of hard and soft engineering, as required; strong public participation in 3 threatened communities
		10) *Improved Monitoring Network and Early Warning System for Belize's Coastal Zone to Increase Resilience to Climate Change*	**Objective:** To provide marine environmental early warning for decision making, operation and management **Scope:** Belize's Coastal Zone **Target Group:** Stakeholders in the fishing and tourism industry, marine developers and policymakers **Time Horizon:** Five years The technology will consist of installation of a network of nine environmental/ marine monitoring platforms with sensors to record climatic and marine parameters at nine critical spanning and aggregation sites, and coral reef clusters. Data from the marine monitoring network and other marine information will be used for Coral Reef & Marine Resource Early Warning…

1.11 Prioritized Adaptation Technology Factsheets

Once stakeholders were satisfied with the selected adaptation technologies and the draft factsheets, the Multi-Criteria Analysis (MCA) was conducted by sector.

Table 7 shows the list of the six (6) prioritized climate change adaptation technologies per sector derived from the MCA process. Three technologies were prioritized for the Agriculture Sector, but a fourth, namely "*Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties*", was later selected for prioritization, following lengthy small group discussions with the personnel from the University of Belize's Plant Propagation Laboratory and the Ministry of Agriculture Crop Section and the Crop Research and Development Unit. It was established that impending climate change impacts could likely reduce grain yields and threaten Belize's food security. As a security measure, it was recommended that an expansion of potato cultivation be carried out, with climate resistant seedlings that can be imported from Peru or another source, and these can then be propagated locally by the University of Belize Plant Micro-Propagation Laboratory, then grown in nurseries to increase crop material for farmers.

The criteria selection and weighting were done in small group meetings per sector and the results of the prioritized technologies are summarized in Table 7 below.

These are the Climate Change adaptation technologies that will be considered in the Barrier Analysis and Enabling Framework phase of the TNA project in Belize.

Table 7: Summary of Prioritized Adaptation Technologies by Sector

Sector	Technology	Score
Agriculture	◦ Heat and Drought Resistant variety of open-pollinating corn and black beans seeds for reproduction and marketing	54.0
	◦ Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement	49.5
	◦ Refurbish Seven Protective Structure Cooling Systems	44.8
	◦ Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties	31.7
Coastal and Marine Ecosystems	◦ Improved Monitoring Network and Early Warning System for Belize's Coastal Zone	52.0
Water	◦ Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize	73.0

CHAPTER 2: INSTITUTIONAL ARRANGEMENT FOR THE TECHNOLOGY NEEDS ASSESSMENT AND STAKEHOLDERS' INVOLVEMENT

2.1 National Technology Needs Assessment Team

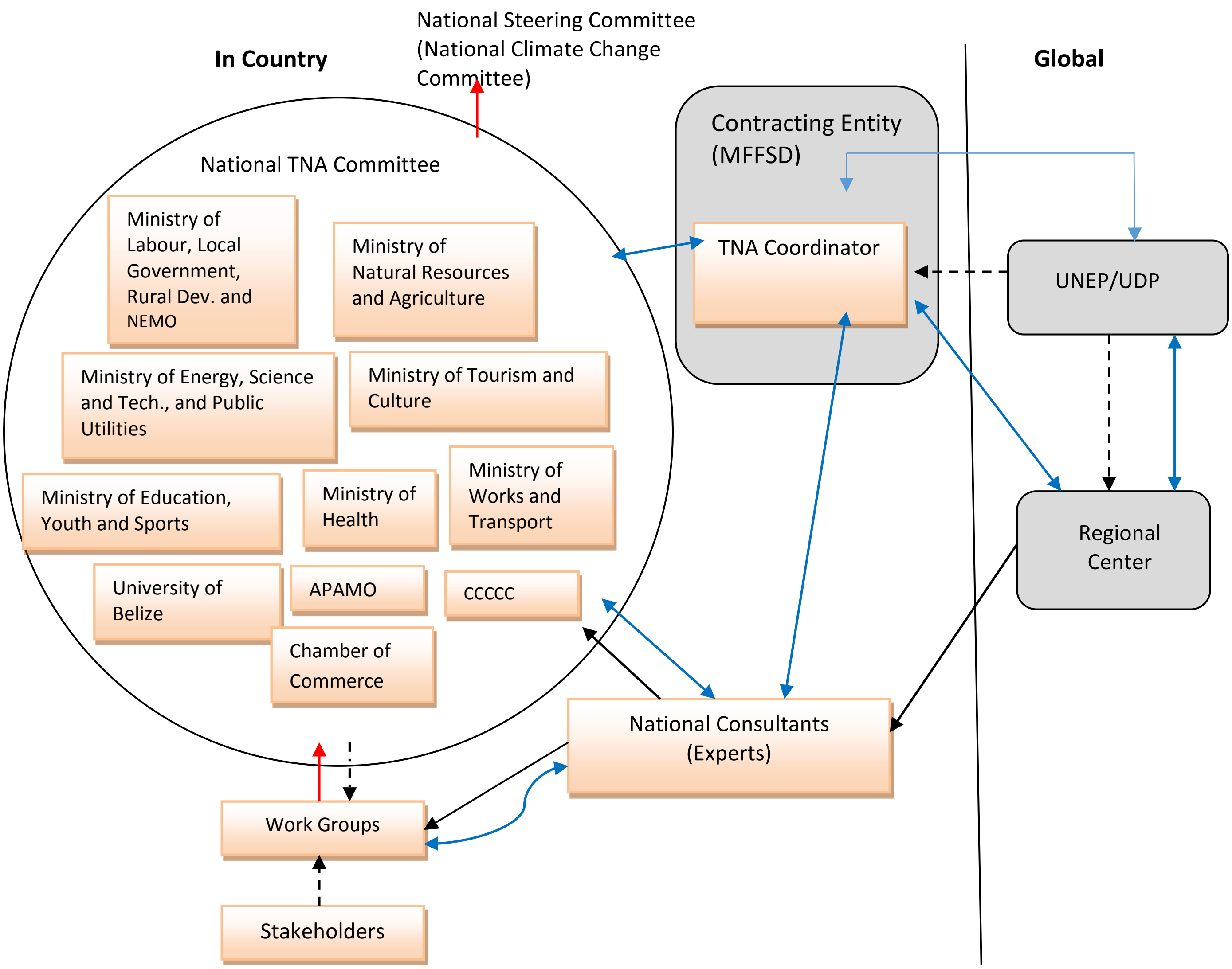


Figure 9: Institutional Arrangements for TNA Phase II Project in Belize

(Source: Terms of Reference National Technology Needs Assessment Consultant)

The Belize National Climate Change Committee functions as the national TNA Committee for the duration of the project. The national TNA Team comprises the TNA Coordinator, the TNA Assistant Coordinator, the TNA Sector working groups, the national consultants, and key stakeholders.

2.1.1 National TNA Coordinator

The National Climate Change Coordinator, of the National Climate Change Office of Belize is designated as the National TNA Coordinator. The National Coordinator serves as the in-kind contribution of the Government of Belize to the Project. The National Climate Change Coordinator is assisted by the Assistant National TNA Coordinator, who initially served as a consultant to the project, but who currently holds the position of Climate Change Officer in the National Climate Change Office.

2.1.2 National Project Steering Committee (NPSC)

The Belize National Climate Change Committee functions as the National Project Steering Committee. The CEO in the Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development chairs this committee.
Members of the NPSC include:

1. Ministry of Forestry, Fisheries and Sustainable Development — Chair
2. Ministry of Economic Development- Vice Chair
3. Ministry of Natural Resources and Agriculture
4. Ministry of Health
5. Ministry of Works and Transport
6. Ministry of Tourism, Culture and Civil Aviation
7. Ministry of Labor, Local Government, Rural Development and NEMO
8. Ministry of Energy, Science and Technology, and Public Utilities
9. Representative from the Private Sector (Vice Chair)
10. Representative from NGO/CBO Umbrella Group
11. Representative from the University of Belize

2.1.3 The Technology Needs Assessment Consultant and Team

The TNA Consultant appointed by UNEP/DTU is the Lead Consultant or Team Leader. The Lead Consultant is also the Climate Change Adaptation Consultant, and is assisted by a Climate Change Mitigation Consultant (who was appointed by the team leader). The Team Leader has the responsibility for coordination and assignment of tasks. Team members are encouraged to make contact with stakeholders in the search for data and information. To date, all stakeholder's meetings and workshop preparation have been facilitated by the Team Leader in collaboration and with the support of the Assistant National TNA Coordinator. The team participates in each of the workshops that were held since the National Inception Meeting.

2.1.4 Technology Needs Assessment Working Groups for Climate Change Adaptation

Members of the Technology Needs Assessment working groups include, but are not limited to, the following organizations:

(i) Agriculture
- Crop Research and Development Unit, (CRDU/MAFFESD)
- Crop Section (CS/MAFFESD)
- Farmers Representatives
- Caribbean Agricultural Research and Development Institute (CARDI)
- Inter-American Institute for Cooperation in Agriculture (IICA)
- University of Belize, School of Agriculture Representative (Micro-propagation Lab)
- PRO SOLAR

(ii) Water
- Hydrology Department
- National Meteorological Service
- Belize Water Service
- Public Health (MOH)
- Rural Development

(iii) Coastal and Marine Ecosystems
- Coastal Zone Management Authority and Institute
- Fisheries Department
- Forest Department
- Healthy Reefs
- Belize Port Authority

The Working Groups are national stakeholders who participate in the technology selection process by reviewing outputs of the consultant(s), conducting technical evaluation and providing technical advice as needed.

2.2 Stakeholder Engagements

2.2.1 Initial Stakeholder Engagement Process for the TNA

Stakeholders' initial formal engagement with the TNA process was through Inception Mission of 23rd to 26th March 2015 at the National Climate Change Office. During the Inception Meetings, stakeholders were consulted in various focal group discussions whereby the project was introduced and the initial sector prioritization was done. During this phase, time was dedicated to the verification of the sectors selected for mitigation and adaptation technologies, and the updating of the Work Plan. Engagement of stakeholders continued through the National Inception workshop on 26th June in Belize City. Some persons and organizations were identified as relevant stakeholders due to their contribution to matters related to climate change, whether serving as members of climate change committees, staff members of department dealing with any aspect of climate change. They came from the public and private sector, and civil society.

After selection of the National Consultant during the Mission, a National Inception Workshop was held on 23rd June at the Best Western Biltmore Plaza Hotel in Belize City. The discussions at the workshop led to the selection of various sectors in which technologies would be prioritized. The sectors discussed by stakeholders were, inter alia, health, water, agriculture, coastal and marine ecosystems, and tourism. After the workshop, discussions continued with the Assistant National Coordinator which led to the priority sectors being narrowed down to Water, Agriculture, Coastal and Marine Ecosystems.

Documents such as the technology factsheets were circulated to stakeholders inviting comments. Some were contacted individually by the consultants via telephone seeking data and information to improve the factsheets, while a few were engaged personally. The Working Groups which conducted the initial screening of the factsheets were composed of national stakeholders, and they were again engaged during the prioritization workshop. The names and other details of national stakeholders are described in Annex 1.

2.2.2 Second Round of Stakeholder Engagement to Consider Adaptation Technologies

The objective of the second round of stakeholder's consultations was to draft improved factsheets based on previously selected 'sectors' and newly, proposed adaptation and mitigation technologies. By mid-June, 2016, the MCA process for ten (10) climate change technology factsheets was completed. These were vetted by the sector stakeholders and the same were submitted to the TNA-Belize project Coordinator.

2.2.3 Consultation Process

A series of consultative meetings with key stakeholders in the previously selected sectors for the climate change adaptation technologies were held beginning in late February, 2016. The climate change adaptation Consultant met with technical personnel from the Ministry of Agriculture; Ministry of Labor, Local Government, and Rural Development; Public Health; Fisheries Department; Coastal Zone Management Authority and Institute; Forestry Department; Hydrology Unit; Public Utility Commission; Pro Solar; Caribbean Agriculture and Development Institute (CARDI), Farmers Groups, Pan American Development Foundation, and others. The consultations were carried out using face to face interviews, small working group meetings and field visits.

Meetings were also held with the Assistant National TNA Coordinator and the National TNA Coordinator to review the draft factsheets. The Lead Consultant also held working sessions with the Mitigation Consultant in an effort to help draft the Land use, Land use Change and Agro-forestry factsheets, and the Micro-hydro dam factsheet for the Energy sector.

Table 8 is a summary of the main findings and issues discussed for the formulation of the updated climate change adaptation factsheets that were vetted for the Multi Criteria Analysis. See Annex II for a review of some of meetings and small group sessions.

Table 8: Climate Change Adaptation Technology Consultation Sessions

Sector	Small Group Sessions/Workshops	Dep./Agency
Agriculture	Crops for technology transfer should be grains, specifically yellow corn and beans (small red, red kidney, and black beans). The technology for improved grain production in Belize is at the top of the MOA's list of crops being promoted in its strategy to ensure food safety and livelihood security among small farmers and farming communities in Belize. Thus, the technology will encompass not only the new varieties of corn and beans seeds, but also the complete process from land preparation, planting, harvesting, storage of grains, marketing and replanting. Seed production groups will ensure the viability of the seed stock. Seed for planting and marketing will be available to famers at a reasonable price.	Grain Seed Research, Development and Propagation Center, Ministry of Agriculture, Central Farm. Farmer Cooperatives and farming groups
	The Agriculture Research and Development Unit in the MOA will spearhead the proposed "*Improved drip irrigation systems for crop water requirement, fertigation and water harvesting for five small farming groups*" and "*Refurbish Seven Covered Structure Cooling Systems*". The ARDU provides services and training to farmers in drip and sprinkler irrigation systems and cover structure installation. The proposed, improved drip irrigation systems for cultivation under Covered Structures and small open field plots, will integrate water harvesting and fertigation technology. One major disadvantage with Cover Structure technology in Belize is the elevated temperatures that develop in these greenhouses during hot, sunny days, which limits the number of working hours inside the Cover Structures.	Agriculture Research & Development Unit, Central Farm
	The justifications cited for improved drip irrigation technology are: water use efficiency, reduction of climate footprint, and high initial cost. Farmers can expect reduced cost of production in the medium and long term, and improved pastures for livestock production in the long term; increased use of drip irrigation for crop production is a national priority; and, reduced stress on water resources, soil and forest. Limiting factors include: Initial cost per unit for drip/sprinkler irrigation system; water sources and reliability during the dry season; maintenance costs; and training of participating farmers.	Ministry of Agriculture, Belmopan
	The Caribbean Agriculture Research and Development Institute – Belize focuses on grain stock seed investigation and production for distribution among small farmers. The Institute also works with farmers cooperatives interested to increase their production of onions, vegetables and grains. The San Carlos Farmers	CARDI, Central Farm

	Cooperative in the Orange Walk District and the Valley of Peace Farmers Group are two of several farmers cooperatives working with CARDI and the MOA's Grain Seed R&D and Propagation Center.	
	An initiative is underway to develop a business plan for the University of Belize (UB) Plant Micro-propagation laboratory at the Central Farm campus. Seed (germ plasm) of new varieties of white, Irish potato good for making chips and resilient to warmer temperatures and drought could be a crop for the prioritized "Crop Diversification and New Variety". The UB Plant Propagation Lab could serve as the institution to test, validate, and reproduce seedlings for experimental plots. Through the MOA, these could be disseminated to farmers.	University of Belize Plant Propagation Laboratory, Central Farm
	Pro Solar, a local renewable energy company, provided preliminary costs for Cover Structure cooling systems. Specification were provided for various size of Covered Structure, and the PV systems to run the cooling fans during the daytime.	Pro Solar, Belmopan
Water	For the Technology Option "Water Safety Plans", the technology: "*An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize"* was proposed by the Small Group of stakeholders for the Water Sector. Rural Water Systems (RWS) are managed and operated by Village Water Boards, but some of these local water service providers run into difficulty when the operations are mismanaged. The result is that the entire community suffers the consequences of breakdown in their potable water supply. The technology transfer will focus on an Integrated Water Resources Management System from source protection to the end users and waste water treatment.	Ministry of Labor, Local Government and Rural Development
	The Public Health Bureau in the Ministry of Health is the agency responsible for monitoring and treating the Rural Water System (RWS) water quality status on a regular basis. This is also a bottle neck in the supply chain for potable water services for some rural communities. The technology transfer will target eight communities that suffer frequent breakdown of their water supply system.	Public Health Bureau, Ministry of Health
	The Hydrology Unit expressed an interest to help draft a Climate Change adaptation technology factsheet on groundwater resource monitoring for the northern Districts, as a basis for a Drought Early Warning System for stakeholders in this drought-prone region of the country. Water for domestic use, agriculture and industry in the northern districts is derived from ground water sources. But very little data exist on the	Hydrology Unit, Ministry of natural Resources

	characteristics of the groundwater resources.	
	The National Climate Change Office (NCCO) is the coordinating agency that provides support for the TNA project in Belize. The National Coordinator and the Assistant National Coordinator provide the guidance and support to the local consultants. The Consultants have held several important meetings with the Assistant TNA Coordinator on issues related to the TNA project.	National Climate Change Office
Coastal and Marine Ecosystems	The Fisheries Department has a number of programs and projects for marine resources management and ecosystem protection. These include the Lion Fish monitoring program, Water Quality monitoring, Turtles Program, and the Spanning Aggregation program. What is needed is an improved Marine Environmental monitoring system and capacity building to keep a consistent and high-quality database of the physical changes in sea water chemistry, tides, sea currents and other marine parameters. The Fisheries Department has demonstrated an interest in a technology transfer for an upgraded network of Marine Environmental monitoring stations that could provide the basic, daily data on the status of the Marine environment. Using this data and together with other sources of information, the Fisheries Department plans to develop a Marine Early Warning Service for the Belize Coastal Zone.	Fisheries Department, Belize City
	The Coastal Zone is vitally important for productive sectors such as Fisheries, Tourism, Transport, Commerce, recreational fishing and adventure, and livelihood security of coastal communities, to name a few. The marine resources and ecosystem services are threatened by anthropogenic activities and climate change, which directly or indirectly impact stakeholders such as fishers and their families, other coastal communities, and stakeholders in general. The Coastal Zone Management Authority and Institute (CZMAI) supports the efforts of the Fisheries Department in trying to upgrade its marine environmental monitoring network, to gather baseline data for its Marine Early Warning program. The Early Warning System will provide the necessary information and alerts to inform stakeholder of impending ecological degradation, and help policymakers to evaluate the status of the marine environment, and make informed decision to reduce the impacts and build resilience.	Coastal Zone Management Authority and Institute, Belize City
	Shoreline and beach erosion has been identified as one of the biggest threat to coastal and marine ecosystem, including coastal communities. The CZMAI supports	Pan American Development Foundation (PADF), Dangriga Town & Monkey River

	the work of the Pan American Development Foundation (PADF) in trying to halt the creeping beach erosion in the Dangriga Town and Commerce Bight areas of coastal Stann Creek District. However, the areas of maximum beach erosion rates are farther south in Monkey River Village, Sein Bight Village and Hopkins Village. The PADF was forthcoming in proposing a climate change adaptation technology transfer entitled: *Soft Engineering and Ecosystem Restoration (SEER) Technologies to Address Shoreline Erosion in three threatened Coastal Communities in Southern Belize.* A number of consultation meetings were held with various stakeholders in the Stann Creek District and PADF, to assess the shoreline erosion problem and draft the factsheet.	
Feb 7-8, 2017	The NCCO organized a two-day workshop on the TNA Project requested by the Global TNA Project Coordinator from UNEP/DTU Partnership. The objective of the workshop was to present the progress made on the updated factsheets and the MCA for the Mitigation and Adaptation technologies, and present the draft Climate Change Adaptation Report. During the second day of the workshop, participants were organized in small groups to conduct the MCA for the Energy and the Agroforestry technologies. The MCA for the Transport Sector technologies was not done because of the absence of participants from the Transport Sector. There was also a need to update one of the Transport Sector factsheet. A small group meeting with the Global Coordinator, the National Coordinator and the Consultants to discuss the way forward to complete the TNA project in Belize, resulted the development of a work plan to submit the draft TAP by the end August, 2017, and endorse it by the 2nd week in September, 2017.	TNA Workshop, Belmopan. All Sectors & Stakeholders
March 23, 2017	Presentation of the status of the TNA Project to the National Climate Change Committee (NCCC) in Belmopan by the National Coordinator and the Lead Consultant. The NCCC expressed their thanks for the update and support for the successful completion of the TNA project in Belize.	TNA project status presentation to the National Climate Change Committee (NCCC)

CHAPTER 3: TECHNOLOGY PRIORITIZATION FOR THE AGRICULTURE SECTOR

3.1 Key Climate Change Vulnerabilities in the Agriculture Sector

Agriculture is very important for the economy of Belize. In earlier years, agriculture was the primary sector which contributed substantially to the growth of the Gross Domestic Product (GDP). For instance, in 2007, Agriculture and Forestry contributed 9.1% to the GDP of Belize (GEO Belize, 2010). In recent years, this has changed, but the sector is still important because of its export earnings and the employment it creates for a large percentage of the population in rural areas of Belize (DOE, 2012).

Economic performance in the agriculture sector is primarily dependent on traditional export crops such as sugar, citrus and banana which currently account for about 60% of the earnings with citrus exports being the principal source of income followed by sugar and banana. Rice, corn and beans are the main domestic food crops.

It is expected that climate change would have severe impacts on the agriculture sector of Belize. Current climate changes are already affecting the agriculture sector: variability of yields/harvests for rain fed agriculture is already suffering from changes in the timing and amounts of rainfall and there is widespread perturbation of the agricultural calendar. Intense rainfalls are causing problems of soil drainage and erosion, and warmer temperatures are leading to the increased incidence of yield-reducing weeds, pests and diseases.

Future climate changes would very likely exacerbate these conditions. Climate change is expected to be accompanied by increasing water deficits and moisture stress. This in turn will force farmers to increase irrigation and use more chemicals and fertilizers, and change the choice and mix of crops/cultivars, all of which would definitely increase the costs of agricultural production and threaten overall food security in Belize (IPCC, 2007; R. Thompson, Project officer MOA, personal comm. August, 2016).

Previous studies have shown that climate change may lead to yield reductions of sugarcane, citrus, beans, rice and maize (GOB, 2012).

Apart from climate, non-climate factors also need to be considered. For instance, the sugar sector in Belize suffers from a lack of investment and the need for modernization at the farm, processing and transport levels. Also, the costs of producing sugar cane are steadily increasing because of poor or non-existent farm drainage systems, lack of modern plant types and harvesting machinery, and badly maintained roads that at times of heavy rains and floods prevent collection trucks from reaching farms. After harvest, sugarcane is transported to the ASR-Belize Sugar Industry (BSI) factory by trucks owned or hired by the farmers.

It is apparent from the foregoing that the agricultural sector of Belize would suffer mainly negative impacts from future (2060-2069) climate change. Yields of the major crops, namely sugarcane, rice, bananas, citrus and Red Kidney beans, are all expected to decrease. These decreases in crop yields would result from an increase in air temperature accompanied by higher evaporation rates, and rainfall variability, depending upon the location in Belize. In addition to impacts relating to water stress and temperature, banana plantations are also susceptible to hazards such as storms and hurricanes which can wipe out an entire crop. As mentioned above, a drought earlier in 2015 devastated the entire crops of corn, beans and rice in north-western Belize. According to farmers, millions of dollars invested in these crops were lost; revealing the high level of vulnerability of a small country to the impending climate change phenomenon.

3.2 Decision Context

The National Adaptation strategy to address Climate Change in the Agriculture Sector in Belize crafted in 2015 recognizes the sector's critical importance to Belize's development for foreign exchange earnings and savings, employment, and food and nutrition security. The policy states that Climate Change and climate variability is foreseen to impact Belize's agriculture systems and practices, affecting 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* (CCCCC, 2015).

Recommendations proposed in the Nationally Determined Contribution (NDC) include both short and long-term measures to address gaps in technological development relevant to crop production, better soil management practices, diversification into drought-resistant crops and livestock, and farm production adaptation such as land use, land use topographic mapping, and increase use of low-water irrigation systems.

Since it is recognized that adaptation measures can reduce future vulnerability of the farming community, strategies and action plans were developed with a view to minimizing or eliminating the impacts. Some efforts to introduce and implement programmes, projects, and policies to reduce identified climate change vulnerabilities and adaptation needs in key areas have been initiated.

In the vulnerability assessment for food security (Green, 2007), various crop simulation models were applied in simulations to project physiological responses to climatic parameters, soil, and crop management. Three staple crops were selected for the vulnerability assessment study, namely rice, maize, and beans. The results show losses for these staple crops because of 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.
The selection of adaptation technologies for the identified vulnerable sectors was based on:

- National Development priorities;
- Contribution to sustainable development objectives as identified in policy framework and strategy;
- Recommendations from National Communications and the NDC;

- Benefits for communities and stakeholders;
- Longevity of the technology;
- Technical support requirements of the technology at the time of availability;
- Cost;
- Social acceptance/environmental impact;
- Climate Change adaptation potential.

The technologies selected for the Agriculture sector during the revision of the technology needs with stakeholders in the first quarter of 2016 were:

1) *Improved drip irrigation systems for crop water requirement, fertigation and water harvesting for five farmers groups plus the training station at Central Farm.*
2) *Refurbish Seven Covered Structure Cooling Systems.*
3) *Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties better suited to Belize's current and future climate.*
4) *Heat and Drought Resistant variety of open-pollinating corn and black beans seeds for reproduction and marketing among small farmers in Belize.*
5) *Micro climate monitoring system for sustainable soil and land management in Agriculture and Agroforestry.*

3.3 Overview of existing technologies in Agriculture sector

3.3.1 Agroforestry

Agroforestry is practiced mostly at the small farmer level, on farms averaging between 10 to 25 acres, but there is at least one large commercial operation existing in the country. A number of citrus farmers in the Stann Creek District are planting pineapples between the citrus trees. Bowen and Bowen Limited, one of the largest companies operating in the country, plants coffee within the natural forest on its property in northwest Belize. The product is sold in local supermarkets countrywide. In the southernmost district, Toledo, which experiences the highest rainfall, an increasing number of farmers are growing cacao and raising bees under the cover of the natural forest. There is an ongoing project funded by the United Kingdom Department for International Development which is providing assistance for expansion of this initiative. The organically grown cacao beans are for guaranteed sale to a certified buyer in the United Kingdom.

Some small to medium sized farmers practice mixed farming in order to have different products at different times of the year. Combinations of corn, plantains, chickens, a few heads of cattle and pigs might all be included in the mix. Some who raise pigs or chickens may also plant corn in order to have their own source of feed.

3.3.2 Drip Irrigation

Drip irrigation allows for maximum efficiency and water conservation over most irrigation systems. Water is delivered to the plant root zone directly using thin walled tubing laid either on top or just below the surface. Emitter pores along the tube regulate water flow. The system allows small amounts of water to be delivered over large areas and can be used for fertigation (Perry, 2015).

Disadvantages of this system include high initial cost, frequent maintenance due to clogging, and high management expertise is required. Another setback occurs if water is high in iron, since deposits often deteriorate pipes. Advantages of this system include the ability to control fertilizer applications, such as nitrogen, which decreases cost of production.

3.3.3 Rainwater Harvesting

While rainwater harvesting has been primarily used for domestic applications in Belize, it is becoming increasingly important in agriculture practices. Ad hoc use of water retention ponds by small farmers in Belize to water crops during the peak of the dry season is commonly practiced. These ponds and "bajos" are often exploited by further digging manually or mechanically in order to reach the water table; thereby making water available from these sources. This is the practice used to construct water ponds for cattle and other livestock. Entire communities are often dependent on these water sources as was seen by farmers using water from a nearby lagoon in properties owned by Santander Limited (GOB, 2012).

3.3.4 Sprinkler Irrigation

The large banana farms in the mid-south of the country are the primary users of sprinkler irrigation, with large volumes of water used during the growing season. It has been observed that Mennonite farmers in the Orange Walk District use sprinkler irrigation for cultivation of beans. Flood irrigation is the norm for rice cultivation by the Mennonite farmers of the Orange Walk District. This technology again uses large volumes of water.

3.3.5 Crop Diversification and New Varieties

Diversified crop varieties are recommended as a part of the National Adaptation Strategy to address Climate Change in Agriculture (See Table 9 below). Improved varieties are recommended for most of the crops as an adaptation strategy (CCCCC, 2014).

In Northern Belize, some level of crop diversification is now being practiced by sugar cane farmers. A few of these farmers are now planting papayas on a section of their land (S. Garcia, personal communication). Intercropping at the small scale and subsistence level has taken place for many years in this country.

Table 9 below presents a summary of the adaptation technologies considered by the Ministry of Agriculture for adaptation to climate change. This list is included in the National Agriculture Strategy.

Table 9: Risks, Impacts and Adaptation Strategies for Crops and Livestock

Crops, Livestock and Aquaculture	Risks	Climate Change Impacts	Adaptation Strategy
1) Sugarcane	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 pest incidence will result in decreasing yields	-improved drainage and install efficient irrigation systems; -plant heat, pest, and flood resilient varieties, and 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 pest 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 Integrated Pest Management (IPM)
4) Corn	Excessive rainfall, droughts and high temperature, pests	Increased heat waves, droughts and periodic excessive rainfall, increased pest 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	Increase in extreme events, increased pest incidence, decrease in	-adjust planting date to match rainfall pattern; improve soil fertility;

	and diseases	yields	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 pest incidence	-erect improved crop cover structure; fertilization; practice IPM; use organic crop technology; plant heat and pest resistant, 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.

Source: National Adaptation Strategy (and Action Plan) in the Agriculture Sector (CCCCC, 2014)

3.4 Adaptation Technology Options for the Agriculture Sector and Benefits

3.4.1 Crop Cover Structures (Tropical Greenhouse) and Improved Cooling Systems

A tropical greenhouse is not to provide a warm and humid environment for crop, but to create an ideal condition in which plants can be protected against heavy rainfall, direct solar radiation, disease, insects and birds. High relative humidity and ambient temperature microclimate in a tropical greenhouse creates a complicated dynamic system that is strongly influenced by changes of external conditions, making it a challenging environmental control task (Shamshin & Wan Ismael, 2013).

Protective cropping structures were introduced in Belize under the 9th European Development Fund (EDF) funded Agriculture Enterprise Development project (AED), and was well received by vegetable farmers. Some structures have been properly managed and some farmers have experimented with lower cost design structures (Salazar, 2013; Frutos, 2014).

As indicated, one main purpose of Protective Covered Structure (PCS) is to create a controlled environment for optimum growing conditions compared to growing outside in an un-controlled environment (FAO, 2011). A farmer or grower has many options in the design of the greenhouse structure and on how much control he/she may want or need for the crops that are being grown. Specifically, Protective Covered Structures or Tropical Greenhouses contribute to increased productivity, improved produced quality, reduced cost of production, and reduce dependence on pesticides (Ramirez, 2010).

Protective Covered Structures in Belize are of four types, namely: Tropical Greenhouse, Bubble House, Tunnel and Plastic Covered Structure (Ramirez, 2010; Reyes, 2010).

Tropical Greenhouse

The specifications are as follows:

- Standard Dimension is 54’ x 82’ x 23’ (16.5 m x 25.0 m x 7.0 m).
- Capacity- 750 plants.
- Estimated cost: US $ 15,400.00 (includes frames, cover material, installation, irrigation etc.)

This new imported design included balconies that allows farmers to produce an alternative crop. The height of the structure creates exceptional head space for air circulation and plant growth.

Bel Bubble House

The specifications are as follows:

- Standard Dimension is 20’ x 40’ x 10’ (6.1 m x 12.2 m x 3.1 m).
- Capacity- 220 plants.
- Estimated cost: US $ 1,760.00 (includes lumber, cover material, irrigation, labor, etc.)

This is a local modification of the Tropical Greenhouse constructed from bush posts, lumber and PVC pipes with the goal to reduce cost.

Tunnel

The specifications are as follows:

- Standard Dimension is 14’ x 100’ x 10’ (4.3 m x 30.5 m x 3.1 m).
- Capacity- 400 plants.
- Estimated cost: US $ 1,400.00 (includes posts, pipes, cover material, labor, irrigation etc.)

This type of covered structure is generally more affordable and easier to assemble that the other types. It is recommended for low income farmers who wish to practice greenhouse crop production.

Plastic Covered Structure

The specifications are as follows:

- Standard Dimension is 40’ x 50’ x 12’ (12.2 m x 15.2 m x 3.7 m).
- Capacity- 450 plants.
- Estimated cost: US $ 1,000.00 (includes lumber, cover material, labor, irrigation etc.)

The main benefit of this structure is to reduce the negative impact such as increased incidence of pest and disease damage resulting from periods of prolonged rainfall. There is no use of anti-viral netting so issues of high internal temperature and cost of material is eliminated. However, the crops are more vulnerable to pest and disease attacks.

Most PCS by design and nature can become too warm, thus greatly affecting production and quality of the crop. Cooling is a critical part of the controlled environment and is considered as a basic necessity for greenhouse crop production in tropical and subtropical regions to moderate the problems of high temperatures during the summer months and to adapt to the effects of climate change. Development of effective cooling system that provides congenial microclimate for crop growth is a difficult task as the design is closely related to the local environmental conditions (Kumar, et al., 2009). Basic cooling designs and systems incorporate the following cooling technologies:

- Natural Ventilation (Air exchange) and shading systems
- Mechanical Ventilation powered with solar energy
- Evaporative Cooling: i) Evaporative cooling fan-pads, and ii) High pressure fogging.
- Earth-to-air heat exchange system

***Natural Ventilation*:**

Natural ventilation allows the greenhouse structure to ventilate and cool by natural air movement within and outside the structure. The objective of natural ventilation is to maintain the same temperature inside the greenhouse as it is outside the greenhouse. This can be hard to accomplish because of influences by the solar heat gain through the covering, the type of covering used on the structure and directional placement of the structure on the land in relation to the prevailing winds (Parsons, 2015; FAO, 2011). In greenhouses with natural ventilation, internal and external shade systems can control the heat generated by the solar gain. Shade systems also help control the intensity of the light in the greenhouse, however one disadvantage with shading is the reduction of photo synthetically active radiation (PAR) required by crops (Kumar, et al, 2009). Based on the design of the naturally ventilated greenhouse, one can expect to see temperature difference ranging from near ambient to 10 degrees or more. Kumar et al (2009) indicated that the volume/floor ratio of greenhouse should be large as possible if local wind speed is not too high to maintain favorable environment for crop growth, recommending that combined sidewall vent area should be equal to the combined ridge vent area, and each should be at least 15 – 20 % of the floor area of the greenhouse for tropical conditions.

Shade Mesh: Shade mesh, along with ventilation are a very effective weapon to reduce the temperature inside greenhouses, while favoring plant transpiration.

Mechanical Ventilation with the use of Solar Energy:

Covered structure cooled with natural ventilation can be augmented with mechanical ventilation to improve the airflow and extract the warm air out of the house. Designing for one air exchange per minute for the greenhouse will make ambient temperatures possible inside. Rodriguez (2016, personal comm.) indicated that this technology is seldom used in Quintana Roo, Mexico for multiple tropical greenhouse array because of the high cost of installation and energy needs, and the drying effect the forced ventilation has on sensitive crops.

***Evaporative* cooling:**

Evaporative cooling is the most effective cooling method for controlling the temperature and humidity inside a greenhouse, however, its use in the humid tropics is restricted because of the high humidity environment (Kumar, et al., 2009).

i) *Evaporative cooling fan-pads*

In Belize, 90 % of the PCS or tropical greenhouses in use are inadequately ventilated and this has been identified by agricultural experts as a major hindrance to optimizing the capacity and usefulness of PCS. The proposed solution is to refurbish all of the operational PCS and those that will come on line in the near future, with mechanical ventilation such as calibrated hot-air exhaust fans running on solar energy. The alternative is to run these fans from the electrical power grid, but three constraints identified with this option are: i) too costly for small famers, ii) the greater majority of the PCS and farms have no direct access to the national grid, and iii) smallest farmers have limited or no access to additional credits to cover a monthly, electricity expenditure. Also, a PCS cooling system monthly cost would increase the overall cost of production for small farmers in Belize, and this would result in an increase cost of agricultural produce for the local consumers, which in the long run would be unsustainable.

Where suitable, a combination of factory-produced evaporative wet pads and fans can be installed to run as a combined system together with natural ventilation. The cooling cells of the wet pads are made from a specially formulated cellulose paper impregnated with insoluble anti-rot salts. It is designed with an exclusive cross-fluted configuration which induces highly turbulent mixing inside the pad between the water and the air, and contributes to the evaporative efficiency. The cross-fluted design makes pads a strong self-supporting pad with high evaporative efficiency and low pressure drop (resistance to air flow). Besides the cooling pads, other components of interest in a complete evaporative cooling system include water distribution and return systems.

ii) High pressure fogging

Nebulizer or fog/mist system sprays small droplets (diameters of 2 – 60 μm) with high pressure nozzles that can be run by a 1 HP pump per tropical greenhouse unit from a nearby water reservoir (Kumar, et al. 2009). Cooling is achieved by evaporation of droplets. This method can also be used to increase the relative humidity apart from cooling the greenhouse. Rodriquez (2016. Personal comm.) reports that this method in combination with appropriate shading and natural ventilation is the preferred cooling technologies in Quintana Roo, Mexico. Rodriquez (2016) added that an aluminet mesh ceiling curtain, white plastic ground cover, and hydroponic one-meter coconut husk bags accommodating four seedlings or plants are also used to enhance the cooling system, and ensure higher crop development and improved yields.

Earth-to-air heat exchange system (EAHES)

The ground potential of the earth can also be used for cooling the greenhouse in summer because of its constant year-round temperature (26 – 28 °C) with earth to air heat exchange system. Though earth-to-air heat exchanger system can lower the interior temperature of a greenhouse to a remarkable extent, the major disadvantage of using EAHES is the initial cost involvement and the less longevity of the metallic pipes due to corrosion (Kumar, et. al., 2009).

3.4.1.1 Benefits of using Crop Cover Technology

Table 10 summarises some of the benefits of crop covered structures.

Table 10: Benefits of Crop Covered Structure Cooling Systems

Benefits	**Crop Cover Structure Cooling Systems**
Economic	- Family income increased; stimulate local economy - Famers can diversify crop varieties as market demands changes
Social	- Provide jobs; provide family with income and food security.
Environmental and Climate Change Adaptation	- Provide an ambient and comfortable environment; Protect crops from aggressive rainfall, pest and diseases; conserve water use and reduce the need to deforest more areas for agriculture production. - A cost effective and sustainable climate change adaptation technology for small farmers.

Plate 1 below shows crop covered structures belonging to the University of Belize that require efficient cooling system to improve the micro climate for students and the agronomists. The excess heat that develops in the covered structures or greenhouses from about mid-morning to mid-afternoon limits the agronomic work that can be carried out in the covered structures and increases stress on the plants.

Plate 1: Crop covered structures at Central Farm that require cooling system

(Source: R. Frutos, June 2016)

3.4.2 Improved Drip Irrigation

Drip irrigation is designed for minimum use of water and labour in order to achieve the optimum irrigation of plants in arid and semi-arid regions (Studer and Liniger, 2013; De Tricheria, et al., 2016). Drip irrigation conserves water, and is highly efficient in water applications, but it requires resources for the acquisition of materials.

Advantages of this system include the ability to control fertilizer applications, such as nitrogen, which decreases cost of production. The technology has potential for small cash crops and subsistence applications.

In Belize, drip irrigation is used for small scale farming, primarily for vegetable crops, to some degree of success. In Central Farm, drip irrigation techniques have been applied at various stages. One of the primary challenges with the use of this technology is the difficulty in removing parts of the irrigation hoses to plant new crops. Clogging of hoses is also time-consuming (GOB, 2012).

In the Village of Medina Bank, Ya'axche Conservation Trust, a local NGO, installed drip irrigation as part of its community livelihood and outreach program (Source: Ya'xche Conservation Trust, 2015: https://yaaxche.wordpress.com/tag/drip-irrigation).

Holder (G. Holder, Undated Publication) recommends drip irrigation practices in Belize for vegetable production in various communities. According to Holder, drip irrigation was introduced in the mid nineteen eighties by USAID for use in crops produced by the Belize Agro Business Company.

This technology is suitable in areas with surface or sub surface water sources that are relatively free of sediment or with low sediment loads, where short term crop production is feasible, and where significant periods of water stress occur even in the rainy season (G. Holder, Undated Publication).

Possible benefits of this technology will accrue by equipment protection, and by input suppliers, vegetable producers, papaya producers, the economy through import substitution, in the case of vegetables, and foreign currency earnings with papayas (G. Holder, Undated Publication).

3.4.2.1 Benefits of Improved Drip Irrigation

A summary of the benefits related of improved drip irrigation is contained in Table 11.

Table 11: Benefits of Improved Drip Irrigation

Benefits	Improved Drip Irrigation
Economic	- Reduce cost of crop production; potential to increases yield; stimulate local economy and provide cash crops for local and export markets.
Social	- Increases technical knowledge of farmers; ensure food security for families and communities.
Environmental and Climate Change Adaptation	- Minimum and efficient use of water and fertilizer application (fertigation) to plant root; reduce the need for expanding agriculture frontier into forest reserves; - Very good climate change adaptation technology rain-dependent agriculture systems in the tropics.

Plate 2 below shows one of the rudimentary, drip irrigation demonstration plots at the MOA's training centre at the Belmopan Agricultural Showgrounds.

Plate 2: MOA drip irrigation demonstration plot at the Agricultural Showgrounds in Belmopan

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(Source: R. Frutos, April 2016)

3.4.3 Rainwater Harvesting

Rainwater Harvesting (RWH) is the practice of using technologies for the collecting and storage of water for use in domestic or agriculture purposes (Studer and Liniger, 2013). Studer and Liniger define water harvesting as ***"****The collection and management of floodwater or rainwater runoff to increase water availability for domestic and agricultural use as well as ecosystem sustenance"*.

According to the IFAD (Studer and Liniger, 2013), a RWH system usually consists of three components: (1) a catchment/collection area which produces runoff because the surface is impermeable or infiltration is low; (2) a conveyance system through which the runoff is directed e.g. by bunds, ditches, channels (though not always necessary); (3) a storage system (target area) where water is accumulated or held for use - in the soil, in pits, ponds, tanks or dams.

The harvesting of rainwater is applicable in semi-arid areas with common seasonal droughts. It is mainly used for supplementary watering of various crops including cereals, vegetables, fodder crops and trees. Its use is also applied in the provision of water for domestic and stock use, and sometimes for fish ponds. RWH can be applied on highly degraded soils.

In terms of adaptation and resilience to climate variability, RWH reduces risks of production failure due to water shortage associated with rainfall variability in semi-arid regions, and helps cope with more extreme events. The technology also enhances aquifer recharge, and it enables crop growth (including trees) in areas where rainfall is normally not sufficient or unreliable. Belize has a distinct dry and rainy season, and this seasonal variation is now being exacerbated by climate change. Therefore, Belize is now at risk to greater than normal prolonged dry seasons, and periods of low to no rainfall patterns during the rainy season. Such was the case in 2015, when a drought devastated various crops in northern Belize.

In the light of this, RWH is beneficial due to increased water availability, reduced risk of production failure, enhanced crop and livestock productivity, improved water use efficiency, access to water (for drinking and irrigation), reduced off-site damage including flooding, reduced erosion, and improved surface and groundwater recharge. Improved rainwater management contributes to food security and health through households having access to sufficient, safe supplies of water for domestic use (Studer and Liniger, 2013).

With respect to social and environmental benefits resulting from the adoption and upscaling of RWH techniques, those recommended must be profitable for land users and local communities, and techniques must be simple, inexpensive and easily manageable. Incentives for the construction of macro-catchments, small dams and roof catchments might be needed, since they often require high investment costs. The greater the maintenance needs, the less successfully the land users and / or the local community will adopt the technique (Studer and Liniger, 2013).

Rainwater Harvesting is an option for inducing, collecting, storing and conserving local surface runoff (rain or surface water flow that occurs when soil is infiltrated to full capacity) for agriculture in arid and semi-arid regions (Boers and Ben-Asher, 1982). Both small and large-scale structures are used for rainwater harvesting collection and storage including water pans, tanks, reservoirs and dams.

Techniques available for increasing runoff within ground catchment areas include: i) clearing or altering vegetation cover, ii) increasing the land slope with artificial ground cover, and iii) reducing soil permeability by the soil compaction and application of chemicals (UNEP, 1982). Impermeable membranes can also be used to facilitate run-off. Ground catchment is applicable for low topographic areas and is suitable for large-scale agricultural production as it allows for in-situ storage and usage of fresh water for irrigation.

Conveyance systems for transporting water from the catchment to the storage device include gutters, pipes, glides, and surface drains or channels. Larger-scale conveyance systems may require pumps to transfer water over larger distances. For household-level rainwater harvesting, gutters, down pipes, funnels and filters are required to transfer and clean collected water before it enters the storage device.

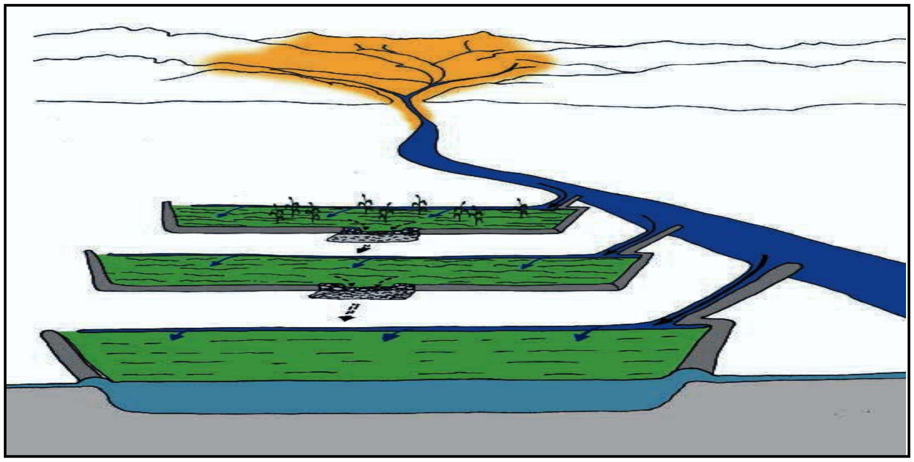

Figure 10: Flood Water Harvesting

(Source: Studer and Liniger, 2013)

Belize has traditionally practiced limited rainwater harvesting; mostly for domestic applications. In the agriculture sector, crops are planted according to seasonal variations of rainfall. Water harvesting has always been limited to provide drinking water for animals, and at small subsistence and small farming operation for irrigation. These consist of elevated tanks of various capacity to collect rainwater from farm structure roof catchments, including crop cover structures and distribution lines (Ramirez, G., Crop Research & Development Unit, *personal comm.* Oct.2016*)*.

Applications in the agriculture sector has been somewhat limited to cattle and other animal rearing, whereby farmers have used this method for obtaining a water source for their livestock to drink from. The low area on their land is excavated to a reasonable depth; vary per area, which serves as a catchment area/reservoir. This then serves as the main water supply for the livestock. While this is not used presently in irrigation for the farms lands, it is a system that can assist the farmers in irrigating their lands. Of course, areas that have low rainfall will find this method not too appropriate; thus, needing catchment ponds.

In the mid-1990s, a small dam at a perennial creek in the Village of Los Tambos, Cayo District, was constructed in order to increase water harvesting and to supply water to the community for various uses. The water was used to raise fish, but mostly to supply small subsistence farming that experienced water stress primarily during the dry season. The catchment dam was used for several years to various degrees of success (E. Avella, Personal Observation).

Rainwater harvesting technology contributes to adaptation by making use of water from sources other than ground or surface water. More efficient use of water supply during periods of drought is also a strategy for adaptation to the reduced availability of water that is projected because of Climate change. Groundwater depletion due to excessive abstraction, land use change and population growth is likely to be exacerbated by these changing precipitation patterns.

Due to the need for water conservation practices and the potential for water resources constraints during the peak of the dry season, one company, Belize Sustainable Agriculture Limited, has proposed to construct storage ponds for the irrigation of corn (Avella & Fernandez, Natural Resource Consulting, 2012.). These ponds will serve both as sediment filtration systems and for water retention for use during peak water demand periods. According to the development plans of this company, the retention ponds will be constructed in 2017 (Mario Fernandez, Personal Communication).

While the use of rainfall harvesting has been mainly used in Belize for provision of water for households and for the cattle industry, the uses can be expanded for general agricultural purposes and irrigation. One of the various catchment areas for rainfall run-off would be the many lagoons, tributaries and rivers. These could be dammed to increase and guarantee the catchment and channel of water to the farmlands via trenches as a general irrigation process. This would assist in the agricultural production even during droughts. This is not a major method used in Belize's agricultural business, but it is important for agricultural development.

Belize's agriculture sector is also diversifying into sugar cane production. The Santander cane farming company located near Valley of Peace Village, Cayo District, proposes to use the vinasse for fertigation, and this may also require the application of various storage and retention ponds (Avella and Garcia, 2012). Another sugar production and processing facility is presently in the planning stages for installation near La Democracia Village, Belize District (M. Fernandez, Environmental Consultant, personal communication, 2015). Again, retention ponds for storage and rainwater harvesting are being planned.

A small sugar cane cultivation and organic farm is being developed by Belcampo Limited and Noble Spirits Belize Land Limited in the Toledo District. Sugar cane will be used to produce rum after the installation of a small distillery capable of distilling approximately 1,000 liters of alcohol per day (Wilderness Group Consulting & Belcampo Limited, 2014). The technology proposed for treatment of the effluent will include aerobic and anaerobic systems, with a lime treatment pond to adjust for pH. This pond will be diluted with rainwater, and its storage capacity can also be used for irrigation of crops.

These examples are a few of the potentially excellent applications that water harvesting will continue to have as the country's agro-industrial growth continues. Annex 6 provides more information about Rainwater Harvesting.

3.4.3.1 Benefits of Rainwater Harvesting

Table 12 is a summary of the benefits of rainwater harvesting for domestic and agricultural use.

Table 12: Benefits of rainwater Harvesting

Benefits	Rainwater Harvesting
Economic	Once the infrastructure is in place, accessing this freshwater resource is free! Minimal cost involved. Initial costs can be accessed from the public purse if the rainwater harvesting is for the local community.
Social	Reduce costs to source freshwater and saving s can be used to meet other expensive for small farming communities.
Environmental and Climate Change Adaptation	Sourcing water from rainfall rather that ground water or from surface freshwater bodies or Reverse Osmosis. Environmentally friendly and an excellent, indigenous climate change adaptation technology to reduce the stress on already stressed freshwater resources.

3.4.4 **Sprinkler Irrigation Technology**

Sprinkler Irrigation technology is a type of pressurized irrigation system that consists of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. These devices replenish the water consumed by crops or provide water required for softening the soil to make it workable for agricultural activities. The goal of irrigation is to supply each plant with just the right amount of water it needs. Sprinkler irrigation is a method by which water is distributed from overhead by high-pressure sprinklers, sprays or guns mounted on risers or moving platforms. A wide variety of sprinkler systems ranging from simple hand-moved to large self-propelled systems are used worldwide. (See the Sprinkler Irrigation Fact Sheet at Annex 4).

A sprinkler irrigation system typically consists of:

i) A pump unit which takes water from the source and provides pressure for delivery into the pipe system.

ii) Main pipes and secondary pipes which deliver water from the pump to the laterals. In some cases, these pipelines are permanently installed on the soil surface or buried below ground. In other cases, they are temporary, and can be moved from field to field.

iii) The laterals deliver water from the pipes to the sprinklers. They can be permanent but more often they are portable and made of aluminum alloy or plastic so that they can be moved easily

iv) Sprinklers, the water-emitting devices which convert the water jet into droplets. The distribution of sprinklers should be arranged so as to wet the soil surface in the plot as evenly as possible.

Sprinkler irrigation technology can support farmers to adapt to climate change by making more efficient use of their water supply. This is particularly appropriate where there is (or is expected to be) limited or irregular water supply for agricultural use. The sprinkler technology uses less water than irrigation by gravity, and provides a more even application of water to the cultivated plot.

A wide range of sprinkler systems are available for small and large-scale application. Set systems operate with sprinklers in a fixed position. These sprinklers can be moved to water different areas of the field, either by hand or with machinery. Hand-moved systems are more labor intensive and may be more suited where labor is available and cheap. On the other hand, mechanically operated systems require a greater capital investment in equipment. Mobile systems minimize labor inputs by operating with motorized laterals or sprinklers, which irrigate and move continuously at the same time (Savva and Frenken, 2002).

Large scale irrigation requires a system that can efficiently deliver water in a relatively short period of time. One such example is the center pivot systems that have the ability to deliver a uniform amount of water over a large area. Center pivot irrigation is a form of overhead sprinkler irrigation consisting of several segments of pipe (usually galvanized steel or aluminum) joined together and supported by trusses, mounted on wheeled towers with sprinklers positioned along its length To achieve uniform application, center pivots require an even emitter flow rate across the radius of the machine. Since the outer-most spans (or towers) travel farther in a given time period than the innermost spans, nozzle sizes are smallest at the inner spans and increase with distance from the pivot point (Source: wikipedia.org/).

Figure 11: Center Pivot Sprinkler Irrigation System

(Source: Wikipedia, the Free Encyclopaedia)

Sprinkler irrigation systems are efficient because they can supply water in large areas in efficient ways, thus reducing water loss. Labor costs are also less than most other systems, and avoids unnecessary erosion as a result of other irrigation systems. It also reduces the need for tillage, thus reducing time and soil compaction.

As a source of economic, social and environmental benefit, the Sprinkler irrigation technology can help farmers to adapt to climate change by making more efficient use of their water supply. This is particularly appropriate where there is (or is expected to be) limited or irregular water supply for agricultural use. The sprinkler technology uses less water than irrigation by gravity, and provides a more even application of water to the cultivated plot.

While in Belize the sprinkler irrigation system is used on a small scale in the agricultural business, the system is one that needs to be investigated more and utilized. One of the reasons the system is not widely used is the cost. The general cost is related to; 1.) Having the required reservoir to supply the water when needed 2.) Importing the irrigation system and 3.) The number and size of pumps required, especially in remote areas. This system was necessary during the 2015 drought that affects the northern districts. An extremely large acreage of corn was lost in 2015 due to the drought the area experienced.

The Belize Sustainable Agriculture company plans to use sprinkler irrigation technology for the production of corn, for which it plans to install several large retention ponds as a source of water supply (Avella and Fernandez, 2012). These ponds will be supplied by surface runoff during the rainy season.

Sprinkler irrigation also has the potential for use in other crops such as beans. Other companies are already considering sprinkler irrigation technologies in Belize. A new proposed sugar cultivation company near La Democracia, Belize District, is considering the application of sprinkler irrigation to produce sugar cane, and other experimental crops (M. Fernandez, Personal communication).

Sprinkler irrigation systems would change the need to plant based on seasonal schedules that are dependent on the initial rainfall at the onset of the rainy season. This would allow more efficient management of crops, providing a more reliable time for harvest, and marketing of products. Large scale agriculture establishments would be able to ensure the initial water supply to new crops that would allow these to grow while the heavier rains begin; thus providing a head start in terms of harvesting and selling of products.

The National Agriculture Strategy and Action Plan calls for the installation or improvement of efficient irrigation systems for the production of corn, bananas, and rice in Belize.

3.4.4.1 Benefits of Sprinkler Irrigations

Table 13 contains a summary of the benefits of sprinkler irrigation systems to meet crop water requirements in larger acreage of crop production.

Table 13: Benefits of Sprinkler Irrigation Systems

Benefits	Sprinkler Irrigation Systems
Economic	Initial cost is high but the returns to a single farmer or to a group of farmers or farming cooperatives could soon cover this cost, since two or even three cropping seasons per year can be done per year for corn, sorghum and other grains (Mr. Redman, grain farmer, Cayo District, Belize; personal comm., July 2016).
Social	Contribute substantially to improved food production and livelihood of farming communities when system is used by farmer's group to reduce costs.
Environmental and Climate Change Adaptation	More efficient use of farm water supply. This is particularly appropriate where there is (or is expected to be) limited or irregular water supply for agricultural use. The sprinkler technology uses less water than irrigation by gravity (e.g. flood irrigation), and provides a more even application of water to the cultivated plot.

3.4.5 Crop Diversification and New Varieties

The introduction of new cultivated species and improved varieties of crop is aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. Factors influencing the decision to adopt crop diversification include:

- Increasing income on small farm holdings
- Withstanding price fluctuation
- Mitigating effects of increasing climate variability
- Balancing food demand
- Improving fodder for livestock animals
- Conservation of natural resources
- Minimizing environmental pollution
- Reducing dependence on off-farm inputs
- Depending on crop rotation, decreasing insect pests, diseases and weed problems
- Increasing community food security.

Crop diversification practices in Belize have already begun in some areas. Diversification of crops would result in the production of alternative crops that would be profitable when traditional crops are not. New crops with higher yield and water efficient use would reduce costs and boost economic benefits to communities.

In small scale farming in Belize, many farmers have employed intercropping systems in order to maximize profits and buffer failures of a mono crop, in the event of an unexpected failure of one crop.

Figure 12: Intercropping on a Small Farm in Belize

New and improved crop species can be introduced though two different processes:

1. Farmer experimentation with new varieties. Farmers have introduced new and improved species over centuries in response to environmental stress conditions. There are many thousands of existing varieties of all of the important crops, with wide variation in their abilities to adapt to climatic conditions. Agricultural researchers and extension agents can help farmers identify new varieties that may be better adapted to changing climatic conditions, and facilitate farmers to compare these new varieties with those they already produce. In some cases, farmers may participate in crossing select seeds from plant varieties that demonstrate the qualities they seek to propagate to develop new varieties with the characteristics they desire. (www.climatetechwiki.org/content/crop-diversification-and-new-varities).

2. Crop Diversification and New Varieties contribute to adaptation by introducing new and improved crop varieties that enhance the resistance of plants to a range of stresses that could result from climate change. These potential stresses include water and heat stress, water salinity, excess water stress and the emergence of new pests. Crop varieties that are developed to resist these conditions will help to ensure that agricultural production can continue and even improve despite uncertainties about future impacts of climate change. Varieties with improved nutritional content can provide benefits for animals and humans alike, reducing vulnerability to illness and improving overall health (www.climatetechwiki.org/content/crop-diversification-and-new-varities).

In the 1980's sugar earnings plunged to a low of $45.9 million due to conditions such as smut disease, high domestic interest rates, depressed world sugar prices and limited quota. Crop diversification for the export market became the central focus. This saw the advent of the Papaya industry and the ballooning of the corn production industry.

When farmers cultivate a single crop type they are exposed to high risks in the event of unforeseen climate events that could severely impact agricultural production, such as emergence of pests or drought. With a diversified plot, the farmer increases his/her chances of dealing with the uncertainty and/or the changes created by climate change. This is because crops will respond to climate scenarios in different ways. Whereas the drought may affect one crop negatively, production in an alternative crop may increase.

The one crop system was seen this year to have resulted in major loss as Belize experienced some serious drought that affected North Western Belize, resulting in entire corn and rice crops to be lost, with financial losses amounting to millions of dollars.

Benefits of Crop Diversification and New Varieties

Table 14 is a summary of the economic, social, environmental and climate change adaptation potential of crop diversification and introduction of new varieties into the farming system in Belize.

Table 14: Benefits of Crop Diversification and New Varieties

Benefits	Crop Diversification & New Varieties
Economic	Crop diversification provides better conditions for food security and enables farmers to grow surplus products for sale at market and thus obtain increased income to meet other needs related to household well-being. Crop diversification and climate resilient varieties ensures higher yields, and enable farmers to gain access to national and international markets with new products, food and medicinal plants. Diversification can also manage price risk, on the assumption that not all products will suffer low market prices at the same time. Generate revenue and stimulate the local economy.
Social	Increase food security and balancing food demand. Diversifying from the monoculture of traditional staples can have important nutritional benefits for farmers in developing countries and can support a country to become more self-reliant in terms of food production.
Environmental and Climate Change Adaptation	Crop diversification and climate resilient varieties reduce risks, is an environmentally friendly farming system, and a climate change adaptation strategy to stave off food insecurity, and halt the agricultural frontier in sensitive, tropical, forests ecosystems.

3.4.6 Soil Conservation

Soil conservation provides adaptation benefits through the prevention of soil loss from erosion or reduced fertility caused by overuse, acidification, salinization or other chemical soil contamination. Soil conservation is the act of keeping the soil in place and healthy. Where erosion is taking place or the soil is becoming contaminated with metals, acids or through overuse, soil fertility is lost.

Soil is a fundamental requirement for crop production since it provides plants with anchorage, water and nutrients. Furthermore, minerals and organic nutrient sources are present in soils, which are supplemented with external applications, or fertilizers, for better plant growth. Fertilizers enhance soil fertility and are applied to promote plant growth, improve crop yields and support agricultural intensification (Source: Climate techwiki.org, 2015).

Fertilizers are typically classified as organic or mineral. Organic fertilizers are derived from substances of plant or animal origin, such as manure, compost, seaweed and cereal straw. Organic fertilizers generally contain lower levels of plant nutrients as they are combined with organic matter that improves the soil's physical and biological characteristics. The most widely-used mineral fertilizers are based on nitrogen, potassium and phosphate (Source: Climateteckwicki.org).

Soil conservation also includes restoration. Soil restoration of degraded lands and peatlands, are now recognized by the IPCC (IPPC, 2007), as extremely important soils retaining CO_2 and N_2O. In Belize, lands submerged by water, including peat lands, are increasingly being developed for urbanization and in some cases for agriculture.

The United States Soil and Water Conservation Society (SWCS) (Soil and Water Conservation Society, 2003), reports that in the United States, climate change is resulting in precipitation changes that in turn result in increased runoff and soil erosion. It goes on further to state that "the potential for climate change—as expressed in changed precipitation regimes—to increase the risk of soil erosion, surface runoff, and related environmental consequences is clear".

The report by the SWCS further explains that a change in precipitation regime also produces a change in the level of risk to which agricultural land is exposed. Generally, in situations where there is greater annual precipitation heightens the risk of soil erosion especially if there is an increase in storm intensity more so than increase in frequency of storms. This increase in precipitation also increases, runoff, and leads to related environmental and ecological damages. In general, the risk increases at a greater rate than precipitation amount or intensity. However, it also states that other high-risk baseline factors also contribute to greater soil degradation, pollution of surface water, pollution of groundwater, or a combination of all three.

The fact is that models and forecasting continues to confirm the potentially damaging impacts of climate change, including those that can result from surface runoff and soil erosion and soil cover loss.

Soil conservation as an adaptation measure has tremendous potential in Belize because land degradation is becoming increasingly important, primarily due to increased urbanization, inadequate waste disposal (liquid and solid waste), and the advance of the agriculture frontier. At times squatters and farmers with little or no resources have encroached in marginal lands that would best serve in reserve state. In Belize, illegal encroachment of National Lands by citizens seeking livelihoods from neighbouring countries also threaten lands that are under protected areas status.

For example, the Chiquibul protected areas and adjacent lands are under constant threat from degradation due to illegal extraction of forest resources, and gold, and illegal cultivation among others.

There have been dispersed efforts towards soil conservation, including organic farming, composting and re-forestation efforts throughout the country. The country should capitalize on these efforts, since climate change will continue to threaten lands and increase the risk for erosion and soil cover loss.

Figure 13: Compost from Food Waste (Left); Organic Farming (Right), Black Rock Lodge

3.4.6.1 Benefits of Soil Conservations

Table 15 is a summary of the benefits for farmers who practice soil conservation and soil fertility enhancement.

Table 15: Summary of Benefits of Soil Conservation

Benefits	**Soil Conservation**
Economic	- Reduce the need to invest in expensive fertilizers; reduce production costs overall; increases farmer's assets - Stem soil erosion and contamination
Social	- Ensure family livelihood security; help keep communities together by increasing employment, improving health and education opportunities. Help stem the urban migration.
Environmental and Climate Change Adaptation	- A critical climate change adaptation technology that can help reduce land degradation and help reduce farmer's carbon footprint - Increases soil fertility and reduce the need to deforest more land for agriculture.

3.5 Criteria and Process of Technology Prioritization for the Agriculture sector

The technologies selected for the Agriculture sector during the revision of the technology needs with stakeholders in the first quarter of 2016 were:

1) *Improved drip irrigation systems for crop water requirement, fertigation and water harvesting for small farmers*

2) *Covered Structure Cooling Systems*

3) *Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties better suited to Belize's current and future climate*

4) *Heat and Drought Resistant variety of open-pollinating corn and black beans seeds for reproduction and marketing among small farmers in Belize*

5) *Micro climate monitoring system for sustainable soil and land management in Agriculture and Agroforestry*

Table 16 shows the seven criteria selected for the technology prioritization process for the five climate change adaptation technologies for the Agriculture Sector.

The Agriculture Sector small working group was of the opinion that "Capital Investment Cost" was the most important criteria for the technology transfer interventions being proposed under the TNA project. The preferred value for this criterion was "Low". "Operating Cost" was also considered to be critical for the successful implementation of the technology transfer. Again, the preferred value was "Low".

"Adaptation potential" of these technologies was selected as third-in-line because the over-arching objective for the technology transfer was for stakeholders and beneficiaries to build resilience and livelihood security in the face of impending climate change impacts, which in turn translates to a measure of the sustainable development of Belize.

The other criteria, namely "Job creation/poverty reduction, Life of technology, Technology replication, and Environmental impact (% increase in eco-agriculture)" all had the preferred values as "High".

Table 16: MCA Criterion and Category for Agriculture Sector Technologies

	Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)
Criterion 1	Capital Investment cost	cost	$	Low
Criterion 2	Operating cost	cost	$	Low
Criterion 3	Adaptation potential	Social	% increase resilience	High
Criterion 4	Job creation/poverty reduction	economic	# persons employed	High
Criterion 5	Life of technology	Technology	# years	High
Criterion 6	Technology replication	economic	local capacity	High
Criterion 7	Environmental impact	Environmental	% increase eco-agriculture	High

Table 17 is a summary of the weighting allotted to each criterion. Here "Adaptation potential" and "Environmental impact" (% increase in eco-agricultural practices) carried the larger weights of 20 and 17, respectively. The stakeholders agreed that Capital Investment Cost or Operational Costs should not preclude the importance of Climate Change Adaptation potential or positive environmental impacts of the technology, hence the higher 'weighting' for these criteria.

Table 17: Criterion and Weight (%) for Agriculture Sector Technologies

Criterion	Allocation of budget	Weight %
Capital Investment cost	15	15%
Operating cost	10	10%
Adaptation potential	20	20%
Job creation/poverty reduction	10	10%
Life of technology	15	15%
Technology replication	13	13%
Environmental impact	17	17%
	Total 100	**100 %**

Plate 3 and Plate 4 are scenes of the small group discussions and deliberations during the MCA and Barrier Analysis sessions for the Agriculture technologies at Central Farm.

Plate 3: Agriculture Technicians discuss criteria and weighting during MCA exercise at Central Farm

Plate 4: Agriculture technicians and plant propagation specialist at the small group meeting for the MCA and Barrier Analysis sessions.

3.6 Results of Technology Prioritization in the Agriculture sector

Table 18 is a summary of the prioritized Agriculture Sector Adaptation technologies resulting from the Multi Criteria Assessment (MCA) process. As can be observed, the prioritized technologies for the Agriculture Sector were:

- "*Heat and Drought Resistant variety of open-pollinating corn and beans seeds for reproduction and marketing";*
- "*Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement*";
- *"Protective Structure Cooling Systems."*

After further consultation with key stakeholders in the Agriculture Sector, it was recommended that technology No. 4 which scored fourth in the MCA process, namely *"Establish an in-country Irish* *potato clean-stock production unit to produce quality seed-tuber planting material varieties"*, be considered for further evaluation and analysis in the Barrier Analysis and Enabling Framework stage of the TNA process. The reason being that drought resistant potato seed propagation in Belize is viable and a priority in the food security strategy, in the light of pressing climate change stress on crop production.

Table 18: Prioritized Agriculture Sector Adaptation Technologies

Rank	Option	Weighted Score
1	◦ Heat and Drought Resistant variety of open-pollinating corn and beans seeds for reproduction and marketing	74.0
2	◦ Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement	49.5
3	◦ Protective Structure Cooling Systems	44.8
4	◦ Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties	31.7
5	◦ Micro climate monitoring system for sustainable soil and land management in Agriculture and Agroforestry	20.4

CHAPTER 4: TECHNOLOGY PRIORITIZATION FOR THE WATER SECTOR

4.1 Key Climate Change Vulnerabilities in the Water Sector

4.1.1 Water Resources Sector

Water supply in Belize comes from mainly three sources including underground, surface water (rivers, lakes and lagoons) and desalinisation of seawater (Ambergris Caye and Caye Caulker). The underground water resources are considered extensive, especially in the Savannah and Campur provinces. The Department of Agriculture promotes and encourages irrigation and relies heavily on underground water although no assessment of the underground water resources and its quality has been done. Despite Belize's water abundance, recent issues with water scarcity in some areas and water quality have become more commonplace as various stresses on water resources increase. Key issues with water vulnerability in Belize are the uneven distribution of water resources. The southern region (Toledo) has the lowest population, with the highest amount of freshwater availability, whereas the central and northern regions (Orange Walk and Corozal) both have much larger populations and much less water resources. Freshwater supplies are considered sufficient for the current population, though there is an increased stress on these supplies due to population growth, increases in economic and agricultural activities, as well as an increase in droughts incidents (GOB, 2015).

Rainfall is projected to decrease slightly and become more variable as demonstrated by intense rains and flooding on the one hand and droughts on the other. The risks would be from flooding due to excessive rainfall in the low-lying coastlands, as well as the impact on agricultural production, which would be subject to the alternating conditions of excessive rainfall and flooding on the one hand and drought on the other.

Belize's water sector will also be affected by sea level rise and storm surges causing saline intrusions into coastal aquifers and soils and flooding of coastal lowlands and towns, where the bulk of the population of Belize is located. (GOB, 2015).

The lack of information regarding groundwater, especially in northern Belize leads to a difficulty in the management of future water resources under climate change and increases the vulnerability of communities. In 2008 an integrated water management policy and an integrated water management authority was formed in the Ministry of Natural Resources and Agriculture. Such an approach allows an equitable management of water resources, which will be particularly important with declining water resources under climate change (CARIBSAVE, 2012).

The demand for fresh water resources in Belize emanates from three (3) broad economic sub-sectors: agricultural, industrial and domestic/residential. The growing population and economy will lead to greater competition amongst these three key sectors, for increasingly lesser and lesser water supplies.

The economic effects of climate variability on agriculture are already evident as seen in recent incidents of flooding and drought in Belize (BEST, 2008, 2009).

Belize has currently four hydropower sites, Mollejon (dam), Chalillo and Hydro Maya (run of the river) on the Macal River, and a small-scale power plant at Blue Creek on the Rio Hondo. Hydropower generation utilizes high volumes of water. Therefore, any significant change in the hydrological cycle will affect hydropower facilities and will threaten the reliability and security of Belize's electric supply. River flow would be further reduced if agriculture and potable water demands were given higher priority. With reduced rainfall, water replenishment rates may not keep up with rates of usage. This will cause hydroelectric dams to be less efficient leading to higher costs of electricity as the country becomes increasingly reliant on fossil fuels (BEST: 2008, 2009). The introduction of technologies that enable adaptation to projected water availability will build resilience within this sector.

4.2 Decision Context

The vulnerability of water resources to the impacts of climate change is related to the following:

- higher evaporation and evapotranspiration rates arising from increase in temperature;
- changes in intensity, quantity and frequency of rain events (less rainfall is expected but higher intensity);
- Sea level rise will likely result in salt water intrusion into coastal aquifers, exacerbating water scarcity in a warmer climatic regime;
- Sea level rise will enhance storm surges associated with higher intensity, landfalling tropical cyclones, pushing the salt water lens farther inland, and increasing salinization

rates;

- Climate change will also exacerbate unsustainable land use in the upper watersheds, directly impacting runoff rates, and reducing recharge of groundwater;
- Climate change will intensify the hydrological cycle, resulting in short periods of intense, life-threatening rainfall, followed by extended and punishing droughts.

The main objective of the National Climate Change Policy, Strategy and Action Plan (NCCPSAP) is to build resilience to the negative impacts of Climate Change in key sectors, namely: economic sector, society and the environment. The policy is cognizant of the negative effects on the productive sectors such as the coastal zone and human settlement, fisheries and aquaculture, agriculture, forestry, tourism, water, energy and health; the physical environment such as land and infrastructure, including roads and coastal structures, as well as the sustainability of natural ecosystems and biodiversity.

The Belize Nationally Determined Contribution (NDC, 2016) highlights the priority sectors and main actions to be implemented to build resilience, in accordance with the NCCPSAP. In the water sector, the proposed actions to be implemented are: design and conduct an IWRM programme at the watershed level; enhance the protection of water catchment (including groundwater resources and recharge areas); develop water conservancy management systems; conduct water resource assessment (especially groundwater); devlop flood control systems and drought monitoring; step-up trans-boundary cooperation regarding water resources; strengthen the human resource capactiy in the water sector; strenghten the compliance monitoring capacity of staff; and underatke water policy reform..

The National Integrated Water Resources Act was drafted in 2010 but has still not been fully implemented. It is a comprehensive legislation that provides for the establishment of a Water Resources Management Authority. It introduces control and regulations for the abstraction of water and the pollution of water through discharge of effluents. The Act also incorporates a Master Plan for the management of the country's water resources. Uncontrolled use of water had been described as a contributing factor to vulnerability of Belize's water resources.

The enforcement of this Act is essential to ensure the longevity of water supply in the future. The control in the number and types of wells being drilled for water sources is a part of the program to monitor the availability and use of the water resources for agricultural and domestic purposes. A program is presently being addressed by the Public Utilities Commission (PUC) to map the various aquifers as well as to determine the status of fresh water and its availability in the Country. The PUC also maintains the mandate to establish tariffs for water use for domestic and commercial supply. There is also monitoring of the levels of water in some rivers and other surface water sources by the Hydrology Department and the National Meteorological Service. Water use, abstraction from rivers, for industrial, agriculture and energy generation is currently unregulated, but the enforcement of the National Integrated Water Resources Act should enable control of such activities.

There are a few farmers who utilize sprinkler irrigation for cultivation of beans in the northern districts, but the data is not recorded. The Belize Ministry of Agriculture has been encouraging the use of irrigation to reduce water use and improve the quality of crops and yields through reliable water supply.

4.3 Overview of Existing Technologies in the Water Sector

Options for Adaptation technologies under consideration for the Water sector include: a Water Resource Database; Water Reclamation and Reuse, Water Desalination, Water Safety Plans, and Water Efficient Fixtures and Appliances

4.3.1 Water Resource Database

The Belize Water Service Limited (BWSL) has monitoring equipment in place to trace, identify and quantify leakage, and a water balance account system/database on supply and demand, based on supply, consumption and leakage. Over the years since BWSL was established, it has made significant improvements in reducing the Non-Revenue Water (NRW) which has resulted in water loss volume being reduced by 20.3% since 2004. The company has gone to great efforts to improve efficiency of operations in almost every area and process with a view to improving customer satisfaction, response times, and reducing costs. Figure 14 is graph of water productivity, sales and non-revenue water recorded by BWSL for the period 2002-2009. Since 2009, the company has continued to reduce leakage in its distribution system and kept NRW at an acceptable level. BWSL Database on water supply and demand, leakage and customer service information is an example of a technology that can be replicated at the national level for the management of both surface and groundwater resources.

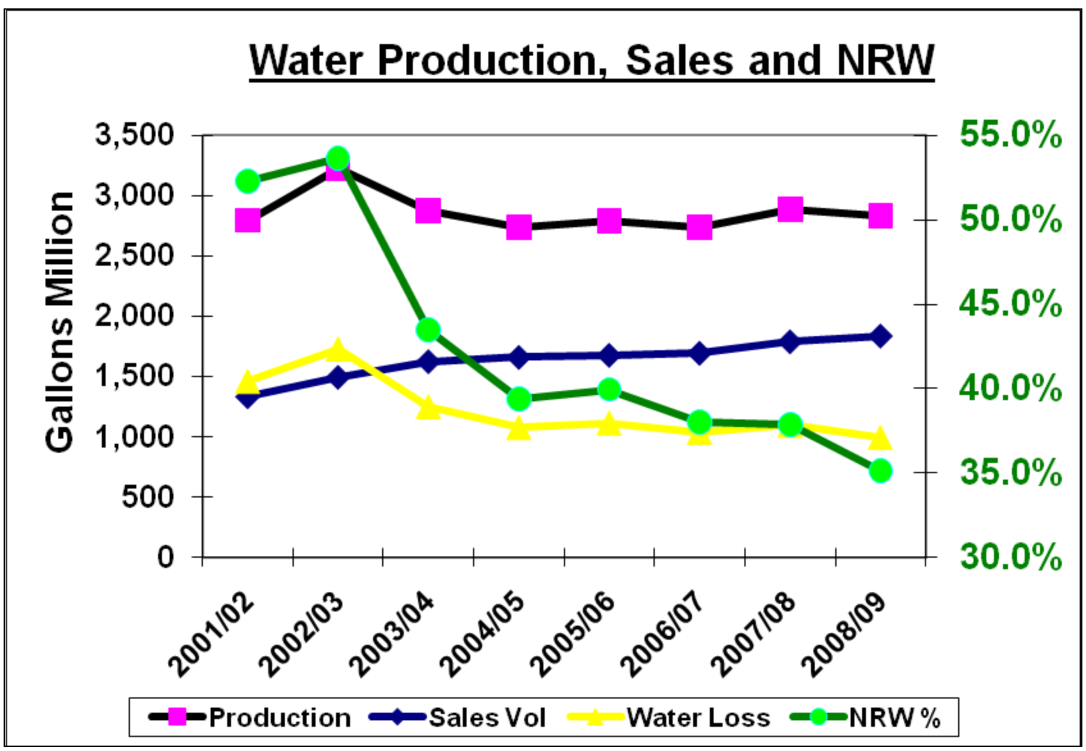

Figure 14: BWSL Water Production, Sales and NWR for the Period 2002-2009

(Source: Source of data is from BWSL, Belize)

4.3.2 Water Reclamation and Reuse

Companies such as the American Sugar Research-Belize Sugar Industry (ASR-BSI), Santander Sugar Company, and Crystal Bottling Company, all have technology in place for internal water reclamation, recycling and reuse. The waste water generated from less-intensive production process is stored in large storage tanks, treated and recycle through the system for reuse in cooling systems, cleaning and washing.

4.3.3 Water Desalinization

Water desalinization through Reverse Osmosis is done locally on a small scale at large tourist resorts and hotels, mainly at the Cayes or offshore tourist destinations, where connection to the national water service provider is not possible. At the municipal level, water desalinization with Reverse Osmosis technology is established at San Pedro, Ambergris Caye; Caye Caulker and Placencia. The water desalinization plants are privately owned and operated, and the product water is sold to BWSL for distribution. The water desalinization plants at San Pedro, Ambergris Caye, the largest of these three, is owned and operated by Consolidated Water Belize Limited (CWBL). The plant has the capacity to produce 470,000 gallons of fresh water per day from sea water. The product water is stored in CWBL's 1 million Gallon tank, then pumped into the BWSL elevated tank for distribution. Figure 15 is schematic of the CWBL reverse osmosis water desalinization system. Figure 16 shows CWBL water storage tank and one set of filters used at the RO plant.

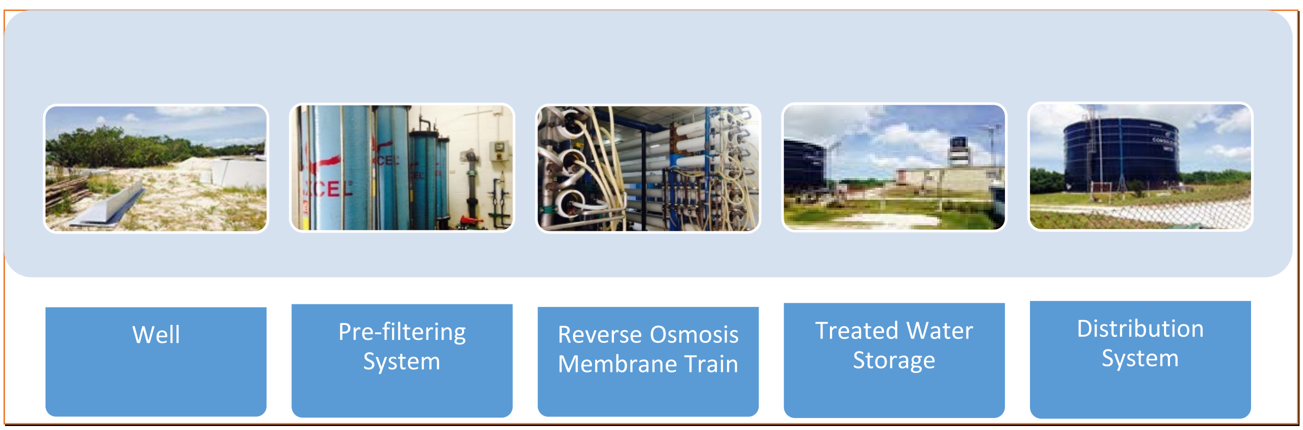

Figure 15: Schematic of a typical Reverse Osmosis System

Figure 16: CWBL water storage tank and filters used at the RO Plant in San Pedro

Reverse Osmosis desalinization plants come in different size and capacity. There are also small, mobile systems that are less expensive. The initial cost and maintenance costs of this technology are high, and the disposal of brine is either via deep injection wells or directly into the sea, away from the shoreline, where it causes minimal impacts.

4.3.4 Water Efficient Fixtures and Appliances

Water efficient fixtures and appliances are now locally available at several hardware stores in Belize. These include: Low-flow aerators, Facet controls, Low-flush and composting toilets, water efficient appliances with green tag, and pressure reducing valves. Low-flush and composting toilets come with technologies such as pressure-assisted toilets that use compressed air to assist the flush; pump assisted toilets; vacuum assisted toilets utilize a vacuum inside the tank to pull the wastes; ultra-low flush tank toilets; composting toilets; flush-o-meter toilets that utilize a flush valve which allows a metered amount of water to enter the toilet under pressure; and waterless urinals that requires no water except for occasional cleaning.

4.3.5 Water Treatment and Bottled Water

Reverse Osmosis (RO) and ultraviolet light technology is used for water treatment to improved quality for the bottled water industry. In Belize, small entrepreneurs are investing in the bottled water industry as demands for this product increases.

4.4 Adaptation Technology Options for Water Sector and their Main Adaptation benefits

4.4.1 Water Safety Plans

The World Health Organization (WHO, 2008) Guidelines for Drinking Water Quality (GDWQ) is the basis for current water quality standards in many countries around the world. In the GDWQ, Water Safety Plans (WSPs) are described collectively as a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. WSPs enable identification of threats to water safety during any and all steps in the catchment, transport, treatment and distribution of drinking water. When implemented successfully, the WSP approach can ensure that water quality is maintained in almost any context.

A Water Safety Plan consists of three separate activities: system assessment, monitoring and management.

System assessment: During this phase of a WSP, potential hazards to water quality and health are identified at key steps or locations, normally referred to as Critical Control Points (CCPs), within specified boundaries of a water supply chain. Associated risks of negative health outcomes due to these hazards are also quantified at this time.

Monitoring: once health risks have been defined, they are used to develop a prioritized and system-specific plan for monitoring and controlling hazards at each CCP during the monitoring phase of a water safety plan. Such a plan will define operational parameters and associated sampling and reporting methods. Critical limits or targets for these parameters should be defined at this time.

Management: The actions necessary to correct any issue identified during monitoring are established in the management phase of a WSP. Such measures may include alleviation of source water contamination through controlling activities in the watershed, optimization of physical or chemical treatment processes, and prevention of recontamination during distribution, storage and handling (Water Safety Plans, 2010). By controlling hazards at the water supply system's CCPs, any issue that occurs in the catchment or distribution network can be detected and corrected before water of poor quality is delivered to the consumer.

WSPs contribute to climate change adaptation at the catchment level primarily through increased resilience to water quality degradation. The WSP approach allows for water suppliers to be flexible and responsive to changing input parameters. This means that the monitoring, management and feedback components of a successful WSP naturally absorb the acute impacts of climate change. The WSP approach can also be modified to adapt to long-term climate change and slow-onset hazards by recognizing how the water supply system may be affected by specific climate change effects, by factoring these effects into the risk assessment, and by identifying appropriate control measures.

Belize does not have Water Safety Plans in place. Limited monitoring of water quality occurs, and water is routinely treated for domestic and commercial Water resources management at the catchment level is shared responsibility. For example, the management practices employed by the Forest Department seek to maintain, protect, and preserve forest cover in watersheds, which assists replenishment of the aquifers and surface water. The Lands and Surveys Department recommends that a minimum of 66 feet of riparian forest is preserved on the banks of all permanent water ways and on the coast. This assists with maintaining water quality by limiting runoff and functioning as filters against nutrients and pollutants. Neither the economic not the environmental benefit is realized because these regulations are not consistently enforced. See Annex 5.

4.4.1.1 Benefits of Water Safety Plans

A summary of the economic, social and environmental benefits of Water Safety Plans is contained in Table 19. Plate 5 shows the Water Sector small working group experts deliberating during the MCA and Barrier Analysis exercise for the Water Sector technology factsheets.

Table 19: Summary of Benefits of Water Safety Plans

Benefits	Water Safety Plans
Economic	- Improve efficiency of water delivery services (E.g. Rudimentary Water Systems); - Reduce cost of production; - Help reduce health cost; - Provide jobs
Social	- Address incidence of water-borne diseases among community members - Ensure reliable water services for communities
Environmental and Climate Change Adaptation	- Contribute to water conservation efforts; - Very effective climate change adaptation measure - Control on the groundwater withdrawal volumes and reduce stress on the aquifers

A summary of the economic, social and environmental benefits of Water Safety Plans is contained in Table 19. Plate 5 shows the Water Sector small working group experts deliberating during the MCA and Barrier Analysis exercise for the Water Sector technology factsheets

Plate 5: Water Sector Small Working Group deliberate during MCA and Barrier Analysis exercise at the NCCO in Belmopan

4.4.2 Water Efficient Fixtures and Appliances

Water Efficient Fixtures and Appliances in homes, institutions and businesses can contribute greatly to water conservation efforts. In Japan, residential per capita water use increased by about 25% in the 1980s, leveled off in the 1990s and began to decline in 2000. This progress has been attributed to the increasing use of water efficient appliances and fixtures (Nakagawa et al., 2010).

The most common water efficient appliances include dishwashers and clothes washing machines; popular fixtures include toilets, showerheads and faucets. They can simply use less water while yielding comparable performance (e.g. low-flow showerheads). Alternatively, these appliances can be more complex, as devices that use gray water from the sink for toilet flushing. Other products give visual or audible feedback to the user about resource consumption and rely on behavior change (Elizondo and Lofthouse, 2010).

The transfer of the water efficient technologies from wealthy countries to developing countries can potentially hasten progress toward the per capita decline in water use and conservation of water resources. Making efficient appliances available on the market is necessary but may not be sufficient. Three major strategies to increase the use of water efficient appliances and fixtures are discussed below:

- Mandates – mandating water efficiency standards for new construction and replacement of old fixtures and appliances; mandating use of water efficient products in government facilities.
- Labeling – certification systems for water efficient products; adding the estimated cost of use, also called the "second price tag," to labels.
- Tax incentives – for purchasing and installing efficient products; for retro-fitting and replacing older fixtures.

Educating users, metering individual homes, implementing volumetric pricing, fixing leaks, and limiting outdoor water use are also important steps for conversion (Elizondo and Lofthouse, 2010; USEPA, 2008).

The adaptation benefits derived from Water Efficient fixtures and appliances is through water conservation which is an essential part of comprehensive strategies to reduce pressure on existing water resources. The industrial and agricultural sectors account for a large majority of global freshwater use. However, total freshwater withdrawals reported for 163 countries by the Pacific Institute showed that in the median country residential water use accounted for 16% of total freshwater withdrawals (Gleick et al., 2006). Therefore, residential conservation efforts can make a strong positive contribution to reducing pressure on water resources.

Excessive use of water in Belize is as a result of improper plumbing. The Belize Water Services Limited (BWSL) has shown in their annual report that a large volume of losses were as results of major leaks in households as well as improper appliances, specifically toilets. The water losses were also found to have been due to old main pipe lines that had been installed. Presently the company had undergone a major upgrading of their pipelines which has reduced their losses considerably. The BWSL along with the Public Utilities Commission (PUC) and Central Building Authority (CBA) are in the process of revising the plumbing code as well as working with the Education Department to get plumbers trained and licensed. The expected outcome of this project is the reduction of water losses in the household due to improper plumbing and appliances. The loss reduction will minimize the volume of water extracted from the river and other surface water sources as well as wells in the rural areas.

There would be economic and environmental benefits if Belize was to implement a policy of installing and utilizing water efficient fixtures and appliances. The initial capital cost would be higher than that of the older fixtures and appliances, but savings would be realized over the short and long term thereby providing economic and social benefits. Environmental benefits accrue from reduced extraction and waste of water. See Annex 8 for additional information.

4.4.2.1 Benefits of Water Efficiency Fixtures and Appliances

Table 20 is a summary of the benefits of water efficiency fixtures and appliances. In general, water efficiency fixtures and appliances are is cost effective in the medium to long-term and is a means of water conservation in large hotels and resorts where daily water use among visitors is normally two to three times the water consumption of the local population.

Table 20: Summary of the Benefits of Water Efficiency Fixtures and Appliances

Benefits	Water Efficiency Fixtures & Appliances
Economic	- Stimulate market for trading of water efficiency appliances and fixtures; - Reduced water loss; - Increase value of property.
Social	- Reduction in water bills and water use footprint in homes and public sector buildings; - Reduction of per capita water use
Environmental and Climate Change Adaptation	- Water conservation - Personal and effective adaptation technology for homes and public buildings and industry; - Enhances hotels and resorts *Green Label*; - Indirectly contribute to ecosystem water needs and viability

4.5 Criteria and Process of Technology Prioritization for the Water sector

4.5.1 Multi-Criteria Analysis Process for Water Sector Technology

The Multi-Criteria Analysis (MCA) process for the Water Sector was conducted with the Small Working group for the water Sector. The MCA process was reviewed and the group proceeded to conduct the analysis using the MCA Excel tool.

The Criterion approved by the Group in order of importance were: Capital Investment Cost, Water Resource Resilience, Adaptation potential, Job creation/poverty alleviation, Technology replication, Environmental impact, Operating cost, and Life of technology. Table 21 is a summary of the criteria and value preferred. Table 22 shows the list of criteria and the allocated weighting.

Table 21: MCA Criterion and Category for Water Sector Technologies

	Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)
Criterion 1	Capital Investment cost	cost	$	Low
Criterion 2	Operating cost	cost	$	Low
Criterion 3	Adaptation potential	Social	level of resilience	High
Criterion 4	Job creation/poverty reduction	economic	# persons employed	High
Criterion 5	Life of technology	Technology	# years	High
Criterion 6	Technology replication	Local capacity	# of persons benefiting directly from training/ capacity building	High
Criterion 7	Environmental impact	Environmental	level of water stress	Low
Criterion 8	Water Resource resilience	Environmental	level of resilience	High

Table 22: Criterion and Weight (%) for Water Sector Technologies

Criterion	Allocation of budget	Weight, %
Capital Investment cost	15	15%
Operating cost	10	10%
Adaptation potential	14	14%
Job creation/poverty reduction	12	12%
Life of technology	10	10%
Technology replication	12	12%
Environmental impact	12	12%
Water Resource resilience	15	15%
	Total 100	**100 %**

4.6 Results of technology Prioritization in the Water sector

The results of the prioritization of the Water Sector technology factsheets are shown in Table 23. As can be observed the technology that scored the highest was: “*An Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize*”. The second prioritized technology was; “*Water Efficient Fixtures and Appliances*”.

The Water Sector Working group endorsed the first of these prioritized technologies to be considered for the Barrier Analysis and Enabling Framework phase of the TNA process.

Table 23: Prioritized Water Sector Adaptation Technologies

Rank	Option	Weighted Score
1	An Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize	73.0
2	Water Efficient Fixtures and Appliances	50.2
3	Drought Monitoring System for Northern Belize with Specific Focus on Groundwater Resources	27.0

CHAPTER 5: TECHNOLOGY PRIORITIZATION FOR COASTAL AND MARINE ECOSYSTEMS

5.1 The Nationally Determine Contribution and the Coastal and Marine Sector

The Nationally Determine Contribution (NDC) endorses the policy actions of the NCCPSAP and the Growth and Sustainable Development Strategy (GSDS) with respect to the Climate Change. The over-arching goal is to increase resilience and reduce vulnerability of livelihoods with respect to critical infrastructure, tourism, food security, sustainable forest management, protected areas management, coastal and marine resources, water scarcity, energy and health.

In the case of the Coastal and Marine Resources Sector, the focus is to:

- Increase the capacity of the Coastal Zone Management Authority and Institute (CZMAI), and municipal authorities to ensure the developments inside the coastal and urban areas include an adaptation strategy;
- Implement mangrove forest restoration and seas and river defence structure and riparian forest, to halt coastal and riverine erosion and ecosystem disruption;
- Manage and regulate coastal zone development, especially in vulnerable areas such as Belize City and Corozal Town;
- Include climate change adaptation strategies in management and development planning in all coastal and marine sub-sectors;
- Review and strengthen marine legislation and building codes;
- Revise and streamline the current legislation and policies in the coastal zone to eliminate overlaps and close existing gaps;
- Strengthen the Fisheries Department to implement the regulations on Marine Protected areas and the No-Take Zones, to ensure the sustainability of the Fisheries Industry and resilience of the marine ecosystems.

5.2 Key Climate Change Vulnerabilities in the Coastal and Marine Ecosystems Sector

Climate change and climate-driven sea level rise impose additional threats to marine and coastal systems already under pressure from population concentration and increasing population growth in the future. Human presence, including infrastructure facilities, is becoming a significant direct and indirect control on coastal ecosystem functions and coastal processes.

Increased coastal erosion and more extensive inundation are expected from rising sea levels; storm surges may flood greater areas than now, thereby impacting on primary production, and may cause saline intrusion up estuaries and into groundwater aquifers. These biophysical impacts may cause loss of coastal habitats, property damage, flooding and loss of life, as well as having economic consequences for rural production and urban lifestyles. In many cases the effect of a change in climate and sea level are going to exacerbate problems that already exist.

The impacts of climate change and climate-driven sea level rise and storm surges will certainly have an impact on coastal ecosystems and economic activities in the coastal zone of Belize. The area most susceptible to the effects of climate change is the coastal ecosystem. Anticipated increases in sea surface temperatures, salinity, pH, sea level, and intensity of tropical cyclone events have direct implications on the future state of the coastal zone and the ability of the national population and visitors to utilize the resources it provides. Belize's coastal ecosystems and rich biodiversity will also be affected by global climate change. Delicate marine ecosystems such as sea grass beds, mangroves and coral reefs are directly dependent on climatic conditions for distribution, function and growth. Change in climatic conditions can lead to degradation of these already threatened ecosystems (Clarke et al. 2013).

Other sectors that will be vulnerable to future climate change and sea level rise and storm surges, via direct and indirect impacts are fisheries and tourism. (See: Singh et al, 2014). For instance, several coastal areas of Belize, such as Monkey River in Toledo District (Galen University Applied Research and Development Institute (2007) and Caye Caulker, Rocky Point and San Pedro (CARIBSAVE, 2012) are experiencing severe problems of coastal erosion and loss of beaches that is critical for the tourism sector. Furthermore, coastal communities that depend on fishing and agriculture would also be at risk to climate change, sea level rise and storm surges (Singh et al., 2014).

5.3 Decision Context

The Nationally Determined Contribution (GOB-NCCO, 2016) calls for the strengthening of the Coastal Zone Management Authority and Institute (CZMAI) and municipal authorities. The strengthening and capacity enhancement of these bodies will ensure that development within the coastal zone promulgates a climate change adaptation strategy; implement of mangrove restoration and/or sea and river defense structures; manage and regulate further development along the coast line; include adaptation strategies in management and development in all coastal and marine sectors; and revise and streamline current legislation and policies that relate to the management and regulation of developmental activities in the coastal zone.

The *Integrated Coastal Zone Management Plan* crafted by the Coastal Zone Management Authority and Institute in 2013 outlines a vision and implementation plan for sustainable use of coastal resources, supports an integrated approach to development planning and adapting to climate change. The Plan contains critical measures for climate change adaptation relevant to this sector, which includes the identification of short, medium and long-term strategies to address the threats of climate change on coastal communities as well as coastal and marine resources. Once the revision of the Mangrove Regulations is completed and published, these will complement the effort to introduce better management of the coastal and marine ecosystems. Implementation of the Integrated Coastal Zone Management Plan will mean reduction in the uncontrolled removal of mangroves allowing this ecosystem to continue to provide protection of coastal residences, agricultural and infrastructural developments, and protection against coastal erosion. The habitat for fisheries would be protected, further contributing to economic benefits. Properly regulated development in the coastal zone will limit or reduce the removal of coastal vegetation while cover, ensuring that the functions of the coastal ecosystems (mangroves, sea grass beds, littoral forests) are preserved.

5.4 Overview of Existing Technologies in the Coastal and Marine Ecosystems

Technologies for adaptation to climate change in the "Coastal and Marine Ecosystems" sector include Land Claim, Managed Realignment, Beach Nourishment, Sea Walls, Coastal Setbacks, Habitat restoration, and Wetland Restoration among others. Those selected for consideration here are Sea Walls and Habitat Restoration.

Belize City and Corozal Town are two major residential coastal areas. Belize City was the former political capital city until the 1970s when a new capital city, Belmopan, was built fifty miles further inland on higher ground. Belmopan was built in direct response to the hurricanes that had caused major damage to Belize City on more than one occasion, especially Hurricane Hattie in 1961. The old capital, lies at sea level, so sections of the city had been protected by the construction of sea walls, even though these sea walls did not surround the city completely. Corozal Town is a coastal town in the north which is also at sea level. Sections of this town have similarly been protected by sea walls. There are other coastal communities with significant development value for Belize, such as Placencia, Dangriga Town, and Ambergris Caye, but none of these have sea wall protection. Sea walls as a protection technology was in use in Belize long before the threats posed by climate change were recognized as being related to climate change.

Land Claim has long been utilized in Belize, although not as a measure to adapt to climate change. As Belize City expanded and housing demand grew, the government sought to acquire land by dredging the sea bed near the shore, and filling low wet coastal areas that were periodically inundated since they were at sea level. This created additional land areas for residential use infrastructure development.

5.5 Adaptation Technology Options for Coastal and Marine Ecosystems

5.5.1 Habitat (Wetland) Restoration

Habitat restoration is an adaptation technology that encompasses site-specific actions designed to improve the biological productivity or functioning of a particular ecosystem or area. Habitat restoration takes a variety of forms, depending on the project's purpose, its legal context, site characteristics, and other factors. Often, habitat restoration seeks to return an area to a *baseline condition*– for example, a particular vegetative community–that existed prior to an injurious incident such as a storm event or human induced changes. Habitat restoration seeks to improve the biological value of an area to compensate for a specific loss elsewhere–an approach to restoration known as *mitigation.* A third approach is *habitat creation,* the establishment of a habitat type in a location where it did not previously exist.

The most commonly restored wetland ecosystems for coastal protection are salt marshes and mangroves. Sea grasses may also be employed as a coastal defense, to dampen waves but on their own they are seldom considered an adequate shore protection alternative (USACE, 1989). Wetland habitats are important because they perform essential functions in terms of coastal flood and erosion management. They induce wave and tidal energy dissipation (Brampton, 1992) and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilize shore sediments, thus reducing erosion (USACE, 1989). Wetland restoration re-establishes these advantageous functions for the benefits of coastal flood and erosion protection.

Restoration is required because many of the world's wetlands have become increasingly degraded through both natural and human activities. The 2015 Mesoamerican Reef Report Card describes the status of 248 sites along 1000 km of the coast of Mexico, Belize, Guatemala, and Honduras (Healthy Refs, 2015) (www.healthyreefs.org). Techniques have been developed to reintroduce coastal wetlands to areas where they previously existed and to areas where they did not. The diversity of wetland types means there are numerous methods for restoring wetlands. In Belize, as stated above, this would address mangrove, coral, and possibly sea grass restoration. The method adopted will depend on the habitat which is being restored.

For mangrove restoration, it is necessary to collect plant propagules (a structure, such as a cutting, seed or spore that propagates a plant) from a sustainable source, prepare the restoration site for planting and directly plant propagules at regular intervals at an appropriate time of year (de Lacerda, 2002). In re-establishing mangroves, it may also be desirable to establish nurseries to stockpile seedlings for future planting (de Lacerda, 2002). The efforts to plant mangroves in Belize have largely used propagules collected from the wild. Mangrove re-establishment can also be achieved by planting dune grasses. These grasses provide a stable, protective substrate for mangroves to establish their root systems in. However, as the mangroves grow, they will eventually overshadow the dune grasses, causing them to die. Thereafter, the mangrove becomes the dominant species (USACE, 1989). (Source: www.climatetechwiki.org)

Mangrove planting was an inexpensive and simple activity designed to directly increase local mangrove stocks and provide a tangible rallying point for local groups interested in mangrove conservation.

Habitat Restoration is *beneficial as an adaption technology* because it has the potential to repair human impacts on the coastal environment, the potential to reduce coastal flooding and erosion and also to provide new habitats and environmental benefits. It is the restoration and repair of damage to coastal habitats that have lost their potential to provide physical protection from the effects of storms, wave action, and sea-level rise, to restore their potential for protecting and enhancing the environmental and social services (livelihoods) provided by those habitats.

Small scale efforts at habitat restoration have been implemented in various parts of Belize. A few yards of mangrove replanting have been done in Placencia and in San Pedro through the intervention of a non-government organization and some concerned citizens. The intent was to restore sections of an ecosystem that had been lost because of development pressures. Another effort at habitat restoration initiative was in the form of coral rehabilitation, also done through the intervention of a concerned scientist. Pieces of coral that were broken off by wave action were used to establish a nursery off the coast of Placencia, and then later transplanted to an area off Laughing Bird Caye east of Placencia after they demonstrated resilience by taking root on the substrate. Environmental benefits are derived from habitat restoration because of the enhanced function of the ecosystem resulting from the repairs. Economic benefits can also be realized from the enhanced fishery in the area where the ecosystem has been allowed to recover.

5.5.1.1 Benefits of Habitat Restoration

Table 24 is a summary of the benefits arising with marine habitat restoration interventions. Plate 6 is a view of the intense beach erosion in the Monkey River community in southern Stann Creek District. Monkey River is a fishing and tourist destination community, but the persistent beach erosion has forced some villagers to abandon the area, while others try to salvage their property with rudimentary shoreline defenses that are being demolished by the strong wave actions.

Table 24: Summary of the Benefits of Habitat Restauration

Benefits	Habitat Restauration
Economic	- Improve the natural value of an area and contribute directly or indirectly to the local economy; - Contribute positively to the Eco-tourism sub sector; - Improve the conditions of natural breeding habitat for fisheries and other marine wildlife.
Social	- Provide jobs and security to buffer communities; - Help preserve wetlands and reduce flood impacts in some coastal communities.
Environmental and Climate Change Adaptation	- Beneficial adaptation measure; - Improve biological and esthetic value of an area.

Plate 6: Intense Beach Erosion in the Monkey River Community, Stann Creek District

5.5.2 Coastline Protection and Seawalls

Coastal protection and seawalls are other options for coastal and marine adaptation to climate change. The main advantage of a seawall is that it provides a high degree of protection against coastal flooding and erosion. If properly designed and maintained a seawall will also fix the boundary between the sea and land to ensure no further erosion occurs. Seawalls can also provide protection against wave action.

Seawalls require less space compared to other coastal defenses such as dikes due to design and narrower footprint. The increased security provided by seawalls help to maintain the value of the land they protect, and can be built to provide recreational and tourism services. In relation to adaptation to climate change, another advantage of seawalls is that it is possible to progressively upgrade these structures by increasing the structure height in response to sea level rise. If properly built and maintained, seawalls are potentially long-lived structures. The construction of seawalls in vulnerable areas of the coast provide social and economic benefits due to the element of safety of life and property behind the wall that is afforded, and the maintenance of the economic value of the protected properties behind the walls. Environmental benefits are afforded by the control of erosion and reduced land loss.

Seawalls have been constructed in certain sections of the coastline in Belize City, and Corozal Town. This adaptation technology has also been used in the offshore cayes such as Caye Caulker and San Pedro Ambergris Caye to reduce the vulnerability of the coast to wave action.

5.5.2.1 Benefits of Seawalls

Table 25 below is a summary of the benefits of shoreline defences such as seawalls, rip raps and dikes.

Table 25: Summary of the Benefits of Seawalls

Benefits	Seawalls
Economic	- Save-guarding private coastal assets and infrastructure; - Protection of key coastline and beach replenishment - Contribute directly to the National Tourism Master Plan and Strategy
Social	- Help preserve life and property of key coastal communities and livelihood. - Contribute to the preservation of recreational sites on the costa
Environmental and Climate Change Adaptation	- Effective coastline protection and erosion control; - Attenuate increased wave action due to sea level rise and during storm events.

5.5.3 Marine Environmental Early Warning System

As Global Warming intensifies and the effects of climate change overshadows natural climate variability, the marine ecosystem will experience increasing ocean acidification and thermal stress which will continue to impact coral reefs around the world and the Caribbean, resulting in more coral bleaching events and marine ecosystem disruption (NOAA/CCCCC, 2012). It is therefore critical to systematically monitor the various parameters that impact the coral reefs in Belize, complimenting and supporting the NOAA/CCCCC Caribbean Coral Reef Early Warning System (CREWS) network and the Fisheries Department/CZMAI Marine Conservation and Climate Change Adaptation Project (MCCAP), *Component 1: Improving the protection regime of marine and coastal ecosystems*. Strong Climate Change Early Warning Systems improve climate risk planning, management and action and are necessary to address the impacts of Climate Change, especially coral bleaching.

The threats to the coastal zone arise from a number of activities connected with tourism and recreational facilities, increase in population and expansion, utility supply, dredging and minerals extraction, land clearance, pollution, waste disposal, fisheries and aquaculture, and agriculture runoff (CZMAI, 2014). Some pollution and ecosystem health indicators in the marine environment are: Water Clarity, Dissolved Oxygen, Coastal Wetland Loss, Eutrophic Condition, Sediment Contamination, Benthic Index, Fish Tissue Contaminants, and Multiple Marine Ecological Disturbances (Guefact, 2007).

The Fisheries Department proposes to upgrade the Marine Monitoring and Early Warning System of Belize as a means to reduce the negative impacts of climate change on sensitive marine ecosystems, and contribute to the sustainable use and management of marine resources.

5.5.3.1 Benefits Marine Early Warning System

Some of the benefits associated with Coastal and Marine Early Warning systems are presented in Table 26. The technology transfer in connection with an effective Coastal and Marine Early Warning System comprises of the Hardware, Software and Orgware.

Table 26: Benefits of Coastal and Marine Early Warning Systems

Benefits	Marine Early Warning System
Economic	- Save-guarding the private coastal assets and infrastructure; - Preserving sensitive coastal and marine ecosystems from further degradation (e.g. MPAs); - Providing scientifically-based information and early warning for decision-makers and policy.
Social	- Keep communities informed on threats to their livelihood via popular media;
Environmental and Climate Change Adaptation	- Coastline protection and replenishment; - Effective adaptation option for sea level rise. - Help in the effort for coral reef replenishment efforts.

5.6 Technology Prioritization for the Coastal and Marine Ecosystems Sector

5.6.1 Coastal and Marine Ecosystems Sector: MCA Criteria and Category

The Multi-Criteria Analysis (MCA) process for the Coastal and Marine Ecosystem Sector was conducted with the Small Working Group consisting of presentative from the Fisheries Department, CZMAI, Pan American Development Foundation and a member of the fisherfolks community. The MCA process was reviewed by the Lead Consultant and Assistant TNA Coordinator, then the group proceeded to conduct the analysis using the MCA Excel tool.

The Criterion approved by the Working Group, after some discussion for clarification, in order of importance were: Capital Investment Cost, Marine Resource Resilience, Adaptation potential, Job creation/poverty alleviation, Technology replication, Environmental impact, Operating cost, and Life of technology. Table 27 is a summary of the criteria and value preferred. Table 27 shows the list of criteria and the prescribed weighting.

Table 27: MCA Criterion and Category for Marine Ecosystems Technologies

	Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)
Criterion 1	Capital Investment cost	cost	$	Low
Criterion 2	Operating cost	cost	$ per year	Low
Criterion 3	Adaptation potential	Social	level of resilience	High
Criterion 4	Job creation/poverty reduction	economic	# persons employed	High
Criterion 5	Life of technology	Technology	# years	High
Criterion 6	Technology replication	Local capacity	# of persons benefiting directly from training/ capacity building	High
Criterion 7	Environmental impact	Environmental	Erosion rate	Low
Criterion 8	Marine Resource resilience	Environmental	level of resilience	High

Table 28: Criterion and Weight (%) for Coastal and Marine Ecosystems Technologies

Criterion	Allocation of budget	Weight, %
Capital Investment cost	15	15%
Operating cost	10	10%
Adaptation potential	14	14%
Job creation/poverty reduction	12	12%
Life of technology	10	10%
Technology replication	12	12%
Environmental impact	12	12%
Marine Resource resilience	15	15%
	Total 100	**100 %**

5.6.2 Results of Coastal and Marine Ecosystems Technology Prioritization

The result of the prioritization of the Coastal and Marine Ecosystem Sector technology factsheets are shown in Table 29. As can be observed the technology factsheet that scored the highest was: "*Improved Monitoring Network and Early Warning System for Belize's Coastal Zone*". The second prioritized technology was: *"Soft Engineering and Ecosystem Restoration (SEER)"*.

The Coastal and Marine Ecosystem Sector Working group endorsed the first of these prioritized technologies for consideration in the Barrier Analysis and Enabling Framework phase of the TNA process in Belize.

Table 29: Prioritized Coastal and Marine Sector Adaptation Technologies

Rank	Option	Weighted Score
1	Improved Monitoring Network and Early Warning System for Belize's Coastal Zone	52.0
2	Soft Engineering and Ecosystem Restoration (SEER)	34.0

CHAPTER 6 SUMMARY AND CONCLUSIONS

6.1 Summary

6.1.1 Initial TNA Activities Resulting in Sector Selection and Factsheet Prioritization

Belize is a participating country in the Technology Needs Assessment Phase II project. The TNA Phase II process began with the UNEP/DTU representatives visiting Belize in March 2015. This Mission facilitated the introduction of the project to Belizean stakeholders. During that event, one of the outputs was a preliminary selection of sectors that would be considered for the application of mitigation and adaptation technologies. The stakeholders were representatives of government ministries and were able to select the sectors based on national development priorities, vulnerabilities of the sectors, and their potential for adaptation to climate change, and mitigation of greenhouse gas emissions. National development priorities were established on the basis of government sector policies, strategies, and plans that were published, being implemented, or being drafted.
Establishment of the project management team, refining the work plan, and recruiting of a national consultant were activities addressed during the Mission. The Belize National Climate Change Committee (BNCCC) was designated the National TNA Committee or National Project Steering Committee for the purpose of project implementation.

The National TNA team comprises the National TNA Coordinator, the Assistant National Coordinator, Sector Technology Working Groups, stakeholders, and the National Consultants. The National Climate Change Coordinator of the National Climate Change Office, located in the Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development, serves as the National TNA Coordinator, and represents the Government of Belize's in-kind contribution to the Project. The Assistant National Coordinator provides technical support as a consultant to the project. The Sector Technology Working Groups are comprised of representative from government ministries and departments, statutory bodies, non-governmental and community-based organizations, the private sector, and the University of Belize.

A national Inception Meeting was held on June 2015 in Belize City to verify the sectors chosen earlier by stakeholders, and to update the Work Plan. That meeting confirmed that the sectors to be treated by adaptation measures were Agriculture; Water; Coastal and Marine Ecosystems. The Inception Meeting was followed by the workshop of the Technology Working Groups held in early

October in Belmopan. In preparation for the Working Groups' workshop, the national consultant was required to identify suitable technologies (for adaptation to climate change) and prepare Technology Fact Sheets for circulation to the members of the Working Groups. The task of the Working Groups was to conduct an initial screening of the technologies using data and information provided in the Fact Sheets. A minimum of three technologies was requested for each of these three sectors, but a total of eleven were eventually submitted for evaluation. The screening process eliminated some of the technologies, since a few of the Fact Sheets did not offer adequate data. A few of the technologies were eliminated because they were not considered suitable for Belize. The output of the Working Groups was the subject of the two-day Technology Prioritization.

Another Workshop held in Burrell Boom Village in mid-October, 2015. This workshop involved a wider group of stakeholders than that of the Working Groups. On the first day of the workshop, stakeholders were concerned that some of the Technology Factsheets did not present sufficient data and information. Stakeholders offered assistance by making recommendations about additional sources of data. Other recommendations from participants were that the Factsheet data be made relevant to Belize and applicable to the local scenario. The consultants worked during that night to incorporate new information that had been provided by stakeholders, and improved a few of the Fact- sheets in preparation for the following day's sessions. The purpose of this workshop was to prioritize the technologies by applying weighted evaluation criteria. Ten criteria were selected and weighted by the stakeholders and consultants. These weighted criteria were applied to the technologies using the Multi Criteria Decision Analysis tool. The output of this tool was a ranking of the technologies. The analysis of the mitigation technologies produced the following selection and ranking listed below:

The list below shows the criteria, and their weights, that were applied to the to the MCDA table to prioritize the adaptation technologies.

Selected criteria utilized in the evaluation of the adaptation technologies were:

(i) Capital cost
(ii) Maintenance cost
(iii) Operating cost
(iv) Job creation
(v) Poverty reduction
(vi) Life of the technology, and
(vii) Reduction of vulnerability.

A basic explanation of these criteria was presented in section 1.8 of this Report.

Based on the selection process, the adaptation technologies being that were referred for further study in the next stage of the TNA process were:

(i) Crop Diversification in the Agriculture sector
(ii) Water Safety Plans for the Water Sector
(iii) Habitat Restoration for Coastal and Marine Ecosystems
(iv) Rainwater Harvesting for the Water Sector, and
(v) Drip Irrigation System for the Agriculture sector.

6.1.2 Subsequent TNA Activities for Drafting, Vetting and Prioritize New Factsheets

Following the revision of the first draft of the Belize TNA Reports in early 2016, and acting on the advice of the National Climate Change Coordinator, the process of drafting, vetting and prioritizing new, country-relevant Factsheets was begun within the previously, selected vulnerable sectors for Adaptation, namely: Agriculture, Water, and Coastal and Marine Ecosystems; and for Mitigation, namely: Energy, Transport, and Land use, Land use Change and Agro-Forestry.

The Lead Consultant, (Adaptation Consultant) and the Mitigation Consultant, in coordination with the Assistant National TNA Coordinator, conducted a series of consultations with key stakeholders per sector in the public and private domain. With substantial inputs from the stakeholders, ten new adaptation technologies were drafted and circulated among stakeholders. Small working group sessions and discussions were held to improve the Factsheets and by the mid 2016, the adaptation factsheets were completed, as listed in Table 1.3 (Chapter 1).

The drafting and vetting of the corresponding Mitigation Factsheets was slower, and had a major drawback around June-July 2016, when the Mitigation Consultant did not meet his delivery and a new Consultant had to be identified and contracted to complete the task.

The MCA process for the new Adaptation Technologies was conducted per sector and direct input from the key stakeholders, as per the TNA Guidelines. The results of the MCA process are summarized in the relevant Chapters in the Report.
The list of prioritized Climate Change adaptation technology factsheets per sector to be considered for the Barrier Analysis and Enabling Framework phase of the TNA process are shown in Table 30.

Table 30: Summary of Prioritized Technologies for Selected Sectors

Sector	Technology
Agriculture Sector	i. Heat and Drought Resistant variety of open-pollinating corn and black beans seeds for reproduction and marketing. ii. Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement. iii. Protective Structure Cooling Systems. iv. Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties.
Coastal & Marine Ecosystems	i. Improved Monitoring Network and Early Warning System for Belize's Coastal Zone
Water	i. Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize

In summary, three technologies were prioritized for the Agriculture Sector, but a fourth, namely: "*Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties*", was selected for prioritization, following a series of lengthy, small group discussions with the personnel from the University of Belize Plant Propagation Laboratory and the Ministry of Agriculture Crop Section, and the Crop Research and Development Unit. It was established from vulnerability assessment studies that impending climate change impacts could likely reduce grain yields and threaten Belize's food security. As a security measure, it was recommended that an expansion of potato cultivation be carried out, with climate resistant seedlings that can be imported from Peru or another source, and these can then be propagated locally by the University of Belize Plant Micro-Propagation Laboratory. The seedling can then be distributed to established nurseries to increase crop material for dissemination among farmers.

For the Coastal and Marine Ecosystems sector the technology factsheet for "*Improved Monitoring Network and Early Warning System for Belize's Coastal Zone*", scored higher that the Coastline Protection factsheet. The key stakeholders to lead this initiative will include: Fisheries Department, the Coastal Zone Management Authority and Institute (CZMAI), Fishing Cooperatives and Members, NGOs working in the Coastal Zone, Tour Guide Companies, Belize Tourism Association, and Sea Taxi operators. The Marine Monitoring Network and Early Warning System will provide relevant and timely marine information and bulletins to stakeholders and decision-makers so they can operate safely and help in reducing the stress on marine ecosystems as a result of climate change impacts and other stressors.

In the Water sector, one technology was prioritized, namely: "*Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Beliz*e". The aim of the technology transfer is to address the problem of poor, unsafe and inadequate water supply and services to some rural communities. At the end of the proposed intervention, eight rural water supply systems will have attained an elevated level of management of their Water Boards, timely and effective water treatment at the source (Ground and/or Surface supply), a clean and consistent water supply, improved conservation of this vital resource in the face increasing climatic variability, and a marked reduction of water-borne diseases and infection.

6.2 Conclusion and Recommendations

Climate Change is already affecting the livelihood of much of the Belizean population (GOB/NCCO, 2016). Temperature rise in the range of 2 °C to 4 °C are projected for Belize and adjacent countries by 2100, with a general decrease in annual rainfall of about 10%, in accordance to regional climate model simulations and UNDP Country Profile Studies. Resources and sectors identified as being at most risk to the impacts of climate change are: Coastal and Marine Resources, Agriculture, Water Resources, Tourism, Fisheries and Aquaculture, Energy, Transport, Human Health and Forestry.

Although the country has limited capacity to contribute significantly to the mitigation of global warming, it is committed to the objective of reducing GHG emissions by strategically transitioning to low carbon development, and at the same time, build resilience in all sectors to adapt to the challenges posed and the impacts caused by climate change.

As indicated in Belize’s Nationally Determined Contribution (NDC) under the UNFCCC, Adaptation and Mitigation to climate change are high priority issues for the Government of Belize (GOB/NCCO, 2016). This is evident from the recent drafting and streamlining of a number of policy frameworks as part of the country’s development strategy. These include: Horizon 2010-2030; the National Energy Policy Framework; the Sustainable Energy Action Plan 2014-2033; the National Climate Resilience Investment Plan 2013; the Growth and Sustainable Development Strategy 2016-2019, and the National Climate Change Policy, Strategy and Action Plan 2015-2020.

Cognizant of the importance of dealing with the phenomenon of climate change effectively, the Government of Belize established the National Climate Change Office and appointed a National Climate Change Coordinator within the Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development, to coordinate all actions related to Climate Change, and advise Government on substantive matters connected to climate change that need to be addressed at the highest level. Recognizing that technology interventions are critical for addressing climate change, the National Climate Change Coordinator and support staff are spearheading the implementation the TNA project in Belize.

Following the UNEP Technology Needs Assessment process to select and prioritized critical adaptation technologies in the selected vulnerable sectors (Step 1), six (6) technology factsheets were drafted, vetted and prioritized, for the Barrier Analysis and Enabling Framework (BA&EF) phase or Step II. The prioritized technologies in Agriculture, Water, and Coastal and Marine Ecosystems, were unanimously supported by key stakeholders in these sectors. The ultimate goal is to take these technologies to the Technology Action Plan phase (Step III) of the TNA process, and procure funding for all six adaptation technologies.

Some recommendations to ensure success for the TNA process in Belize for the short and medium term are:

- Educate and inform more stakeholders in the TNA process and its benefits for the country.
- Give stakeholders, especially in the private sector, ownership of the technology transfer.
- Ensure that barriers to the technology transfer are clearly elucidated in preparation for the BA & EF phase.
- Identify potential and practical measures to mitigate barriers for the technology transfer.
- Keep decision-makers informed of the process, and public/private sector stakeholders committed to TNA process and its benefits to build resiliency.
- Begin identifying sources of funding (Local and International) for all the prioritized technologies; both for Adaptation and Mitigation to climate change.
- Consider introducing adaptation technologies in the agriculture and water resource sector for larger, mechanized farmers who are impacting the local environment and natural resources to a greater degree than the small farmers.

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ANNEXES

Annex 1: List of Stakeholders

Name	Position	Organization	Email address
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Dr. U. Trotz	Deputy Director & Science Director	Caribbean Community Climate Change Centre	utrotz@caribbeanclimate.bz
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Mr. Paul Flowers	Director, Policy Coordination and Planning Unit	Ministry of Natural Resources and Agriculture	pflowers@mnra.gov.bz
Ms. Yvonne Hyde	CEO	Ministry of Economic Development	ceo@med.gov.bz
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Irving Thimbriel	(Engineer)- not sure of his post	Ministry of Works	irvingthimbriel@yahoo.co.uk
Nicole Auil	Executive Director	Southern Environ. Association	execdirector@seabelize.org
Dr. Sharon Grant	MCCA Project Coordinator	Fisheries Department	Pc.mccap@ffsd.gov.bz
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Mr. Oscar Salazar	Crop Cover Structure Officer	Ministry of Agriculture Research	okissalazar@Yahoo.com
Mr. Manuel Trujillo	Crop Expert	Ministry of Agriculture	mtrujillo@agriculture.gov.bz
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Miss. Minerva Pinelo	Director, Pan American Development Foundation	Dangriga, Stann Creek District	mpinelo@padf.org

Annex II: Stakeholder's Engagement and MCA for Adaptation Technologies Summary Sheet

Summary of stakeholder engagement

Second Round of Stakeholder Engagement to Consider Adaptation Technologies

Summary

The objective for the months of May through June 2016 was to complete the stakeholder's consultations for drafting improved factsheets based on the previously selected 'sectors' and newly, proposed adaptation and mitigation technologies. By mid June, the MCA process for ten (10) climate change technology factsheets were completed. These were vetted by the sector stakeholders and the same were submitted to the TNA-Belize project Coordinator.

Interviews and Small Group Sessions.

March, 2016

1) **Director: Plant Micro-Propagation Laboratory, University of Belize (UB), Central Farm Campus.**

   The Director of the University of Belize (UB) Plant Micro-Propagation laboratory indicated that there is an initiative to develop a business plan for the UB Plant Micro-Propagation lab at Central Farm. He pointed out that the Ministry of Agriculture (MoA) should have a list of the crops threatened by Climate Change. He indicated that seeds (germ plasim) of a new variety of white, Irish potato, good for making chips and resilient to warmer temperatures and drought could be a crop for the prioritized "Crop Diversification and New Variety". The UB Plant Propagation Lab could serves as the institution to carry out the process of testing, validating and reproducing seedlings for the experimentation plots, and through the MoA, disseminate these to the farmers. The period to the first harvest would be approximately 3 years… The new variety would not necessarily require planting specifically in the cooler part of the cropping season, but could be planted anytime and in all districts of the country. Need to evaluate this option more with the MoA.

2) **Crop Research Supervisor, Ministry of Agriculture (MOA), Central Farm:**
   The Crop Research Officer at the Crop Research and Development Section informed the consultant that the crop for this technology transfer should be grains, specifically corn (yellow 95%, white 5%) and beans (small red, red kidney and black beans). There is a high market demands for corn and beans and these are the priority crops for the MOA. The varieties should be temperature and drought resilient, and open pollinated, so farmers may be able to produce their own seeds. Also, a dependent and reliable institution should be

established that will maintain the integrity of the new variety for the country of Belize. The MoA at Central Farm Crop Section have ben involved in this process already for safeguarding the variety of corn & beans, but at a small scale. If improved varieties resistant to the impacts of climate change can be imported and distributed to farmers an advanced testing/validation process and distribution system, then corn and beans production could be safely produced in warmer climatic conditions to reassure food safety in Belize.

3) **District Agricultural Officer, Central Farm:** The District Agricultural Officer concurred with the Crop Research Supervisor on choice of crop for technology transfer. She indicated that there is indeed a need for expanding grain production in Belize to meet the need of growing market demand. Also, she indicated that the irrigation systems should be a combination of Drip and Sprinkler systems depending on the type of cropping systems. Drip irrigation is better for small scale, cover crops such as vegetable production and other niche or special crops. Sprinkler would be better for open field grain production, particularly for the areas prone to recurrent droughts, but with adequate water supply for the sprinkler irrigation systems.

4) **Acting Director at the Caribbean Agriculture Research and Development Institute (CARDI) – Belize:**

The Acting Director of the Caribbean Agriculture Research and Development Institute (Belize), works closely with the San Carlos Farmers Cooperative in the Orange Walk District. The San Carlos Farmers cooperative is interested to expand their production of onions and grains with the use of center pivot sprinkler irrigation systems, and become more involve in corn and bean seed production. The constraint this group has is finance and adequate water supply during the extended, dry season in northern Belize.

5) **Principal Agriculture Officer (MAFFE&SD):**

The Principal Agriculture Officer in charge of projects pointed out that farms yield are 500 lb./acre of corn. With improved seed variety and good practice, yields could be 2000 lb./acre.

The recommendation for Crop Diversification and New Varieties should be on grain production such as Corn (yellow and white) and Small Red Bean and Black Beans. The technology for improved grain production in Belize is at the top of the list of crops being promoted by the MOA in its strategy to ensure food safety and livelihood security among small farmers in Belize.

The concept is to consider the entire chain of grain production and marketing for famers from the initial acquisition of the improved heat and drought resistant corn and bean seed varieties, to the testing, validation and dissemination of seeds via a specialized institution or farming group who will maintain and monitor the viability of the seeds during the project period (3 – 4 years), the harvesting, processing and storage of the grains, the marketing and replanting.

Thus, the technology will encompass not only the new varieties of corn and bean seeds, but the complete process from land preparation to marketing and replanting. The proposed scale of the programme will cover the six districts of Belize, with a selection of small farmers already engaged in a grain production programmed spearheaded by the Ministry of Agriculture (MOA), but at a smaller scale.

Name: *Technology to improve the competitiveness of corn and bean production among small farmers in Belize*

Competitiveness implies improved yields with good practice; open, pollinated heat and drought tolerant varieties of corns and beans; machinery for shelling, grain storage facilities per farming households; better prices for grain because of improved grain quality; good seeds available for replanting for three to five years; restocking of new seeds varieties after five years; land preparation and replanting. After project cycle completed (3 – 5 years), farmers should be in a better economic position to purchase the climate tolerant, open pollinated seeds and start the cycle once gain.

What is needed for the Factsheet?

1) Current status of corn and beans production in Belize.
2) Geographic extent of corn and beans cultivation across Belize
3) Cost of production per acre
4) Basic information on new, heat & drought tolerant varieties
5) Cost of production, harvesting, processing and storage of grains
6) Market opportunities and benefits
7) Benefits: economic, social and environmental
8) Schematic of complete grain production process
9) Other facts about corn and beans production

Benefits:

a. Economic
b. Social
c. Environmental

Some Barriers:

- Initial cost to purchase certified seeds and to prepare land for planting
- Land tenure issues
- Cool storage for harvested grain crop
- Marketing strategy
- Lack of interest among some farmers
- Limited knowledge about the impacts of Climate Change and need to conserve water and soil

6. Director of Water Management and Climate Change Adaptation, Ministry of Agriculture

Sprinkler or Drip Irrigation?

The Director's recommendation is for "Advanced Irrigation Systems: Drip and Sprinkler Irrigation to improve vegetable and grain yields, and pasture vitality"

Consider the design of drip and sprinkler. Drip irrigation system for cover crop or small acreage of assorted crop production (onions, potato, beans etc.). Sprinkler irrigation system designed for larger acreage of grain production and maintenance of pasture vitality, particularly during height of the dry season or during recurrent droughts.

Why the combined systems? Because each of these technology is used depending in the crop type and size of the cultivation area. Both are applicable for the farming system in Belize.

Justification

- Water use efficiency
- Reduction of climate foot print
- Reduced cost in the medium and long term; high initial cost
- Improved pastures for producers in the long run
- National priority
- Reduced stress on water resources, soil and forests

To consider:

i) Acreage under Drip and Sprinkler irrigation
ii) Number of farmers by district engaged in irrigation
iii) Current cost of installing irrigation system per acres or hectare
iv) Target Group: Farmers already using irrigation; introduce new technology of fertigation, scientific water scheduling, water conservation and new irrigation system itself. Later, extend technology to other farmers.

   Benefits:
   a. Economic
   b. Social
   c. Environmental

   Barriers:

i) Cost per unit Drip / Sprinkler
ii) Water source and reliability during dry season. (Sources: Surface, rivers and streams, rainwater catchment ponds reservoirs, elevated tanks or ponds, ground water. May necessitate solar power to run water pump to get water into the irrigation system.
iii) Maintenance cost.

iv) Attracting and training farmers.

Here again the entire Drip / Sprinkler irrigation process from Acquisition (Initial Cost), Training, Installation, operations and scheduling, and maintenance should be considered.

The scale and time horizon to introduce and implement new technology must be considered in factsheet.

6b. Director of Water Management and Climate Change Adaptation, MAFFESD

The Director of Water Management and Climate Change Adaptation pointed out that soil conservation (i.e. mulching and drainage) are critical to improve yield and conserve natural resources.

6c. Director of Water Management and Climate Change Adaptation, MAFFESD

Rainwater Harvesting: On Farm Reservoirs (OFRs)

Factsheet for OFRs…

Status of OFR Belize?

Initial cost of this technology and maintenance cost.

This will compliment the improved drip or sprinkler irrigation systems? May be gravity fed.

OFRs may be combined with Roof Rainwater Harvesting on Farms and in Rural communities. Initiative already carried out in small communities in the Belize River Valley.

7. Director Crop Research and Development Unit (CRDU), MOA, Central Farm

The CRDU Director and his team of agricultural technicians and agronomists provide technical support to famers throughout the country of Belize in procuring and installing irrigation systems and crop protective structures or greenhouses. The Unit has technical capacity in the operation of small irrigation systems, rainwater harvesting and fertigation. The CRDU also provide training to farmers or farming groups interested in setting up crop protective structures for organic vegetable production and horticulture. The Consultant held several small group meetings with the CRDU team to draft the factsheets for improved drip irrigation technology transfer and refurbishing crop covered structures with efficient, and renewable energy-driven cooling systems. The CRDU team fully supported the TNA-Belize project, and showed much interests in the proposed technology transfer for improved drip irrigation systems and crop covered structure technology.

Small scale cultivation of cabbage under protective covered structure

The Consultant was invited to experience the working conditions inside a crop covered structure during normal working hours on a hot day in April. Indeed, the temperature inside was about 10 to 12 °C than the ambient temperature outside. The illustration shows small scale cabbage cultivation in a typical covered structure in Belize.

Fisheries

8. Principal Fisheries Officer (Fisheries Department, MFFESD, Member of the Coastal and Marine Ecosystems)

Sustainable Tourism Project (STP) ─ 5-year project. US# 15 M ─ IDB

STP2 ─ Infrastructure to boost tourism.

Caye Caulker beach replenishment is part of BTB and the Toun Council initiative, not STP2

Fisheries has a National Coral Reff Working Group, with sub-committees, including:

1) Lion Fish
2) Water Quality
3) Turtles
4) Spanning Aggregation

Need Monitoring programme and capacity building

Habitat Rehabilitation**:** Management of the Coastal Zone

Lisa Card…Fragment of Hope, Placencia, working on coraal reef replenishment, Have coral nurseries.

Marine Conservation and Climate Adaptation Project (MCCAP) ─ 5 years. One year has already elapsed.

Coral Reef replenishment

Habitat Rehabilitation**:** Focus should be on replanting or restoring degraded mangrove areas or strips along the coast and the cayes. The Fisheries Department has a small nursery and replanting program at Hol Chan Marine Reserve. Have been doing small replanting activity in Ambergris Caye.

Species is the Red Mangrove

Need to know: Status of the mangrove deforestation. Check Blue Carbon. Org; Forest Department, Servier.org: study on Mangrove in Belize.

The technology should be: replanting mangrove in critical degraded areas of the coast.

9. Fisheries Officer (Member of the Small Group: Coastal and Marine Ecosystems)

Shoreline restoration is important. Need a comprehensive assessment of the coastal erosion problem. Check Kirah Foreman, kiraforman@yahoo.com

Need a mix of coastal rehabilitation technologies: hard and soft engineering.

Hard…ferroconcrete seawalls where appropriate, mangrove forest restoration, beach/shoreline replenishment; indigenous, innovative technology to control shoreline erosion.

Coastal Zone Management, Authority and Institute, CZMAI)

10. Coastal Planner (Coastal Zone Management, Authority and Institute (CZMAI, Member of the Coastal and Marine Ecosystems)

Question: *What is the biggest threat of Climate Change to Coastal and Marine Ecosystems?*

Answer: *Shoreline and beach erosion, among many others.*

Causes: Sea level rise, changes in weather and current patterns, Erosion problem becoming worst over the decade. Goff Caye for example; wave action and change in current.

Important for tourism and families living along coast and cayes.

Monkey River have experienced significant shoreline erosion. UWI have done some work in this community…Check it out.

Some other initiatives to address problem: PADF Pan American Project to restore coastline in Dangriga Town.

Placencia area initiatives by WWF. Large scale initiative in Money River to try to address the erosion problem there.

Intervention: Conduct a comprehensive study on beach and shoreline erosion problem in Belize.

Prioritize critical areas and build synergy among all stakeholders and players addressing problem.

Find the best technology for the different affected areas. Benefits should be measurable and effective and transparent.

Target communities:

i) Hopkins Village, Fishing and tourism
ii) Saint Bight Village, Fishing and Tourism
iii) Corozal, Consejo Bay, Fishing mainly and residential
iv) Monkey River Village, Fishing and Tourism?
v) Dangriga Town, Fishing
vi) Main Cayes…Ambergris Caye, Caye Caulker, Goffs Caye, Laughing Bird Caye

Study will identify where the critical target zones are and the project will introduce appropriate technology to halt the erosion.

A scene of the intense beach erosion in the Monkey River Community, where the first row of houses has disappeared into the sea. (Source: R. Frutos, June 2016)

Technology will include:

Hard engineering: ferroconcrete walls, rock rip rap retainers, 50 feet geo-tubes (Laru Bey Resort Placencia, BET, Nov, 2015), other forms of retaining walls of special material, etc.

Soft engineering: mangrove forest reforestation, beach replenishment with sand and barriers to protect beach, combination of rip rap and mangrove planting, reforesting littral forest with hardwood and other species, etc.

Mr. Samir Rosado, Coastal Zone Management Authority and Institute (CZMAI)…check "*Beach Profile Study*"

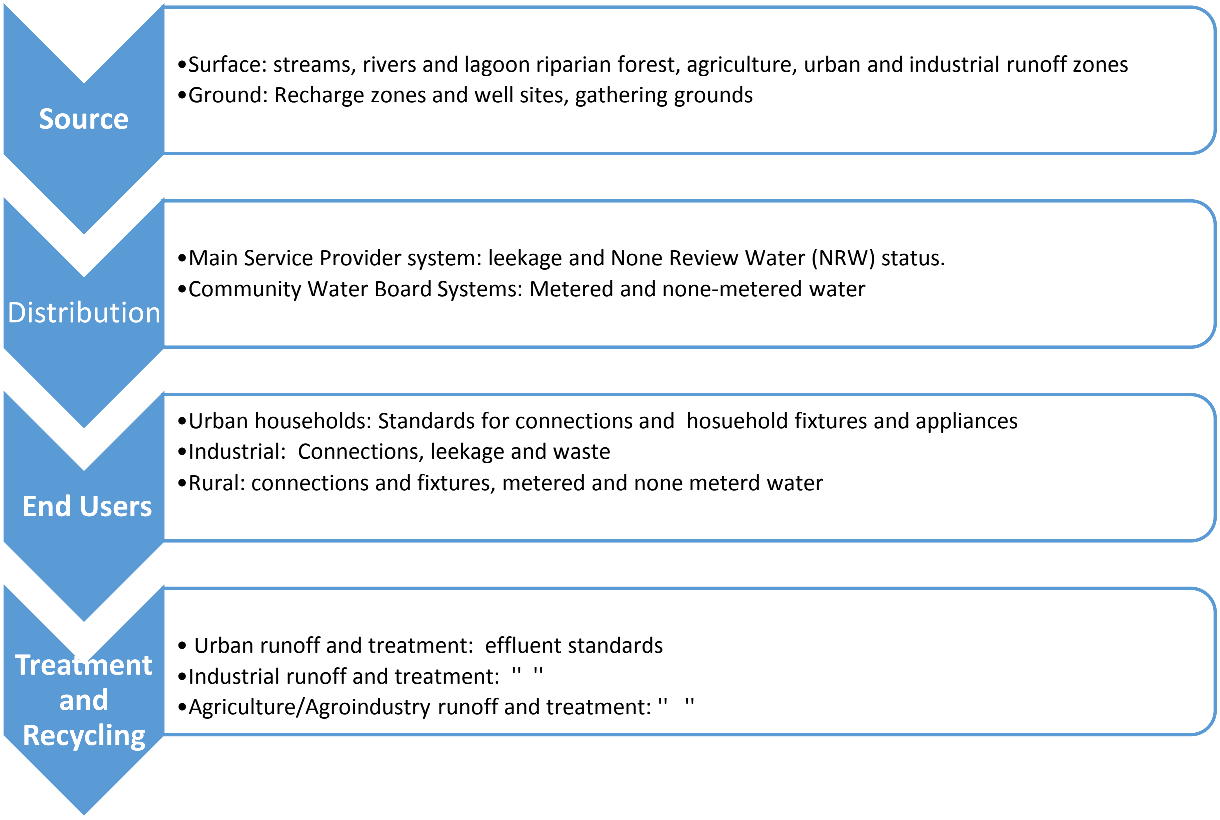
Water

11. Coordinator for Rural Development. (Ministry of Labor, Local Government and Rural Development; Member of the Water Sector Working Group)

There is an urgent need to target Rural Water Systems (RWS) that are experiencing problem to deliver a safe and reliable service to communities, and establishing new RWS in villages that have no water supply services, and depend directly on untreated groundwater or surface water sources.

Technology: ***Water Safety Plans***.

An Integrated Water Resources Management System from source protection to end users and waste water treatment.



12. Chief Hydrologist

Held discussion with the Chief Hydrologist, Hydrology Unit in the Ministry of Natural Resources, on groundwater resource assessments for northern Belize. The Hydrology Unit had an interest to help develop a Climate Change Technology factsheet on groundwater resource monitoring for drought early warning systems for stakeholders in northern Belize.

13. Water Officer, Public Utility Commission (PUC)

Small group meetings were also held with personnel from the Public Utility Commission (PUC), Rural Water and the Hydrology Unit in the Ministry of Natural Resources and Lands, on the matter of Rural Water Systems and Water Safety Plans to alleviate the problems experienced by Rural Water Boards in the safe delivery of potable water to remote communities.

A comprehensive review and editing of the draft TNA reports, with input from of the updated adaptation and mitigation factsheets and the MCA process and outcome, is scheduled to be carried out during September through October, 2016.

May, 2016

Week 1: 2 – 6

- Some modifications of the proposed technology factsheets were carried out during the consultations. By the end of May and mid June the proposed technologies that were being evaluated included the following:

Week 2: 9 – 13

- The climate change Adaptation Consultant (Lead Consultant) held two small group meetings with the Agriculture Sector stakeholder to review the first two adaptation technology factsheets in Belmopan and at Central Farm.
- The Mitigation Consultant was conferring with stakeholders of the Energy sector on two proposed technologies (Solar PV On Grid and Solar PV Off Grid), and had proposed one technology for the Transport sector.

Week 3: 16 – 20

- The Lead Consultant held another series of small group meetings with Agriculture Sector stakeholders and University of Belize plant micro-propagation laboratory personnel, to review the next two adaptation technology factsheets, and proposal for a fifth factsheet for the Agriculture Sector. The Lead Consultant received informative feedback for improving the factsheets.
- Continued discussion with personnel and stakeholders of the Water sector on three proposed factsheets for this sector. Three Water sector factsheets were drafted and scheduled for review during the last week of May and early June.

Week 4: 23 – 31

- Held a series of small group meetings with Agriculture and Coastal and Marine Ecosystem Sector stakeholders to review a fifth factsheet in the Agriculture sector and two factsheets for Coastal and Marine Ecosystem sector.
- After a number of attempts to find out the status of the mitigation factsheet consultations and the number of completed mitigation factsheets, the mitigation Consultant eventually indicated that he had been working on two Energy sector factsheets and will submit the first drafts for review.

June, 2016

Week 1: Jun 6 – 10

- A total of ten Adaptation factsheets were completed in early June.
- The Mitigation Consultant submitted three draft Energy sector factsheets for review (*Solar PV On Grid*, *Solar PV off Grid*, and *Solar Water Heater*) after much attempts soliciting progress updates with the mitigation stakeholder consultations, and status of the remaining mitigation factsheets.
- A new Mitigation Consultant (Mr. Lucien Chung, Civil Engineer and Hydrologist), was contracted to carry on with the review of the three draft Energy factsheets, and completion of the remaining, proposed six mitigation factsheets. The Lead Consultant promised to draft three of these mitigation factsheets.

- Lead Consultant reviewed comments on the mitigation technology factsheets received from TNA-Belize Coordinator and from the Regional Office in Peru.
- A suggestion was made that a different Factsheet template be used instead of the one used by the Guyana Consultants and adopted by the Lead Consultant. This was being considered for all the Mitigation technology factsheets.

Week 2: Jun 13 – 17

- The Lead Consultant, in consultative meetings with sector stakeholders, conducted the MCA process for Agriculture, Water and Coastal and Marine Ecosystems sectors during there separate small group sessions during the second and third week of June. The results of the MCA exercise along with the adaptation factsheet technologies were forwarded to the TNA Country Coordinator.

Week 3: Jun 20 – 24

- Consultative meetings were held with new Mitigation Consultant on the remaining, proposed mitigation technologies, some of the key stakeholders, and the TNA coordinator.
- The Lead Consultant visited key sector stakeholders to discuss the result of the MCA process. Finally, a total of six mitigation technology factsheets were prioritized: three in the Agriculture Sector, two in the Water Sector and one for the Coastal and Marine Ecosystem Sector.

Week 4: Jun 27 – Jul 1

- Lead Consultant met with representatives from the Forest Department to discuss a "Micro-hydro Run-of-the-River electric power facility" proposed in the Forest Reserve & Visitor's Centre in the Mountain Pine Ridge development plan. It was decided to develop an Energy Sector mitigation factsheet for this concept and if successful, could be replicable for other 'off-the-grid' tourists resort and destinations in Belize. It was agreed with other stakeholders that this should be done as it could provide opportunities for job creation, provide social and economic benefits, and will have significant mitigation potential.
- Additionally, another mitigation technology factsheet was proposed by the Forest Department on an innovative pine and tropical timber species reforestation programme for the Mountain Pine Ridge Nature Reserve and the Chiquibul Forest Reserve, devastated by the Southern Bark Beatle infestation of 2000 – 2003 and damaging widespread illegal logging and forest destruction. The reforestation programme will include advance pine and tropical timber tree species nurseries with drip irrigation systems, and small financial contributions by tourist and visitors for planting their own tropical rainforest tree(s) in Belize, thus contributing to the global effort of capturing carbon emission and slowing down global warming.

July, 2016

Week 1: Jul 4 – 8

- Lead Consultant met with representatives from the Forest Department and Friends for Conservation and Development (Local NGO) to discuss the Landscape Management of the Vaca Reserve with buffer communities and farmers working in the area. It was proposed to draft a mitigation technology for this initiative which will be coordinated by FCD under the auspices of the Forest Department. The technology transfer shall include tropical timber species tree nurseries for reforestation component, and advance techniques in Advance Landscape Management and Agroforestry to relieve the stress on forest resources being exploited by farmers and illegal loggers and intruders.

Week 2: Jul 11 – 15

- Lead Consultant and Mitigation Consultant met with Transport Department and Energy Sector stakeholders to discuss two proposed technologies for the Transport Sector, namely:
  Improved Urban/Suburban Public Transport System to reduce fuel use and decrease emissions, and *Reduce carbon emissions of imported vehicles through improved emission control systems and engine efficiency*. Stakeholders were in agreement that some concrete actions were need to improve the transportation system in Belize, and in the process decrease Belize's carbon footprint and contribute to global efforts to reduce fossil fuel emissions. A copy of the deliberations and outcome of this meeting is attached for reference.

Week 3: Jul 18 – 22

- Consultants met with TNA Coordinator to discuss the MCA process results and the status of the Mitigation factsheets. The urgency of the TNA-Belize project was emphasized at this meeting and a way forward was considered for the proposed adjusted work plan for the TNA-Belize project Step II (BA & EF).
- Lead Consultant met with Mitigation Consultant and his assistant in Belize (ChenTech Office) to update the TNA-Bze project Step II Workplan. Very likely that an extension fo two week may be required in December to complete second draft review of the BA & EF Report and submission of the final BA & EF Report.
- Draft adjusted Work Plan submitted to the TNA-Belize Coordinator for review and submission to UNEP-UDP.

Annex III: Prioritized Adaptation Technologies

Summary of Prioritized Adaptation Technologies by Sector

Sector	Technology	Score
Agriculture	◦ Heat and Drought Resistant variety of open-pollinating corn and black beans seeds for reproduction and marketing	54.0
	◦ Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement	49.5
	◦ Protective Structure Cooling Systems	44.8
	◦ Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties	31.7
Coastal and Marine Ecosystems	◦ Improved Monitoring Network and Early Warning System for Belize's Coastal Zone	52.0
Water	◦ Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize	73.0

Annex IV: Climate Change Adaptation Technology Factsheets

Date: April 2016, updated September, 2016

1.

Sector: Agriculture
Sub-Sector/Technology Option: Drip Irrigation Systems
Technology Application: ***Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement for five farmers groups plus training station at Central Farm***

Introduction

Climate change and climate variability are projected to significantly impact agricultural systems and practices such as soil fertility and land preparation, pest and disease control and water requirements (CCCCC, 2014). Increased stress on current livestock breeds and crop varieties is expected with higher ambient temperatures. Climate change and climate variability will also result in less rainfall overall. However, the most deleterious effect on agriculture will come from the variation of seasonal rainfall distribution, leading to more drought events and floods. "Dependent" rainfall for rain-fed agriculture system during critical phases of crop development may not be received; therefore, farmers in Belize will have to adjust to the changes in rainfall pattern or expand the use of advance drip irrigation systems to ensure better yields and acceptable returns for their investments.

Improved drip irrigation systems and fertigation needs to satisfy crop water/nutrient requirements is an established technology for crop production in many countries. In generic terms, the benefits of irrigation are well known and can among others include: yield gap closure; multiple or prolonged cropping; access to niche markets; better crop quality; climate change adaptation; increased opportunities for import substitution and export; and justification for investment in added value (GOB/CDB/FAO, 2015).

Generally, lands that are irrigated have double yields compared to those without irrigation. For example, highland, mechanized, rain fed accounts for the majority of the total 1800 acres of rice in the Toledo District of Belize. The average yield from such production ranges from 1500 – 2500 lbs./acre, while the mechanized, irrigated, low land produces upward of 5000 lbs./acre (Chung, 2011). Also, crop quality, diversity and the ability to extend the growing season, especially for tropical climates, are some of the attributes of irrigated cropping systems. Because of irrigation, much of the world's undisturbed lands are spared the fate of agricultural development and land use change (Chung, 2011).

The proposed improved irrigation technology intervention is intended to support the work of the Crop Research and Development Unit (CRDU) field station in Belmopan, and five district agriculture training/demonstration sub-stations in Belize. The improved drip irrigation/rainwater harvesting & fertigation technology for training and demonstration will target small farmer's groups/cooperatives engaged in vegetable and horticulture cultivation under cover structure practiced by farmers in all six districts. Six improved drip irrigation/water harvesting & fertigation systems are being considered for this adaptation technology transfer, and coordinated, managed and maintained by the CRDU and Extension Services of the Ministry of Agriculture.

Improved drip irrigation system

Improved drip irrigation introduce water directly into the root zone without sprinkling the foliage or wetting the entire soil surface. Such partial-area irrigation methods offer the additional benefit of keeping the greater part of the soil surface (between the rows of crop plants) dry. This discourages the growth of weeds, that would otherwise not only compete with crop plants for nutrients and moisture in the root zone and for light above ground, but also hinder field operations and the control of pests (Perry, 2015). This technology can be used in conjunction with other climate change adaptation measures such as water harvesting, multi-cropping and fertilizer management (fertigation system). Promoting drip irrigation contributes to efficient water use, reduce requirements for broadcasting fertilizers, control weeds, and increases soil productivity. It is particularly suitable in areas with permanent or seasonal water scarcity, since crop varieties planted can adapt to the local conditions.

Investment is required to build worker's capacity in order to efficiently maintain the system and water flow control. Drip irrigation can be used for small or large-scale crop production, and with low cost or more sophisticated components
How the system is operated is very important? With poor management, even the most sophisticated system can result in water loss and inefficiency. Only knowledgeable, experienced and caring management can ensure that appropriate irrigation systems achieve their full potential benefits. Table 1 below is a summary of the percent applied irrigation as per agriculture productive system in Belize (Chun, 2011, in GOB/CDB/FAO, 2015). Except for Wetland rice and banana, the percent of total cultivated area with applied irrigation is small for most other crops.

Table 1. Percent applied irrigation per productive system in Belize in 2011.

Agriculture Water Management (AWM) Baseline in Belize 2011									
	High Value Crops					Field Crops			
	Production Systems								
	Banana	Citrus	Sugarcane	Aboreal	Other	Dryland Rice	Wetland Rice	Corn	Pulses
AWM Total ha.	2,493	19,000	28,000	2,152	1,205	3,183	760	17,398	9,273
Details % irrigated	85	< 1	< 1	< 45	20	< 1	100	< 1	< 3

Source: Chung, 2011 in GOB/CDB/FAO, 2015

In 2015 some 5,427 acres (2196.2 ha) of rice was cultivated with flood irrigation mostly in the Orange Walk District. Less than 50 % of the potato crop (107 acres) were cultivated under drip irrigation, mostly in northern Belize (Mr. Jonathan Can, Extension Officer, MoA, personal communication, April 2016).

Technology Characteristics

Features	Two major type of cropping systems in Belize are *Mono-cropping* and *mixed-cropping* (Chung, 2011). *Mono-cropping* is done usually by medium to large farmers, where their produce is export oriented. Most of the mono-crops are citrus, banana, sugarcane, papaya and rice. *Mixed-cropping*, as expected is done mostly by small farmers, where most of their produce is consumed locally. Some examples are tomatoes, onions, sweet pepper, broccoli and melons. The improved drip irrigation systems will be installed at five

	farming cooperative farming sites, and one at the Ministry of Agriculture field stations at the Agriculture Showgrounds training station in Belmopan, Cayo District. The target farming groups for the proposed advanced drip irrigation systems installation and initial training will be: 1) The Valley of Peace Vegetable producers (mixed cropping under cover structure and small open fields (Improved drip irrigation); 2) The San Carlos New River Cooperative consisting of 26 members, engaged in the cultivation of corn, bean, onions and vegetables (Improved irrigation system). 3) San Antonio Farmers cooperative engaged in the cultivation of potato, black bean, peanuts and vegetables (Improved drip irrigation) 4) Red Bank Village Farmers Cooperative, and 5) Silver Creek Farmers Cooperative (Improved drip irrigation) The Ministry of Agriculture *Agricultural Water Management Investment Plan, Volume 1. Final Report (2015)* calls for "cost effective irrigated agriculture contributing to sustainable food security, poverty alleviation and economic growth", and "An irrigated agricultural sector provided with adequate and appropriate irrigation infrastructure" (GOB/FOA/CDB. 2015).
Capital Investment Cost	Six only improved drip irrigation system with irrigation and water abstraction facility to irrigate 6 acres: *@ US $7,000.00 each* **Cost US $ 42,000.00** Six pumps @ *US $ 1,200.00* **Cost US $ 7,200.00** Six wells @ *US $ 7,000.00* **Cost US $ 42,000.00** **Six 2,000 gallons Water Tanks** @ US $800.00 **Cost US $ 4,800.00** Training extension personnel and four farmers groups @ *US 5,000.00* **Cost US $ 20,000.00** **Total Cost US $116,000.00**
Operating Cost	Spares and maintenance per year US $15,000.00 **Total Cost US $ 45,000.00**
Maturity	Many small farmers in Belize have incorporated the cover structure farming system with basic drip irrigation system for vegetable cultivation, since the late 1980s. However, the limiting factors are water, effective fertilizer application and

	costs.
Country Specific Applicability and Potential	
Status of technology in country	Both drip and sprinkler irrigation systems are in use in Belize. Since its introduction, drip irrigation is used mostly in vegetable and horticulture production under cover shelters, and to a lesser extend for small acreage of onions and potato. Larger acreage of drip irrigation was being applied to papaya plantations but recently this industry was facing cash flow difficulties and forced to close down its operations. Sprinkler irrigation is used mostly in banana cultivation and to a smaller degree in citrus and grain production.
Market potential	A lucrative market exists for grain and pulses. Expanding the use of irrigation for the production of these produce would increase yields and profits for farmers' groups and small farmers in general.
Scale of application and time horizon	Initially the scale of the improved drip irrigation technology will benefit five farming cooperatives, who will be trained in the installation, operation and maintenance of the irrigation systems. These five farming groups will then help in the installation of 6 acres of advanced drip irrigation systems on their farming site under a three-year monitoring and evaluation of crop yields with the advanced irrigation systems Training will also be provided for other farmers in the installation and proper operation of the Center Pivot Sprinkler irrigation systems, with the aim to prepare farming groups run a similar center pivot system on their field for grain production. This will be done on a loan-basis for one or two cropping seasons, then transferred to another grain farming group for use under the same arrangement. After the experience, the farmers group may decide to purchase their own center pivot sprinkler irrigation system, once funds can be identified. The scope of the intervention will be for six cropping seasons or three years.
Institutional and Organizational requirements	Ministry of Agriculture CRDU personnel will be trained to install, operate and maintain the center pivot sprinkler irrigation system and the advance drip systems.
Operation and maintenance	CRDU personnel and members of the farming groups will be responsible for the operation and maintenance of the advanced drip irrigation systems and the Center Pivot Sprinkler systems.
Scale/size of beneficiary group	The scale of the advanced irrigation system technologies will impact five farming cooperatives in four districts of Belize. Farming cooperative members and their communities will be beneficiaries of the intervention.

	During the three years of project cycle, training in advanced irrigation systems will be extended to other farming cooperatives around the country.
Acceptability to local stakeholders	Local stakeholders (decision-makers, agricultural experts and farmers all welcome this proposed technology transfer.
Endorsement by experts	Highly endorsed by the agricultural experts and decision-makers in the Ministry of Agriculture and the Private sector (example Benny's Wholesale; The Seed and Agro Supplies; etc.)
Barriers and Disadvantages	Barriers: 1) Initial cost to small farmers who would like to improve and expend their personal drip irrigation systems; 2) Lack of technical capacity among small farmers; 3) Credit and low-interest financing facilities 4) Market availability for produce 5) Insurance resulting from climate extremes, thief, vandalism 6) Water availability in drought conditions 7) Inadequate extension service
Climate change adaptation Benefits	
Adaptation potential: Sprinkler irrigation technology can support farmers to adapt to climate change by making more efficient use of their water supply. This is particularly appropriate where there is (or is expected to be) limited or irregular water supply for agricultural use. The sprinkler technology uses less water than irrigation by gravity, and provides a more even application of water to the cultivated plot. Drip irrigation contributes to efficient water use, reduce requirements for broadcasting fertilizers (is combined with fertigation), control weeds, and increases soil productivity.	
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	Crop quality, diversity and the ability to extend the growing season, especially for tropical climates, are some of the attributes of irrigated cropping systems. Yields are generally higher; hence the economic returns are significant.
Social benefits	Advanced irrigation systems both under cover and in the open field enable famers to harvest two or more crops per year compared to the traditional one crop. Provided the market demand is available, farmers can see good returns for their investments and improve livelihood for their family and their communities.
Environmental benefits	Advanced drip and sprinkler irrigation have a number of environmental benefits in tropical regions. They provide an improved means of supplying crops with the required water needs during growth and development phases, thereby conserving water; reduce soil erosion and agrochemical runoff into the environment; reduce the need to deforest more virgin forests that leads to uncontrolled expansion of the agriculture frontier in counties like Belize; and help reduce GHG emissions from the agricultural sector.
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2.

Sector: Agriculture
Sub-Sector/Technology Option: Crop Diversification and New Varieties
Technology Application: *Refurbishment of Seven Protective Structure Cooling Systems*

Introduction

A tropical greenhouse is not to provide a warm and humid environment for crop, but to create an ideal condition in which plants can be protected against heavy rainfalls, direct solar radiation, disease, insects and birds. High relative humidity and ambient temperature microclimate in a tropical greenhouse creates a complicated dynamic system that is strongly influenced by changes of external conditions, making it a challenging environmental control task (Shamshin & Wan Ismael, 2013).
Protective cropping structures were introduced in Belize under the 9th European Development Fund (EDF) funded Agriculture Enterprise Development project (AED), and was well received by vegetable farmers. Some structures have been properly managed and some farmers have experimented with lower cost design structures (Salazar, 2013; Frutos, 2014).

As indicated, one main purpose of Protective Covered Structure (PCS) is to create a controlled environment for optimum growing conditions compared to growing outside in a non-controlled environment (FAO, 2011). A farmer or grower has many options in the design of the greenhouse structure and on how much control he/she may want or need for the crops that are being grown. Specifically, Protective Covered Structures (PCS) or Tropical Greenhouses contribute to increased productivity, improved produced quality, reduced cost of production, and reduce dependence on pesticides (Ramirez, 2010).

Protective Covered Structures in Belize are of four types, namely: Tropical Greenhouse, Bubble House, Bel Tunnel and Plastic Covered Structure (Ramirez, 2010; Reyes, 2010).

- **Tropical Greenhouse**

Standard Dimension is 54' x 82' x 23' (16.5 m x 25.0 m x 7.0 m). Capacity 750 plants. Estimated cost: US $ 15,400.00 (includes frames, cover material, installation, irrigation etc.).
This new imported design included balconies that allows farmers to produce an alternative crop. The height of the structure creates exceptional head space for air circulation and plant growth.

- **Bubble House**

Standard Dimension is 20' x 40' x 10' (6.1 m x 12.2 m x 3.1 m). Capacity 220 plants. Estimated cost: US $ 1,760.00 (includes lumber, cover material, irrigation, labor, etc.).

This is a local modification of the Tropical Greenhouse constructed from bush posts, lumber and PVC pipes with the goal to reduce cost.

- **Bel Tunnel**

Standard Dimension is 14' x 60' x 12' (4.3 m x 18.2 m x 4.6 m). Capacity 400 plants. Estimated cost: US $ 1,400.00 (includes posts, pipes, cover material, labor, irrigation etc.)
This type of covered structure is generally more affordable and easier to assemble that the other types. It is recommended for low income farmers who wish to practice greenhouse crop production.

- **Plastic Covered Structure**

Standard Dimension is 40' x 50' x 12' (12.2 m x 15.2 m x 3.7 m). Capacity 450 plants. Estimated cost: US $ 1,000.00 (includes lumber, cover material, labor, irrigation etc.).
The main benefit of this structure is to reduce the negative impact such as increased incidence of pest and disease damage resulting from periods of prolong rainfall. There is no use of anti-viral netting so issues of high internal temperature and cost of material is eliminated. However, the crops are more vulnerable to pest and disease attacks.

Most PCS by design and nature can become too warm, thus greatly affecting production and quality of the crop. Cooling is a critical part of the controlled environment and is considered as a basic necessity for greenhouse crop production in tropical and subtropical regions to moderate the problems of high temperatures during the summer months and to adapt to the effects of climate change. Development of effective cooling system that provides congenial microclimate for crop growth is a difficult task as the design is closely related to the local environmental conditions (Kumar, et al., 2009).

The focus of the technology transfer under TNA project is to refurbish a total of seven existing Bel Tunnel PCS and a larger Greenhouse structure with cost effective cooling systems as a pilot project for demonstration, evaluation and replication among the farming communities in Belize.

Improved PCS designs and systems may incorporate the following cooling technologies:

- **Natural Passive Ventilation (Air exchange) and shading systems;**
- **Mechanical Active Ventilation powered with solar energy;**
- **Evaporative Cooling: i) Evaporative cooling fan-pads, and ii) High pressure fogging.**
- **Earth-to-air heat exchange system.**

Natural Ventilation: **Natural ventilation allows the greenhouse structure to ventilate and cool by natural air movement within and outside the structure. The objective of natural ventilation is to maintain the same temperature inside the greenhouse as it is outside the greenhouse. This can be hard to accomplish because of influences by the solar heat gain through the covering, the type of covering used on the structure and directional placement of the structure on the land in relation to the prevailing winds (Parsons, 2015; FAO, 2011). In greenhouses with natural ventilation, internal and**

external shade systems can control the heat generated by the solar gain. Shade systems also help control the intensity of the light in the greenhouse, however one disadvantage with shading is the reduction of photo synthetically active radiation (PAR) required by crops (Kumar, et al, 2009). Based on the design of the naturally ventilated greenhouse, one can expect to see temperature difference ranging from near ambient to 10 degrees or more. Kumar et al (2009) indicated that the volume/floor ratio of greenhouse should be large as possible if local wind speed is not too high to maintain favorable environment for crop growth, recommending that combined sidewall vent area should be equal to the combined ridge vent area, and each should be at least 15 – 20 % of the floor area of the greenhouse for tropical conditions.

Shade Mesh

Shade mesh, along with ventilation are a very effective weapon to reduce the temperature inside greenhouses, while favouring plant transpiration.

Mechanical Active Ventilation with the use of solar energy: **Covered structure cooled with natural ventilation can be augmented with mechanical ventilation to improve the airflow and extract the warm air out of the house. Designing for one air exchange per minute for the greenhouse will make ambient temperatures possible inside. Rodriguez (2016, personal comm.) indicated that this technology is seldom used in Quintana Roo, Mexico for multiple tropical greenhouse array because of the high cost of installation and energy needs, and the drying effect the forced ventilation has on sensitive crops.**

Evaporative cooling

Evaporative cooling is the most effective cooling method for controlling the temperature and humidity inside a greenhouse, however, its use in the humid tropics is restricted because of the high humidity environment (Kumar, et al., 2009).

*i) **Evaporative cooling fan-pads***

In Belize, 90 % of the PCS or tropical greenhouses in use are inadequately ventilated and this has been identified by agricultural experts as a major hindrance to optimize the capacity and usefulness of PCS. The proposed solution is to refurbish all of the operational PCS and those that will come on line in the near future, with mechanical ventilation such as calibrated inflow and hot-air exhaust fans running on solar energy. The alternative is to run these fans from the electrical power grid, but three constraints identified with this option are: i) too costly for small famers, ii) the greater majority of the PCS and farms have no direct access to the national grid, and iii) smallest farmers have limited or no access to additional credits to cover a monthly, electricity expenditure. Also, a PCS cooling system monthly cost would increase the overall cost of production for small farmers in Belize, and this would result in an increase cost of agricultural produce for the local consumers, which in the long run would be unsustainable.

Where suitable, a combination of factory-produced evaporative wet pads and fans can be installed to run as a combined system together with natural ventilation. The cooling cells of the wet pads are made from a specially formulated cellulose paper impregnated with insoluble anti-rot salts. It is designed with an exclusive cross-fluted configuration

which induces highly turbulent mixing inside the pad between the water and the air, and contributes to the evaporative efficiency. The cross-fluted design makes the pads strong self-supporting, with high evaporative efficiency and low pressure drop (resistance to air flow). Besides the cooling pads, other components of interest in a complete evaporative cooling system include water distribution and return systems.

*ii) **High pressure fogging***

Nebulizer or fog/mist system sprays small droplets (diameters of 2 – 60 µm) with high pressure nozzles that can be run by a 1 HP pump per tropical greenhouse unit from a nearby water reservoir (Kumar, et al. 2009). Cooling is achieved by evaporation of droplets. This method can also be used to increase the relative humidity apart from cooling the greenhouse. Rodriquez (2016. Personal comm.) reports that this method in combination with appropriate shading and natural ventilation is the preferred cooling technologies in Quintana Roo, Mexico. Rodriquez (2016) added that an aluminet mesh ceiling curtain, white plastic ground cover, and hydroponic one-meter coconut husk bags accommodating four seedlings or plants are also used to enhance the cooling system, and ensure higher crop development and improved yields.

*iii) **Earth-to-air heat exchange system (EAHES)***

The ground potential of the earth can also be used for cooling the greenhouse in summer because of its constant year-round temperature (26 – 28 °C) with earth to air heat exchange system. Though earth-to-air heat exchanger system can lower the interior temperature of a greenhouse to a remarkable extent, the major disadvantage of using EAHES is the initial cost involvement and the less longevity of the metallic pipes due to corrosion (Kumar, et. al., 2009).

Technology Characteristics

Features	Protective cropping or covered structures (Tropical Greenhouse) is a relatively new technology to Belizean farmers (Ramirez, 2010). The rapid growth in interest of this technology among farmers has created a great demand for information on the types of PCS, cost, construction, management, production and income generation potentials. Interested parties requesting information on PCS include: farmers, students, home gardeners, schools and other growers. Some reasons expressed by growers to experiment with PCS range from the desire to try an alternative production system that reduce cost of production, reduce or minimize the dependence on harmful pesticides and/or reduce the negative impacts caused by periods of high rainfall and other climate change-related hazards. When choosing a greenhouse and related equipment, it is important to consider the local climate, including its influence on the growth of crops (Ramirez, 2010).

	The preferred technology for PCS cooling system under this initiative is the *Mechanical Ventilation* with strategically positioned inflow, circulation and exhaust fans driven by solar power, and augmented by improved natural ventilation. If the greenhouse structure is naturally ventilated and the aim is to further reduce heat, the addition of mechanical ventilation will improve the airflow and extract the warm air out of the house. Designing for one air exchange per minute for the greenhouse will make ambient temperatures possible inside the greenhouse. In a typical mechanically ventilated greenhouse design, the engineering parameters used for selecting the required number of exhaust fans are calculating the volume of the greenhouse, identifying what the static pressure in the house will be and selecting the placement of the fans in regards to the location of the vents (Parsons, 2015). With the parameters identified, fan selection is based on the cubic feet per minute (CFM) rating of the fan, the static pressure ratings, the actual physical size of the fan and the horsepower rating. With the above fan ratings, one can select the correct fan that produces the highest CFM per watt for energy-efficient operation. Now that the greenhouse has mechanical ventilation, one can use an environmental computer or mechanical thermostats to control the fans. Staging of fans to come on in groups will help save energy costs. There are limitations on the length or distance that you can effectively pull air through the greenhouse without having large temperature differentials from the inlets to the exhaust fans. Engineering specification for Active Mechanical Cooling for one Bel Tunnel size PCS: 5000 Wh per fan/day. A total of nine (9) are recommended, leading to 9 * 5,000 = 4.5KWh/day Power requirement ≈ 5 KWh/day Circulation … 1 fan every 20 feet. Nine fans: 3 Intake, 3 Exhaust, and 3 Circulation Intake and Exhaust fans size: 24 inches Circulation fans (ceiling): 54 inches. Direct current, no batteries will be needed. Cooling system will run only when required during the daytime. Because of Pilot nature of project, more technical service will be required on site.
Capital Investment Cost	**Refurbishment of unit Tropical Greenhouse with dimensions: 54' x 82' x 23'; Volume: 101,844 ft^3**

	1) Redesigning natural ventilations: US $ 2,000.00 2) Ceiling Shading US $ 3,000.00 3) Refurbishing one Tropical Greenhouse: Unit cost is US $ 20,000.00 Total for one Unit US $ 20,000.00 **Sub Total: US $ 25,000.00** **Refurbishment of a typical unit Bel Tunnel with dimensions: 14' x 60' x 12'; Volume: 10,080 ft^3** 1) Redesigning natural ventilations: **US $ 1,000.00** 2) Ceiling Shading **US $ 1,500.00** 3) Unit cost US $ 10,000.00 Total for Seven (7) Units (one in each of the six districts plus Belmopan) **Total cost US $ 70,000.00** 4) Training of 6 Technician in six districts Cost @ US $ 2,000.00 per training **Total cost US $ 12,000.00** **Overall Total cost… US $ 109,500.00**
Operating Cost	Monitoring and evaluation US $ 6,000.00 per year for three (3) years = US $18,000.00 Cost of Spares and material: US $10,000.00 **Total US $ 28,000.00** One Renewable technology provider has the following 5-year de-rated warranty offer: Year 1: 100 % cover for equipment Year 2: Units get repaired or replaced at 50 % discount Year 3: Units get repaired or replaced at 25 % discount etc.
Maturity	Tropical Greenhouse technology has been around for sometime now and it is being improved for efficiency, cooling and automation. New tropical greenhouses will come with the added features of advanced and automated cooling systems and will cost more, but with time these capital cost should have decreased. In the meantime, efficiency and cooling of existing tropical Greenhouses in Belize should be addressed, so that their optimum use in crop production for small producers can be realized.
Country Specific Applicability and Potential	

Status of technology in country	Tropical Greenhouse or PCS are now widely used by many medium size and small farmers in Belize. It is estimated that there are some 2,000 PCS of different types in use across the country.
Market potential	There is a potential market to refurbish all the covered structures and tropical greenhouses with improved and cost-effective cooling systems.
Scale of application and time horizon	Scale of the technology will be at the level of pilot demonstration and training at each MoA training centers in the country, including Central Farm and will run for three years. The third year will be mostly to test, monitor and evaluate scientifically, the effects of the cooling systems on working conditions under the covered structures and yields. Once trained, farmers will then be able to make the modifications to their tropical greenhouses or Tunnel structures with funds from other sources.
Institutional and Organizational requirements	Tropical Greenhouse technicians in the Crop Development and Research Unit (CDRU) of the Ministry of Agriculture will be responsible for all activities related to this technology transfer.
Operation and maintenance	Operation, maintenance and monitoring of the cover structure cooling systems will be carried out by technicians of the CDRU, Ministry of Agriculture, extension officers and farmers.
Scale/size of beneficiary group	The scale of the proposed covered structure cooling system technology will be at the country wide scale, with one refurbished tropical greenhouse and tunnel covered structure in each of the six farm demonstration site in each district. Beneficiaries will be farmer groups in these localities who will be trained in rehabilitating the cover structures and maintaining the systems. Once additional funds can be sourced, farmers will be able to purchase and rehabilitate their own cover structures.
Acceptability to local stakeholders	Key stakeholders and farmers welcome the idea of improving the micro climate of covered structures in Belize
Endorsement by experts	Local agricultural experts in Belize highly endorse the proposed intervention
Barriers and Disadvantages	Barriers: 1) Supply of cooling system components in country 2) High initial cost 3) Lack of Government subsidies for imported components (Solar PV parts) 4) Lack of capacity in electrical and agriculture engineering practices 5) Disadvantages:

	1) Cultural & traditional agricultural practices 2) Cover structures may be susceptible to high winds and floods, depending on their location. 3) Vandalism 4) Lack of interest among some decision makers & farming groups.
Climate change adaptation Benefits	
Adaptation potential: Higher ambient temperatures, reduction in water supply and new strains of plant pest and diseases associated with global warming will impact crop production directly. Improved crop cover structures or tropical greenhouse is an innovative technology to help modify the micro climate from external stress, so as to increase productivity, improve produce quality, reduce cost of production, and reduce dependence on pesticides.	
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	Tropical, cover structure cropping systems are used widely as a reliable form of crop production. Efficient and low-cost cooling systems contribute to the controlled micro climate, to optimize yields and profits to the small, medium and large growers.
Social benefits	Cover structure cropping systems when properly managed and utilized can contribute locally to the nutrient and food security for poor and marginalized communities.
Environmental benefits	The application of fertilizers in covered structures can be controlled and managed with a combined drip irrigation/fertigation system that ensures that the crop gets its required water at critical phase of its development. Waste and leachate is minimized., so is the runoff of other harmful agrochemicals into adjacent waterbodies and the groundwater.

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3.

Sector: Agriculture
Sub-Sector/Technology Option: Crop Diversification and New Varieties
Technology Application: ***Heat and Drought Resistant varieties of open-pollinated corn and beans for seed and grain production among Small Farmers in Belize***

Introduction

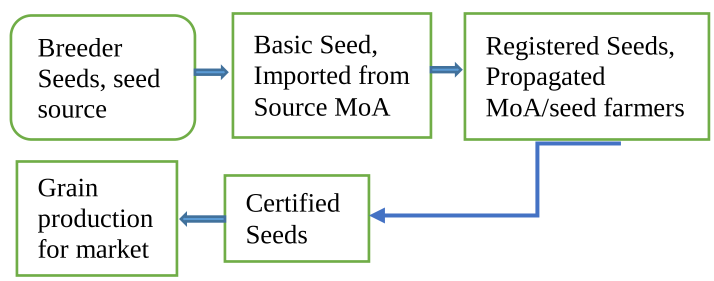
Climate variability and extreme events have been severely affecting Latin America over recent years (IPCC, 2007), and this trend will continue in the foreseeable future. Warmer temperatures, high rainfall variability, extended droughts and reduction in water supply will impact the agriculture sector in many regions of Central America, including Belize (CCCCC, 2014).

Yellow corn, white corn and black beans are staple grains in Belize. Reasonable production of these grains brings needed income for small farmers and contribute greatly to the community's food security. The Ministry of Agriculture/FAO and the Caribbean Agriculture Research and

Development Institute (CARDI) have been involved in conducting programs to supply good quality seed and know-how to farmers that should generate higher yields and reduce the need for more land clearing for milpa farming or slash-and-burn.

The proposed technology transfer to produce *Heat and drought resistant variety of open-pollinated corn and black bean seeds for production and marketing among small farmers in Belize* through the Technology Needs Assessment project (UNEP/DTU, 2013) is an initiative being promoted by the Ministry of Agriculture to increase the capacity of four farming cooperatives and its Grain Production Unit at Central Farm. The objective is to expand the production of climate resilient quality corn and black beans seeds for supplying to small farmers, and a fourth farming cooperative to produce corn and black bean grain for the local market. The intervention will run for three years.

Technology Characteristics	
Features	Capacity **-** Through a FAO project, many farmers have already been exposed to good quality seeds and have seen the results. They have also been introduced to planting to the techniques of planting in rows and proper storage facility. This has been transmitted through Farmer Field School methodologies. The Climate Change adaptation intervention will assist to establish plots, threshing equipment, shelling equipment, cold storage bins, procurement of quality seeds, agro-chemicals, drip irrigation and marketing. The target farming cooperatives are: *Valley of Peace Farmers Cooperative* consists of eight (8) active members. This group will be provided with improved drip irrigation system to enhance the old system they are using, and will be engaged in quality corn and black bean seed production to supply the demand among local, small farmers. *Silver Creek Village Farmers Cooperative* will be supplied with improved drip irrigation system and will also be engaged in the business of quality corn and black bean seed production and sale to other small farmers. *Red Bank Village Farmers Group* will also be engaged in quality corn and black bean seed reproduction under improved drip irrigation supplied through the TNA project technology transfer. *San Carlos Village New River Farmers Cooperative* (Orange Walk District) consist of 26 members. The combine acreage among members is in excess of 500 acres, but the Group is only using 1/10 of the land. The San Carlos group is producing vegetables, water melon, onions, potato, and also corn and beans. The Group has 16 wells from which they abstract water to irrigate their vegetable and onion crop. Corn and black beans are not irrigated at present. This Group is in need of improved irrigation systems to help reduce losses due to recurrent droughts. The proposed intervention will supply the Group with improved drip irrigation and one Center Pivot irrigation system. The San Carlos Farmers Cooperative plans to increase their yellow,

	white corn, and black beans production to supply the local market demand. The Ministry of Agriculture Crop Unit (Central Farm Group) is involve seed production of grain crops such as corn, beans and rice. This group will also participate in this intervention. The Crop Unit will be empowered with a grain storage facility, and other material to continue producing seasonal heat resistant grain during the project cycle. The Unit will also be responsible for coordination of the climate resistant grain seed production under the TNA intervention. The Caribbean Agricultural Research and Development Institute (CARDI Belize) will be the agency responsible for the conservation of seed Germplasm. The objective is to safeguard the quality and integrity of the varieties overtime. The proposed intervention will have positive impacts on marginalized communities, families and small farmers. Pest incidence on hybrid is much more prevalent than for open pollinated, so additional input to address pest will not be necessary. It is envisioned that with an efficient sprinkler irrigation system, the San Carlos Group can attain yields of 5000 lbs./acre which would be exceptional and profitable. The production chain for quality corn and black bean seed and grain is illustrated in the following schematic: 
Capital Investment Cost	Crop establishment Inputs: Initial cost: seed acquisition and importation US $ 4,000.00 Infrastructure for the **three (3)** Quality Seed producing Cooperatives & Grain Unit (CF) each cultivating 6 acres… *Irrigation* systems (3 Units) US$ 14,000.00 *Wells 3* US$ *11,000.00* *Pumps 3* US$ *1,800.00* **Sub Total 1** **US$ *30,800.00*** Harvesting and shelling cost: US $ *3,000.00* Post Harvest Costs: Storage for Cooperatives US$ *12,000.00* Seed Cold Storage (CF Group) US$ 15,000.00 Marketing: US$ *4,000.00* **Sub Total 2** **US$ *34,000.00***

	San Carlos New River Farmers Cooperative (Grain production & Marketing) *Irrigation* system (1 Center pivot Unit, 25 acres) US$ *40,000.00* *Land Preparation* (25 acres) US$ *7,500.00* Crop establishment Inputs: Initial cost: seed acquisition and importation (25 acres) & fertilizer US$ *4,000.00* Harvesting and shelling cost: US $ *3,000.00* Post Harvest Costs Storage: US $ *1,500.00* Marketing: US $ *3,000.00* Training (4 Groups Farmers) US $ 20,000.00 **Sub Total 3** **US $ *79,000.00*** Collection and Maintenance of seed Germplasm (CARDI) **Sub Total 4** *US $ 10,000.00* **Grand Total** **US $ 153,800.00**
Operating Cost/Maintenance	Seed selection and production to maintain integrity for at least six cultivation seasons (3 years, Crop Section MoA, Crop Unit) US $ *500.00* per acre Cost US $ *9,000.00* for 6 acres for 3 years Storage & cooling system (Solar power, four pumps for drip irrigation) US $ *8,000.00* Maintenance for Sprinkler Irrigation system (Research Unit CF technicians, 3 years, @ US $ 2,000.00/year) US $ *6,000.00* **Total Operating Costs** **US $ *23,000.00***
Maturity	Seed production technology in Belize is recent or new among farmers group and the MoA in Belize (2011). CARDI has been the main quality grain seed production agency in Belize since 1980. Capacity building in quality grain seed production is urgently required in the MoA extension service.
Country Specific Applicability and Potential	
Status of technology in country	White corn and black beans production is done by small farmers in most districts in Belize, but at a smaller scale compared with the fully, mechanized operations practiced by the larger Mennonite farmers in the Cayo, Orange Walk and Stann Creek Districts. The yields among small farmers are much lower and the objective of the intervention is to increase yields and facilitate the entire whir corn and black beans production chain from planting to storage, marketing and selection of high quality seeds for the next cropping season.
Market potential	White corn and black beans are staple food in the region. Market demand for quality yellow corn seeds is: 225,000 lbs per year, white corn quality seeds 125,000 lbs and for black beans quality seeds 100,000 lbs.
Scale of application and time horizon	It spans throughout the country. Rural producers used corn as food and also feedstuff for livestock. This proposed

	technology for climate change adaptation is envisioned to cover complete production system for climate resilient and improved quality of white corn and black beans varieties will span from the initial purchase and importation of the seeds, field trials and distribution to target group of small farmers, marketing and evaluation of the crop management and yields, harvest and storage, marketing and selection of new seeds for the next cropping season. It is proposed that this cycle is repeated for three years and by the fourth year all participating farmers will have the capacity to carry on independently or as member of their farmers group. Time horizon is proposed to be for three (3) years.
Institutional and Organizational requirements	Crop Section at Central Farm and District Extension Offices, together with the Agricultural Research and Development Unit (ARDU), Central Farm, Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development, will be the leading Public Service agencies coordinating the intervention for the improved technology for the cultivation of climate resilient corn and black beans. BAHA, CARDI, IIAC will be supporting agricultural agencies providing support for the corn/black beans production, storage & marketing technology transfer.
Operation and maintenance	Extension Officers and ARDU technicians will be trained to operate and maintain the irrigation systems. Farmers cooperative members will also be give training for the irrigation systems, particularly the San Carlos Group who will be trained in operating the Center Pivot Sprinkler irrigation system.
Scale/size of beneficiary group	The scale and size of the beneficiary group will cover all farmers of the four (4) cooperatives and their families and communities.
Acceptability to local stakeholders	This technology for the reproduction of climate resilient quality corn and black beans seeds and grain is highly demanded by the small farming community of Belize. The open pollinated corn varieties will ensure the farmers acceptable yields and a dependent source of high quality corn and black bean seeds, whose integrity will be maintained by the Ministry of Agriculture Crop Unit in collaboration with ARDU and CARDI.
Endorsement by experts	This initiative is highly supported and endorsed by the Agricultural experts of Belize. They are the main stakeholders who have reviewed and endorsed this factsheet
Barriers and Disadvantages	Some of the barriers foreseen for streamlining this technology include: - Initial high cost of establishing the improved production chain among four farming cooperatives producing quality corn and black bean seeds, and one group cultivating grains for the market; - Cooperative members to undertake their share of the responsibilities;

	- Level of education of some farmers; - Adequate source of water for irrigation systems during the long dry seasons in northern Belize.
Climate change adaptation Benefits	
Adaptation potential • **Reduction in deforestation** • **Increase resilience of farmers through improved production and storage of corn and bean seeds** • **Reduction in food insecurity in Belize and risk reduction to adverse climatic conditions.**	
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	Increase yields resulting in higher income for the rural families
Social benefits	Increase food security through the availability of seeds and grain.
Environmental benefits	Techniques introduced will reduce pollution due to increased slash and burn, reduce deforestation and land degradation in sensitive areas in the agricultural zones

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4.

Sector: Agriculture
Sub-Sector/Technology Option: Crop Diversification and New Varieties
Technology Application: ***Establish an in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties better suited to Belize's current and future climate***
Introduction **The International Potato Centre (CIP, 2010) reported that potato is the third most important food crop in the world after rice and wheat. Potato is a major source of carbohydrate in the diet of hundreds of millions of people in developing countries. This includes the population of Belize. According to the International Potato Centre (2010), potato yields more nutritious food at a faster rate on less land and harsher climates than any other major crop. Short duration and wide flexibility in planting and harvesting time are other valuable traits that help adjusting the**

potato crop in various intensive-cropping systems without putting much pressure on scarce land and water resources (Naik and Karihaloo, 2007). Potato (*Solanum tuberosum L.)* belong to the Solanaceae family of flowering plants. One hectare of potato can yield two to four times the food quantity of grain crops. Hence, potato is a critical crop in the response to population growth and increased hunger rate around the world and in Belize.

While potato forms an important component of the Belizean diet the varieties grown in the country are more suited to temperate conditions and so production is restricted to a few areas of the country which have the cooler climates suitable for potato production. Because of these restrictions, national production not always sufficient to meet local market requirements and at certain times of year potato must be imported into the country.

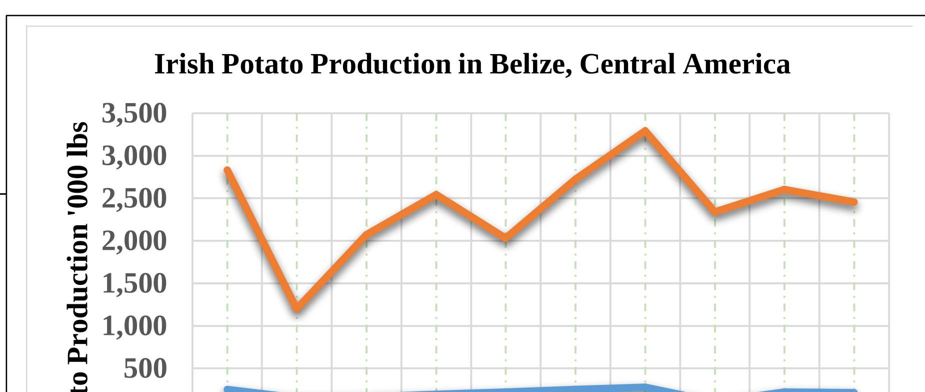
Because the varieties currently grown are temperate types, climate warming will create problems in the future if quality planting material, of heat tolerant varieties, are not made available to farmers. Without such an intervention, the medium and long-term sustainability of potato production in Belize will be under threat which, in turn, will negatively impact Belize's food security.

As potatoes reproduce vegetatively (they are propagated from cuttings) they are more likely to become infected with pests and diseases (especially viruses) transmitted from generation to generation than are seed propagated crops (CGIAR, 2012). Consequently, potato production plots need to be planted each year with fresh "clean" material (i.e. that has been tested free of specified diseases). Belize's annual requirement for such "clean" seed-tubers is currently imported each year, at some expense, from the USA. There is a need for Belize to establish its own national capacity to produce potato seed-tubers. Shortage of good quality seed is the single most important factor limiting potato production in developing countries.

This project will address these issues by establishing a national Irish potato clean-stock production unit that will produce high quality seed-tubers (free of specified diseases) for planting by small-scale farmers. The varieties produced will be better adapted to tropical farming conditions and so, in the short-term, enhance the capacity of Belizean farmers to expand current production into areas where, and months when, potato is not currently grown and, in the medium and longer-term, increase potato farming's resilience to climate warming.

Potato is currently produced by small-scale farmers in San Antonio, Upper and Lower Barton Creek, Springfield village, La Gracia, and El Prograsso of the Cayo District. As potato varieties used require cool conditions for tuber production and these farming communities have the required conditions for growing the varieties currently available in the country during the cool period of November to February. The red la roche and red la soda potato varieties are the varieties mostly planted in Belize.

According to Belize Ministry of Agriculture in 2012 Belize planted 112 hectares of Irish potato, producing 3 million pounds with a yield of 26,910 lbs / ha, ranking 110 in the world in terms of yield. While in 2015, Irish potato production in Belize was 2.24 million pounds and the yield was 25,869 lb. / ha.

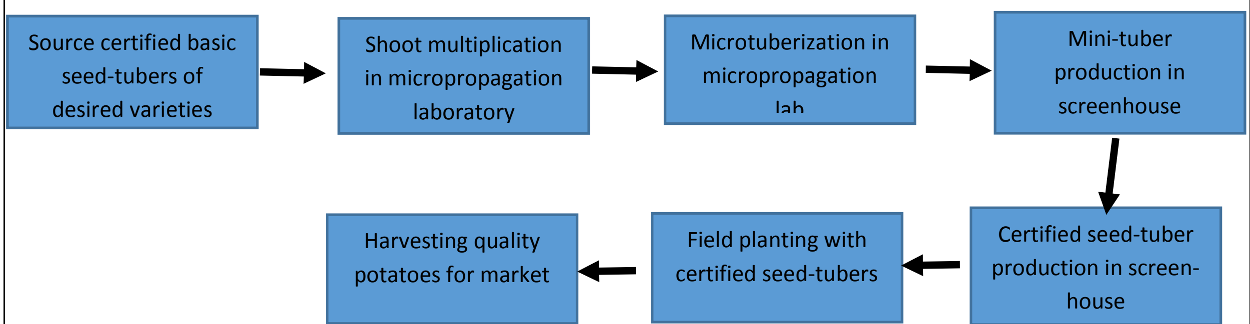


PRODUCTS	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015 (P)
IRISH POTATO										
Production (lbs)	2,580,700	1,054,025	1,906,500	2,347,150	1,809,500	2,473,000	**3,014,000**	**2,231,100**	2,379,737	2,240,300
Acres	251	155	165	195	222	251	**277**	**108**	224	214
Yield (lb)	10,282	6,800	11,555	12,037	8,151	9,853	10,881	**20,658**	10,624	10,469
Hectares	101.6	62.7	66.8	78.9	89.8	101.6	112.1	43.7	90.6	86.6

Source: Ministry of Agriculture, Fisheries, Forestry, Environment and Sustainable Development, (MAFFESD) Belize March, 2016.

Features	Since potato was first planted in Belize it has been observed that after one season in the field the crop becomes infected with insect transmitted viruses. As a result, tubers collected from one season become diseased and cannot be used as seed-tubers for planting the following season. To address this issue, fresh, quality potato seed tubers are imported from the United States into Belize each year. Unfortunately, these varieties have been developed for the temperate climates of northern latitudes. With global warming on the horizon, unless more suitable varieties are made available to farmers, it may become impossible to produce potatoes in Belize. If this were allowed to occur, the country's food security could be jeopardized. Officials in Belize have not, so far, investigated alternative potato varieties, but the urgency to do so increases with the advancing threat of climate change. The problem can be addressed by introducing technology for an in-country potato seed-tuber production system. The system will ensure quality, disease-free and diversified potato varieties that have been trialed locally, and demonstrated for high productivity under Belize's tropical conditions and made available to farmers. Additionally, this technology will permit an increase in national potato production by expanding potato farming in current producing communities to months when production has not previously been possible, and by expanding potato farming into other communities which are too warm for potato farming using the varieties currently available. This will not only reduce the need to import potatoes to supply the national consumer markets, but it will also save on foreign exchange by eliminating the annual requirement to import expensive, foreign sourced seed-tubers. An improved and expanded potato production system resilient to warmer climatic conditions would enhance national food security and bring economic benefits for many farming communities in Belize. ***Process:*** There will be a need for an Expert (Consultant) for two weeks – prior to the project implementation – to develop a full project document for the establishment of a potato seed-tuber production unit / system in Belize, and for the introduction and trials of potato varieties suitable for the market and growing conditions in country. 1) Initial field trial evaluation of (10) certified varieties by Ministry of Agriculture Research and

<table>
<tr><td></td><td>Development Unit and selected farming groups. This will run for two years.
2) Concurrently, work will begin, using selected varieties, to develop and establish the certified tuber seed production system.
3) In the third year, the best performing varieties from the field trials will be introduced into the in-country, seed certification system for later distribution to farmers.</td></tr>
<tr><td colspan="2"><u>Steps to produce certified tuber-seed for quality potato harvest</u>



</td></tr>
<tr><td>Capital Investment Cost</td><td>Potato seed-tuber expert 2-week working visit to Belize to develop full project document. Cost: US$ 12,000.00

The initial cost of new varieties of seed tubers imported into Belize plus UB micro-propagation lab services and nursery infrastructure development will be in the order of US$ 100,000.

Construction of tuberization screenhouses with irrigation and cooling systems US$ 100,000.

Construction of cool temperature-controlled potato storage facilities in three locations – US$ 100,000

BAHA cost for phytosanitary services will run in the order of US$ 5,000 for initial importation of seed tubers and travel of BAHA staff to conduct evaluation in source country.

Through BELTRADE fiscal incentives for agro-business and processing, the climate resilient Irish potato seed tuber shipment will be imported with custom duty exceptions US$ 20,000.

Total Capital Cost: US $337,000</td></tr>
<tr><td>Operating Cost</td><td>Establishment of farmer field trials to evaluate varieties – US$25,000.</td></tr>
</table>

	Approximate cost of seed-tuber production in screen-house or tropical green house by Ministry of Agriculture and farmer groups - US$50,000 per year, for the five years of the proposed project cycle – Total US$250,000. Initial costs for farmer acquisition, cultivation, harvesting and storage of crops for two seasons – US$200,000. Training programmes and consultancy visits – US$100,000. Establishment of standards and certification system – US$50,000 **Total operating costs = US$625,000**
Total Project Costs	**US$962,000**
Maturity	Cultivation of potato in Belize started in 1988, quite recently compared to other staples and traditional crops. The technology related to successful potato production in the country has not been fully realized, and with the increasing constraints related to climate change, there is an urgent need to ensure that potato production increases and expand to other areas of Belize. This will enhance food security and contribute to foreign exchange as quality potato is produced from improved, climate resilient varieties. The technology for clean-stock potato seed-tuber production is well established internationally but is not present in Belize. This is why potato seed-tubers for planting must be imported annually. The International Potato Institute in Peru is well known for its expertise in the development and implementation of this technology and the institute has a number of potato varieties in its catalogue that are adapted to growth in tropical conditions. As a result, it will advantageous for Belize to transfer this technology and varieties to the country in order to expand climate resilient potato cultivation.
Country Specific Applicability and Potential	
Status of technology in country	Irish potato cultivation of the Red la roche and Red la soda (temperate varieties) is carried out mainly in six farming communities in the Cayo District and one in the Orange Walk District. Optimal conditions for the cultivation of potato in these localities is mainly during the cool transition period of November through February. When yields fall below expected quantities or the crop fails, the Belize has to revert to importation of potatoes for the domestic market. The technology for the production of quality clean-stock seed-tubers for field planting in not available in country. Such material is imported each year from the USA.

Market potential	The market demand for Irish potato in Belize is relatively high. Initially potato for local consumption was all imported, but since 1988 when potato cultivation was introduced into the country, much of the potato is produced locally. However, when demands surpass supply, potato has to be imported. With the proposed introduction of improved, climate resilient white varieties adapted to tropical conditions like Belize potato production will be enough to supply the local market in the short term, and for regional export in the medium and long term.
Scale of application and time horizon	The scale for introduction of climate resilient varieties of potato seed tubers for in-country propagation and distribution, will initially be carried out in the three target potato-growing communities, with feed trials and evaluation facilitated by the National Agricultural Research and Development Unit (NARDU) and the MoA Crop Unit at Central Farm. The time horizon for seed tuber introduction, testing, micro-propagation and field trials will run for the first three years. In the fourth and fifth years, locally propagated seed tubers will be distributed to farmers in the three target communities at first, then expanded to other farming communities or groups in Belize during the fifth year. Training of farmers and monitoring and evaluation of yields will be carried out during all field trials.
Institutional and Organizational requirements	*The Micro-propagation Laboratory of the University of Belize (UB)*: The University of Belize established a commercial micro-propagation laboratory at its Central Farm campus in 2012. Initial interest in using this technology to produce planting material has been received from banana, sugarcane, pineapple and citrus farmers in the country, as they recognize the advantages of using micro-propagated plants to establish plantations. The University of Belize Micro-propagation Laboratory is equipped with a media preparation room, plant transfer room, plant growth room and a nursery/plant acclimatization facility. The Lab is staffed by 10 staff trained in the science of tissue culture but who shall require additional training in techniques to produce quality potato tuber seeds. To fulfill the needs for production of new varieties of potato seed-tubers the UB micro propagation lab will require institutional strengthening: additional equipment, some additional infrastructure and equipment, two additional staff members and specialized training. *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. Its main purpose is to safeguard agricultural health and phytosanitary services for the nation and facilitate trade and commerce.

	BAHA support 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. BAHA will play a critical support role through its phytosanitary services for the processing of imported new varieties of potato seed tubers for in-country propagation and deployment to farmers. BAHA will need additional equipment and training to facilitate phytosanitary services to certify to potato seed tuber production system in Belize. The Agricultural Research and Development Unit (ARDU) arose out of the National Coordinating Committee for Agricultural Research and Development (NCCARD). The Unit is based in Central Farm and carries out field trials and training in improve crop management and production. The Unit along with the MoA Crop Section will provide support for the introduction, field trials, training and dissemination of the new, climate resilient varieties of potato seed tubers under this TNA intervention. The unit and department will require additional infrastructure and technical capacity to install and maintain protective structures for nurseries and cooling systems for seed-tuber and produce storage. The Caribbean Research and Development Institute in Belize (CARDI) can participate as one of the institution/agencies that can conduct field trials and M & E to maintain the integrity of the new varieties of potato seed tubers. CARDI will need support in improved irrigation systems for conduct variety field trials. Farmers groups around the country will be recruited to conduct potato variety field trials. Training will be required for Ministry of Agriculture extension officers and farmers in production and cultivation of quality potatoes.
Operation and maintenance	Ministry of Agriculture ARDU and the crops section will have the capacity to carry the field trials and manage the screen-house tuber propagation system and the distribution of seed tubers to farmers. UB Micro-Propagation Laboratory will operate and maintain the propagation of the seedlings as necessary.
Scale/size of beneficiary group	The technology for the introduction of improved climate resilient potato into Belize will target only the current three potato-growing communities (Springfield and lower and upper Barton Creek) during the first three years of the proposed intervention. Field trials will dictate if the

	technology can then be expanded to other interested communities in southern and northern Belize during the fourth and fifth year. Overall the project is likely to impact at least 200 farm families.
Acceptability to local stakeholders	Potato-growing communities in the Cayo and Orange Walk districts are encouraged by the prospect of the introduction of improved, climate resilient varieties for the industry. Farmers in other areas such as the Stann Creek and Toledo districts welcome the introduction of a new and climate resilient crop into the sector as a means of crop diversification, income generation and food security.
Endorsement by experts	Climate resilient varieties of potato is highly endorsed by local agricultural experts because of its many benefits and potential for expansion to other communities in Belize. Experts agree that there is an urgent need for an in-country system / unit for the production of quality disease-free seed tubers for field planting by small-scale farmers.
Barriers and Disadvantages	- High initial cost for imported seed tubers, micro-propagation, field trails for at least three cropping seasons, demonstration and training in the agronomic practices related to the new varieties (including improved irrigation systems). - Adequate Storage facilities (farmers) - Limited market acceptance for new varieties - Farmers prefer to plant grain crops and other tubers - High initial cost of technology - Illegal importation of potato
Climate change adaptation Benefits	
Adaptation potential **Potato varieties that are more suitable for Belize's climate are critical to satisfy the increasing demands resulting from population growth, and the additional stress on the Agriculture sector and food security caused by global warming and climate change.**	
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	The economic benefits for target communities and the country as a whole, will be far reaching in the medium and long term. There is a market for high quality potato in the Caribbean and Central America.
Social benefits	Climate resilient potato could be cultivated for a longer cropping period, both under rain fed and advanced irrigation crop production systems. Potato production for local consumption and export will uplift the standard of living of target communities and contribute to Belize's food security.
Environmental benefits	Potato cultivation with drip and sprinkler irrigation, and under controlled conditions, will eliminate the needs for costly agrochemical use and reduce the need to expand the

	agriculture frontier into virgin tropical forest.

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5.

Sector: Agriculture
Sub-Sector/Technology Option: Soil Conservation & Land Management
Technology Application: ***Micro climate monitoring system for sustainable soil and land management in Agriculture and Agroforestry***

Introduction

Global Warming is projected to generate extreme climatic events in the form of higher temperatures, less frequent but more intense rainfall, and rising sea levels leading to coastal inundation and increased saline contamination. Declines in freshwater resources due to loss of recharge areas and gathering grounds are already occurring in tandem to increasing land demand and exploitation pressures (BEST, 2008). The evolving scenario in Belize is one of a creeping land degradation phenomenon fueled by widespread land use change and the added stress of climate change, on the integrity of the natural environment. Consequently, if agriculture is to remain sustainable, the policy of eco-friendly agriculture as promoted in the National Agriculture Policy 2015-2030 must be streamlined in present and future agricultural sector enterprise.

Three areas of concern related to over exploited land use and bad practices in agriculture are soil erosion, loss of fertility and runoff of agrochemicals into groundwater and surface water bodies, which eventually end up in the marine environment.

Soil conservation and soil fertility are critical for sustainable and eco-friendly agriculture.

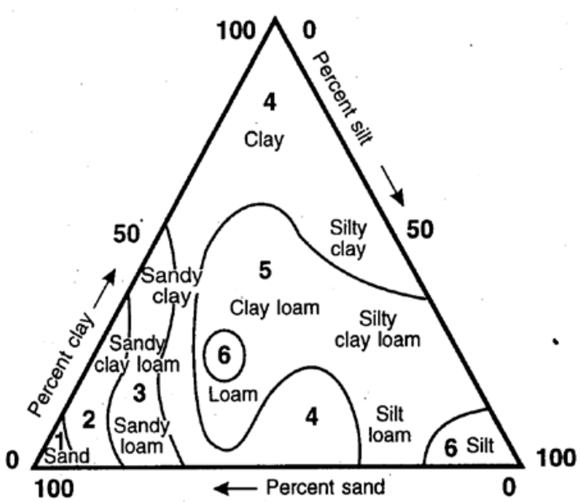
As illustrated below, the agroecosystem is made up of many interacting components. Soil quality is one important part of sustainable agroecosystem management, analogous to water and air quality. Assessing soil quality may help managers identify practices that could be adapted to become more sustainable. Soil quality is one aspect of sustainable agroecosystem management.

Source: http://soilquality.org. NRCS East National Technology Support Center, University of Illinois at Urbana-Champaign, USA.

***Sustainable agriculture:* "An agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use, and a balance with the environment that is favorable both to humans and to most other species", Harwood (1990).**

***Soil Quality:* The Soil Science Society of America's Ad Hoc Committee on Soil Quality define soil quality as "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al., 1997).**

***Soil Texture:* Soil texture provide important characteristics affecting crop selection and agricultural productivity. They determine water infiltration rates, water retention rates, drainage capacity, root diseases, aeration, root penetration, surface crusting, seedling germination and suitability to cultivation.**



To determine your soil textural class, you need to find the relative proportions of sand, silt and clay.

The proposed technology transfer "*Micro climate monitoring system for sustainable soil and land management in Agriculture and Agroforestry*" has as general objective the development of a cost-effective, soil quality micro climate monitoring

Source: Forrest, D. TAFE TROPO's Organic Info Library. http://www.nor.com.au

network and an agroforestry land management system that will record, archive and analyze data, to inform decision makers and farmers on soil conditions, irrigation scheduling, fertilizer application, drainage and soil conservation. The soil quality microclimate monitoring system and agroforestry land management will be housed and coordinated within the Crop Research and Development Unit (CRDU) of the Ministry of Agriculture, with strong public and private sector support. The infrastructure for a soil laboratory exist in Belize, but the technology transfer is envisaged to provide institutional strengthening and material/equipment to conduct soil quality monitoring, laboratory soil analysis and in situ field tests in the first 3 years of the proposed 4-year project cycle.	
Technology Characteristics	
Features	Agriculture experts and farmers in general are cognizant that the soil is the foundation for nearly all land uses (Herrick, 2000). *Micro climate and soil quality monitoring systems for effective soil management* These systems will be deployed at all Ministry of Agriculture (MoA) field demonstration facilities in the districts. Monitoring of micro-climate and soil quality will be done at these facilities and they will be used for demonstration and training for small farmers on matters related to good practices in irrigation scheduling and control, fertigation, and soil fertility/soil conservation, and also integrated pest/disease management for covered structures and open field crop cultivation. The Agroforestry Land Management Section will support the work of the Micro climate/Soil Quality unit, and will possess the capacity to advise farmers on agroforestry and silvo-pastoral techniques, fallow, and green fertilizer, particularly as it relates to soil conservation and soil nutrient replenishment. This technology application will comprise of: i) Micro-climate /soil quality monitoring and testing; ii) Procurement of one soil scientist; while a second candidate pursues an MSc in Soil Science; iii) Installation of soil monitoring system at all six MoA field demonstration facilities; iv) Demonstration & training of soil management and irrigation scheduling and control; v) Developing protocols to address problems of soil fertility reduction and pest/disease control in coordination with Belize Agriculture Health Authority (BAHA); vi) Encourage agroforestry/silvo-pastoral agricultural systems and management through enhanced extension services to farmers and other land use stakeholders. This technology transfer will therefore have a strong training component both for field technician/extension officers and farmers. *Sample of Irrigation scheduling equipment list for six (6) agriculture training and demonstration sites:*

Irrigation Unit's Equipment List		
Item	**Quantity**	**Description**

1	12	Multi-meter – EC/pH/mV/T
2	6	Soil sampling augur – 2 m
3	6	Sample ring kit – 1 m
4	6	Penetrometer
5	6	Hydraulic conductivity tester
6	6	Soil test kits for micro and macro nutrients
7	6	Electronic tapes – 8 m
8	6	Baier sampler
9	6	Drying ovens – 1.9 cubic ft.
10	6	Automatic laser kits – dual slopes
11	6	theodolite
12	6	IrrCAD 10.0 Software licenses
13	12	Soil tensiometers
14	6	AWS with solar panel and sensors to record air, grass and soil temperatures, RH, wind speed and direction, and rainfall rates and amount, solar radiation etc.
15	1	Isuzu Pickup – diesel 4 x 4

Soil Laboratory will be equipped with the appropriate equipment and reagents to conduct detailed soil test for soil fertility and crop selection.

Two soil technicians and one Soil Scientist will be hired. The Government of Belize (GOB) will pay the salary for the Soil Scientist, while the project will salary for the two soil technicians.

Capital Investment Cost	1) Equipment & Reagents for Soil Laboratory…US$ 125,000.00 2) Soil Quality and Irrigation Unit equipment (six sets) excluding Isuzu Pickup truck US$ 180,000.00 3) Salary for two Soil Technicians @ US $ 15,000 per person per year for three (3) years…. US$ 90,000.00 4) Training (1 MSc, Two technicians & Farmers US$ 80,000.00 5) One only Isuzu pickup truck US$ 30,000.00 **Total US$ 520,000.00**
Operating Cost	US$ 15,000.00 per year. Total for three (3) years **US$ 45,000.00**
Maturity	Monitoring of soil micro climate, soil quality and laboratory soil tests is well established and operational in research institutes and instruments manufacturing laboratories, agricultural universities, and soil laboratories in developed countries. Soil test is done in Belize for the basic micro nutrients and other environmental parameters like pH and conductivity, but test for macro nutrients and heavy metals has to be done abroad.
Country Specific Applicability and Potential	
Status of technology in country	Integrated Land Management and comprehensive soil quality monitoring and testing is not carried out in an organized and systematic form in Belize. Agro industries such as the Belize Sugar Industries (BSI-ASR), the Citrus Company of Belize and the Banana Industry conduct their own land management practices and soil quality monitoring and testing, via their respective Research Unit such as SIRDI in the case of BSI-ASR, Citrus Research and Education Institute (CREI, Citrus Company of Belize) and the Banana Growers Association Research Section (BGA, Banana Industry). The MoA through CRDU carries out minimal soil

	quality and land degradation monitoring and evaluation. There is an urgent need for national coordination in Soil Quality Monitoring and Integrated Land Management.
Market potential	An established and fully equipped soil laboratory is highly required for ensuring an ecologically friendly, climate resilient and productive agriculture sector in Belize. The soil micro climate and soil quality monitoring will provide the baseline information and database for the provision of soil testing for famers and other land use stakeholders, who would willingly pay for the service. The Soil Quality and Land Management Unit could become semi-autonomous and sustainable at the end of the four-year project cycle.
Scale of application and time horizon	The technology application will be countrywide, and will run for four years. The first three years will see institutional strengthening, establishment of Soil Laboratory and Land Management protocols. The fourth year will be monitoring and evaluation.
Institutional and Organizational requirements	The Ministry of Agriculture Crop Research and Development Unit (CRDU), private agroindustry research departments/institutes (SIRDI, CREI, BGA), CARDI and other partners will provide technical support to the Soil Quality and Agriculture Land Management Section in the CRDU. Regional and international cooperation will also be sought from established soil agencies.
Operation and maintenance	Coordination for daily operation and maintenance of the technology transfer in Soil Quality Monitoring and Agricultural Land Management will be carried out by the newly established Unit in the CRDU.
Scale/size of beneficiary group	The Belize farming community and gardeners will be the direct beneficiaries of the Soil Micro Climate/Soil Quality Monitoring and Land Management System in the Ministry of Agriculture, Fisheries, Forestry, Environment and Sustainable Development.
Acceptability to local stakeholders	This initiative is very much anticipated by small and local farmers in Belize. Large farmers will also benefit from the services that will be provided by the MoA Extension Service
Endorsement by experts	"The National Adaptation Strategy to Address Climate Change in the Agriculture Sector in Belize", (CCCCC, 2014), recommended the establishment of a Soil and Tissue Laboratory as a Climate Change adaptation measure under Infrastructure and Equipment. The report adds that the major agricultural industries in Belize rely on foreign laboratories for their soil and tissue analysis needs. If CRDU is not in a position to embrace this technology transfer, then it should be positioned at CREI, (the Citrus Company of Belize, a Private Sector entity).
Barriers and Disadvantages	1) High capital cost 2) Lack of political will 3) Little or no coordination at the national level in agriculture research and development 4) Finance not available 5) Weak institutional capacity and training 6) Big farmers may not cooperate 7) Large food import-export ratio
Climate change adaptation Benefits	
Adaptation potential: Soil micro-climate/soil quality monitoring and Agriculture Land Management are critical for sustainable agroecosystems. This technology has great climate change adaptation potential such as reducing land degradation and deforestation, increasing soil fertility and water use efficiency, improve water quality and biodiversity.	
Potential Development Benefits: Economic, Social, Environmental	

Economic benefits	Improved soil quality and land use good practice increases the value and crop yields of agricultural lands, and bring economic benefits to farmers, their family and their community. It also provides employment and enhances food security
Social benefits	Improved soil quality and good land management practices is a security for the farmer and his immediate family and community.
Environmental benefits	Integrated land management and soil quality monitoring help reduce agricultural land degradation, excessive water use, and maintain soil fertility. It also helpsto reduce the use of agrochemicals and arrest the deforestation of virgin tropical forests that is later converted to mono crop agriculture land.

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6.

Sector: Water
Sub-Sector/Technology Option: Hydrological Drought Monitoring
Technology Application: ***Drought Monitoring System for Northern Belize with Specific Focus on Groundwater Resources***

Introduction

Projections by the IPCC (2007) with respect to water resources indicate that by 2020s, the net increase in the number of people across Latin America and the Caribbean suffering from water stress because of climate change is likely to be between 7 and 77 million. During the second half of the 21^{st} century these figures could likely jump to between 60 to 150 million, as potential water availability reduction and increase in demand from an increasing regional population put unprecedented stress on an already scarce resource (IPCC, 2007).

The Government of Belize is cognizant of the threats posed by Climate Change to the water sector and is concerned that these threats are not being appropriately addressed (GOB/CCCCC, 2014). As the population grows and forested areas are invaded, Belize's water sector becomes more vulnerable. Such vulnerabilities are being exacerbated by the pressures and potential impacts of climate change. The imminent effects of sea-level rise, stronger storms, widespread flooding, and salinization of groundwater supplies threaten coastal communities of Belize (Richardson, 2009).

Expansion of the Agriculture frontier leading to more deforestation of virgin forests, unsustainable agricultural practices, unregulated surface and groundwater abstraction, and other undesirable land use changes add to GHG emissions and put additional stress to the country's groundwater resources. Northern Belize is the area most vulnerable to swings in the climate. The impacts of recurrent droughts, elevated day-time temperatures and inundation over the past two decades, have results in millions of dollars in damage to the productive sector (UNDP, 2009). Water supply for domestic and agricultural use comes mostly from groundwater sources in the northern districts of Corozal and Orange Walk. The hydrogeological status of northern Belize and the capacity and condition of the groundwater aquifers in the Coastal plain and Shelf Province of this region is generally unknown. Hence, the urgent need to assess, monitor and institute sustainable management practices of the groundwater in northern Belize, as a first step to develop the National Water Plan, as mandated under the National Integrated Water Resources Act, 2010

Technology Characteristics	
Features	Over the past three decades, increasing acreage of land in Belize have been cleared for cultivation with a resulting increase in deforestation and growth in the number of rural settlements (Cherrington, et al. 2010). The increase in rural migration and unplanned village expansion across the country, and in particular northern Belize, has given rise to an increase in demand for water often met by hand-dug wells that service individual households and irrigation systems for the Papaya Industry and other agricultural enterprise such as rice cultivation, farming cooperatives and livestock producers. The unregulated increase in water wells also means that the level of water usage for domestic and

	agricultural purposes among rural communities is unknown. The proposed technology application, "*Drought Monitoring System for Northern Belize with Specific Focus on Groundwater Resources,* has an overall objective: *to develop an effective hydrological drought monitoring system to address the impacts of recurrent droughts in northern Belize.* The *rationale* is that there is limited data on groundwater quality and quantity for northern Belize to inform sustainable water use and management, particularly during extreme conditions. The hydrological warning system will comprise of the following: 1) Test wells and observation wells with near real time transmission; 2) Data collection platform and Operation Center 3) Disseminate and relay information through appropriate channels The strategic goals to realize the intervention objective are: 1) **Evaluate existing data on groundwater levels in the Orange Walk and Corozal Districts, and conduct monitoring of groundwater from strategic existing wells.** Results of analysis of existing groundwater data and observed data will be used in an initial assessment of groundwater flow regime through the aquifers. 2) **Determine the hydraulic properties of the aquifers.** The transmissivity, storage value, and porosity of an aquifer are critical parameters to know. In combination with hydraulic head from goal #1 hydraulic properties will provide data needed for determining flow through the aquifer performance test (APT). 3) **Conduct water quality analysis to determine the effect on water quality due to coastal influences and agricultural activity in the region.** Common nutrients such as those from fertilizers, sewage effluents, animal and food-processing wastes, and other agrochemicals affect water quality. One of the primary nitrogen species of concern to groundwater quality is nitrates (NO_3^-) due to its mobility in the sub-surface. The level of NO_3^- will be determined as well as the saline intrusion during the dry season. 4) **Review and update protocol for hydrological drought warning**

	The adaptation technology application components will include the following: **i)** A Feasibility Study of the groundwater status in the Corozal and Orange Walk districts. The Study will identify needs and gaps to conduct the groundwater assessment and monitoring in northern Belize for a period of 3 years. **ii)** Assessment: Technology transfer, Training and monitoring **iii)** Mapping groundwater **iv)** Data Analysis and reporting
Capital Investment Cost	Equipment US $ 40,355.00 Vehicle (4 x 4 standard Trans) US $ 37,500.00 Aquifer performance tests US $ 25,000.00 External Lab Tests US $ 50,000.00 **US $ 152,855.00**
Operating Cost	Vehicle maintenance (3 times per year) US$ 1,500.00 Equipment and parts US$ 5,000.00 Fuel (transportation) US$ 32,500.00 Stipend Allowance (Team) US$ 110,000.00 Miscellaneous US$ 2,500.00 Total Operating Costs **US$ 151,500.00** **---** **Total Requested <u>US$ 304,355.00</u>**
Maturity	The Government of Belize through the National Emergency Management Organization (NEMO) has a Hurricane Emergency and Flood Early Warning system, but there is no official drought monitoring system in Belize. This intervention will meet this need.
Country Specific Applicability and Potential	
Status of technology in country	Groundwater monitoring and assessment is practically non-existent in Belize. Groundwater is the major source of water supply for Rudimentary Water Systems in rural Belize. To successfully manage and regulate the water resources of Belize, the National Integrated Water Resource Authority (NIWRA) must have reliable data not only on surface water quantity and quality, but also on groundwater capacity, aquifer characteristics and utilization/abstraction rates of groundwater resources on a continuous basis. The Integrated Water Resources Act, 2010 calls for the development and implementation of a National Water Plan for Belize. Hence, the proposed assessment, and initial monitoring of groundwater in the Coastal Palin and Shelf groundwater province of northern Belize is a start in the right direction to develop a comprehensive Water Plan for Belize. Similar intervention may later be duplicated for other groundwater provinces in Belize.
Market potential	Under the National Integrated Water Resources Act 2010, NIWRA will be established as a semi-autonomous Body,

	responsible for the management and regulation of Belize's water resources. NIWRA will be able to improve collection of fees for water works licenses renewable each year, and fees for annual licenses for water concessions, among other financial flows. Thus, with an effective Water Plan in place, NIWRA will be able to sustain its operations, while the Government of Belize an annual subvention for salary and other costs.
Scale of application and time horizon	The technology transfer for Assessing and monitoring the groundwater resources of Belize is projected to sun for 3 years or 9 dry/wet and transition seasons.
Institutional and Organizational requirements	The Hydrology Unit under NIWRA will be the department conducting the assessment, monitoring, data base management and analysis of groundwater for the target area. Under the intervention, it is envisioned that the Hydrology Unit will received the tools (transport, equipment, three additional personnel and financial support) to conduct all the field works and database management. In-house training will be provided for hydrological technicians. NIWRA will also liaise with its technical associates in line ministries such as the Department of the Environment, Rural Water Department, Forestry, Agriculture Ministry, Belize Water Services and farmers/drillers/water users in the target area to successfully carry out the groundwater assessment for northern Belize. Transboundary cooperation will be strengthened with hydrological technicians of CONAGUA in Quintana Roo, Mexico for the groundwater monitoring of the international Rio Hondo basin that forms the boundary between Belize and southern Mexico.
Operation and maintenance	Operations/use and maintenance of equipment will be carried out by trained hydrological technician in the use and operations of the sensitive groundwater sensors.
Scale/size of beneficiary group	The beneficiaries will be the cane famers and other farmers and households, primarily in rural Orange Walk and Corozal Districts
Acceptability to local stakeholders	The proposed intervention to assess and monitor the groundwater resource of northern Belize will be welcomed by communities and water stakeholders, because most communities are concerned bout the numerous, unregulated perforation of wells, abandoned wells, and the critical lowering of the water table during recent extended dry seasons. Salt intrusion or salinization of the groundwater is a major concern among farmers in northern Belize, and an intervention to begin assessing and monitoring the groundwater in northern Belize highly applauded.
Endorsement by experts	The water experts in the public and private sector endorse this initiative.
Barriers and Disadvantages	Some barriers to this water sector adaptation technology include: - Un cooperative water users (farmers/large grain

<table>
<tr><td></td><td>producers who believe that water should be a free resource;
- Funds to hire three additional staff members for the Hydrology Unit
- Poor training programs
- Climate change deniers
- Lack of Political will to support NIWRA’s effort
- Language barrier in target area and border zone with Mexico
Disadvantage:
- Additional stain on an already overburdened Hydrology Unit
- Field work entails too much effort and time</td></tr>
<tr><td colspan="2">Climate change adaptation Benefits</td></tr>
<tr><td colspan="2">Adaptation potential: Assessing and monitoring the groundwater resources of northern Belize has great climate change adaptation potential in the short, medium and long term. The area is highly vulnerable to climate extremes, particularly recurrent droughts and extensive inundation, and depends mostly on its groundwater resources as the main water source. Large tracks of sugarcane plantation and other agriculture land use has diminished the natural vegetation of the two northern districts. Hence groundwater replenishment has been altered, the water table lowered and saline intrusion into the groundwater along the coastal agricultural strip has result in a deterioration in the groundwater quality. All these effects are being exacerbated by global warming.</td></tr>
<tr><td colspan="2">Potential Development Benefits: Economic, Social, Environmental</td></tr>
<tr><td>Economic benefits</td><td>Assessing the groundwater on a regular basis in the future, monitoring and evaluating withdrawals, and regulating future groundwater works, will have economic benefits to farmers in the area, and ensure quality water for households</td></tr>
<tr><td>Social benefits</td><td>Households and other water users will benefit from a reliable source of water, which will be equitably shared among all communities.</td></tr>
<tr><td>Environmental benefits</td><td>Groundwater sources in watersheds contribute significantly to the surface base flow during the height of the dry seasons and drought episodes. The dry season base flow in streams, rivers and lagoons is essential for riverine and other ecosystems water requirements. In the rainy season, natural runoff and percolation replenish aquifers and maintain the nutrient flow and fertility of soils.</td></tr>
</table>

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7.

Sector: Water
Sub-Sector/Technology Option: Water Conservation
Technology Application: ***Water Efficient Fixtures and Appliances***

Introduction

The Intergovernmental Panel on Climate Change (IPCC) reported (with *high confidence)* that the negative impacts of future climate change on freshwater resources are expected to outweigh the benefits (Bates, e al., 2008). The land area subject to increasing water stress due to climate change will double the land area projected with decreasing water stress by mid 21st century. Areas where runoff is projected to decline will experience reduction in the services provided by water resources, including rain fed agriculture and urban water supply (Bates, et. al, 2008). Climate Change is projected to strongly impact freshwater resources, with wide-ranging consequences for human societies and ecosystems (Bates, B.C., et al. 2008). Also, growing population will push many countries into the category of water stressed and water scarcity by 2050. The situation will be no different in Belize during the 21st century. Rainfall is projected to become more variable, with short periods of high intense rainfall and extended dry spells, even during the rainy season (GOB/CCCCC, 2014).

Water use per capita generally increase as a country's economic development and standard of living rises, while established conservation measures in some of the most developed countries have resulted in a levelling-off or a marked decline in per capita water use (Elliot, et al., 2011). It has been demonstrated that per capita water use in a society follows a pattern of the Environmental Kuznet Curve or EKC (Yang and Jia, 2005; Anisfield, 2010 in Elliot, et al, 2011).

In effect, per capita water use increases rapidly with economic development to a “turning point” after which it begins to decline.
Comparative benefits to electrical energy providers and consumers in the energy sector, resulting from effective measures in energy conservation are possible for the water sector also. Conservation in the water sector may increase resilience to recurrent droughts, prevent groundwater depletion, and can help justify actions at the national or local level to abandon plans for expansion of additional water reservoirs and water treatment facilities, that put additional economic strain on Governments, water/sanitary service providers, and more energy consumption that adds to emissions.

Potable water for residential and commercial use in urban areas and surroundings is provided by the Belize Water Services Limited (BWS). Water is abstracted mostly from surface water sources, treated and supply to the urban centers. Water supply coverage for urban areas in Belize is near 100 %. With over 40,000 customers and a dedicated staff, BWS is recognized as one of the most efficiently run utilities in the country. Sanitation services for urban areas is 75 %. In the rural communities, Village Water Boards manage the Rudimentary Water Systems and piped water. Here, the coverage nationwide is about 98 % and the water source is mostly groundwater.
BWS water production and supply has steadily increased during the years to keep pace with growing population and urban expansion. The company also continued to improve operational efficiency. The number of staff per 1000 customers was reduced, while maintaining a 99.9% continuity of service. Water Losses were reduced even further as the Non-Revenue Water ratio dropped from 24.5% the previous year to 23.6% for the reporting period 2014 -2015 (BWS, 2015).

Improved service delivery, driven by renewed targets and improved policies have led to improvements in customer satisfaction. One noticeable metric was the reduction of 36% in the number customer disconnections for non-payment, while still maintaining collection efficiency at above 98%.
BWS and other water stakeholder in Belize are cognizant that water conservation is a critical component for comprehensive strategies to reduce pressure on existing water sources. Generally, industrial and agricultural services account for a large percent of global freshwater consumption. However, total freshwater withdrawals reported for 163 countries by the Pacific Institute show that in the median country, residential water use accounted for 16 % of total freshwater withdrawals (Gleick et al., 2006). Therefore, residential conservation effort can make a strong positive contribution to reduce pressure on water resources.

The proposed water sector technology “Increasing the Use of Water-efficient Fixtures and Appliances” is one of several technologies available to improve water conservations and help developing countries safeguard this finite resource, and adapt to climate change. The objective is to establish a functioning certification process within an existing agency or technical department, such as the Department of the Environment, to develop and implement standards for water-efficient fixtures and appliances for household, industrial and agricultural use, and develop the guidelines for labeling and tax incentive protocols.

The target groups will be the importers of plumbing material and fixtures, and water appliances, in addition to builders/contractors/water service providers in Belize. The intervention will finance a rapid assessment on “Use of Water-efficient Fixtures and Appliances in Belize” which will inform the working group of professionals with experience from other sectors to develop the Standards for fixtures and appliance, certification and guidelines for installation. The technology will also develop advance technical guidelines for the Institute for Technical and

Vocational Education and Training (ITVET) curriculum, where plumbing and building construction are taught, along with an innovative, effective and sustainable public awareness campaign to sensitize the Belizean household and the public in general on water conservation.	
Technology Characteristics	
Features	The transfer of water efficient technologies from wealthy countries to developing countries like Belize, can potentially hasten progress towards the EKC *turning point*, and conserve water resource (Elizondo and Lofthouse, 2010). Making efficient appliances available on the market is necessary, but may not be sufficient. Three major strategies to encourage and increase the use of water efficient appliances and fixtures are: mandates, labeling and tax incentives. Briefly: • Mandates ─ mandating water efficiency standards for new constructions and replacing old fixtures and appliances; mandating the use of water efficient products in government facilities and other public infrastructures. • Labeling ─ institute certification systems for water efficient products; adding the estimated cost of use, also referred to as the "second price tag" to labels. • Tax incentives ─ implement tax incentives for purchasing and installing water efficient products; for retrofitting and replacing older fixtures. Other strategies that can be utilized in this technology transfer to reduce residential water use may include: educating and sensitizing users on water conservation, improved metering of homes, implementing volumetric pricing, fixing leaks, and limiting outdoor. Implementing these strategic actions can help to change attitude and enhance positive behavioral practices among water users (Elizondo and Lofthouse, 2010, USEPA, 2008 in Elliot et al.). Common water efficient appliances include dishwashers, clothes washing machines, water pumps etc.; while popular fixtures include water-saving toilets, showerheads and faucets among many others. These machines and fixtures are designed to use less water without losing performance (e.g. low flow showerheads). Alternatively, appliances can be more complex, example those that use gray water from sinks for toilet flushing (e.g. the Agustolet, Elizondo and Lofthouse, 2010). Other products give visual or audible feedback to the user about resource consumption and rely on behavioral change (Elizondo and Lofthouse, 2010). Also, the No-reservoir Toilet technology, that flushes with 1.5 gallons directly from inlet pipe, instead of the 3.5-gallon traditional reservoir toilet is a technology already in Belize, but not widely used

	because of the acquisition and installation costs (Benny's Wholesale, Belize City, personal Comm., April 2016).
Capital Investment Cost	- Establishing functioning certification process: Consultant first nine months: US $ 54,000.00 Assistant administrator/secretary Three years of project cycle US$ 45,000.00 Office Space and Equipment US$ 25,000.00 - Meetings @ $ 5,000 /yr US$ 15,000.00 - Training Five/yr @ $3,000 US$ 45,000.00 - Public Awareness for 3 years US$ 30,000.00 - Travel (3 yr. project cycle) US$ 30,000.00 - Incidentals 5 % of cost US$ 12,200.00 - GOB In Kind 20 % of funds req. US$ 51,240.00 **Funds requested** US$ 256,200.00
Operating Cost	Procurement of water certification expert US$ 200.00 Miscellaneous expenditures (3 years) US$ 24,000.00 **Total** US$ 24,200.00
Maturity	The technology for water-efficient fixtures and appliances is not formally regulated and developed in Belize. Environmental certification such as ISO 14001:2015 is required or obtained by some of the larger enterprises such as the Belize Electric Company Limited (BECOL) and Belize Sugar Industries/American Sugar Refining Inc. (ASR-BSI), but specifically, certification for water conservation is not carried out for domestic users. Hotels and resorts do encourage water conservation particularly for bathing and laundry, as part of their eco-friendly label. This approach should be encouraged for importers and retail outlet of water-efficient fixtures and appliances.
Country Specific Applicability and Potential	
Status of technology in country	Certification and incentive scheme for water efficient fixtures and appliances is none existent in Belize. So is the training in the installation and maintenance of water efficient fixtures and appliances
Market potential	Once the program is initiated, there will be a market for water efficient fixtures and appliances among the environmentally sensitive citizenry of Belize. The demands will increase with new development particularly in the hotel and tourism sector.
Scale of application and time horizon	The scale of the intervention will be countrywide and the time horizon is projected for 3 years. The Government of Belize continue with the program in the Department of the Environment and support Line Ministries/Department such as Housing, the Bureau of Standards, and the private sector.
Institutional and Organizational requirements	The institutions spearheading the proposed adaptation technology already exist. The lead agencies for this intervention will be the Department of the Environment in

	the Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development. Support and collaborative institutions include: ITVET training centers in the six district towns, the Social Investment Fund (SIF), Belize Water Service (BWS), Rural Water Department in the Ministry of Labor, Rural Development and Local Government. Direct support for the intervention will come from the National Integrated Water Resources Authority (NIWRA) Hydrology Unit, The Belize Bureau of Standards, the Association of Professional Engineers and the private sector importers and wholesale businesses such as Benny's Hardware, Habet and Habet, the Mennonite community and Rural Development.
Operation and maintenance	Operations will be directly coordinated in the Department of the Environment
Scale/size of beneficiary group	The scale of the beneficiary groups will range from importers/wholesale outlets of water-efficient fixtures and appliances, customers and water service providers, and other water sector stakeholders concerned about the impact of climate change on water resources.
Acceptability to local stakeholders	Local stakeholders, in particular head of households and hoteliers welcome the initiative to seriously conserve water through introduction into the market of innovative and cost-effective technology
Endorsement by experts	Highly endorsed by experts and policymakers.
Barriers and Disadvantages	-The initial cost of purchase of water-efficient fixtures and appliances and installation may be beyond the reach of some consumers. This may also be the case for retrofitting old fixtures and appliances. -Negative attitude and behavior towards water conservation measures by some consumers. -Lack of funds to retrofit. -Lack of knowledge and awareness among decision-makers/politicians about the effects of climate change on water resources and the urgent need to conserve water. *Disadvantage:* -Additional cost to consumers who are willing to participate. -Lack of political will in some quarters. -Little public awareness of new and improved water-efficiency appliances.
Climate change adaptation Benefits	
Adaptation potential: The IPCC (2007) and climate change experts worldwide continue to promulgate water conservation as a genuine and cost-effective adaptation measure to reduce the stress of climate variability and climate change on water resources.	
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	The economic benefits related to water conservation through the use of water-efficient fixtures and water use appliances has far-reaching benefits for consumers (both domestic and

	industrial) such as water tariff stabilization or decrease, increase profits for water service providers, and lowering cost of water treatment.
Social benefits	Ensure good quality water that meets the growing demands of the growing Belizean consumers
Environmental benefits	Water conservation in households, industry and agriculture helps reduce the stress on water resources and help maintain the required water needs of the environment and ecosystems.

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8.

Sector: Water
Sub-Sector/Technology Option: Water Safety Plans
Technology Application: ***An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize***

Introduction

Water is considered the primary medium through which climate change will impact people, ecosystems and economies (Sadoff and Muller, 2009). Safe water for human consumption is critical for the health and wellbeing of all communities. Water is intrinsically linked to the development of all societies and cultures; however, expansion in agriculture and food production, energy, industry, and tourism also place considerable pressure on water resources (WWAP, 2015). Even after two decades or more since the first summit on sustainable development, many countries still face the challenges of eliminating poverty and promoting economic growth, ensuring health and sanitation, preventing land degradation and pollution, and advancing rural and urban development. It is estimated that around 748 million people in the world still do not have access to an improved source of drinking water, and water demand for manufacturing is expected to increase by 400 per cent between 2000 and 2050 globally (WWAP, 2015).

The World Health Organization (WHO, 2008) Guidelines for Drinking Water Quality (GDWQ) is the basis for current water quality standards in many countries around the world. In the WHO water quality guidelines, Water Safety Plans (WSPs) are described collectively as a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. WSPs enable identification of threats to water safety during all phases in the supply chain, from the catchment sites to the transport, treatment and distribution of drinking water. This approach is fundamentally different from those traditionally adopted by water suppliers, which rely on treatment and end-product testing to ensure water safety. When implemented successfully, the WSP approach can ensure that water quality is maintained in almost any water service and delivery systems.

A framework for preventative management and delivery of safe drinking water is illustrated in Figure 1. As illustrated, a WSP consists of three separate activities: system assessment, monitoring and management.

***System assessment*: During this phase of a WSP, potential hazards to water quality and health are identified at key steps or locations, normally referred to as Critical Control Points (CCPs), within specified boundaries of a water supply chain. Typical health hazards might be source catchment contamination, poorly maintained service reservoirs, leaking valve boxes or unhygienic standpipe**

collection systems. Associated risks of negative health outcomes due to these hazards are also quantified at this time.

Monitoring: **Once health risks have been defined, they are used to develop a prioritized and system-specific plan for monitoring and controlling hazards at each CCP during the monitoring phase of a WSP. Such a plan will define operational parameters and associated sampling and reporting methods. Critical limits or targets for these parameters should be defined at this time. It is likely that a combination of observational and traditional water quality monitoring methods will be implemented by trained public health personnel and trained members of the community.**

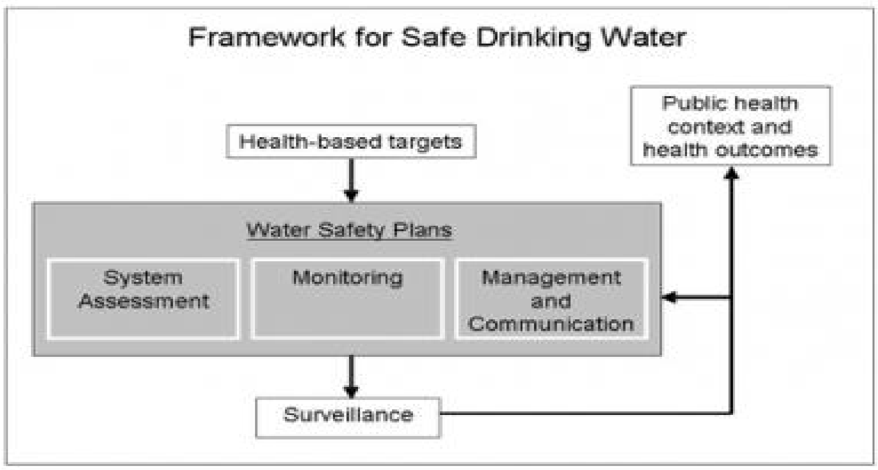

Figure 1: Framework for safe drinking water (source: WHO, 2008)

Management**: The actions necessary to correct any issue identified during monitoring are established in the management phase of a WSP. Such measures may include alleviation of source water contamination through controlling activities in the watershed, optimization of physical or chemical treatment processes, and prevention of recontamination during distribution, storage and handling (Water Safety Plans, 2010). By controlling hazards at the water supply system's CCPs, any issue that occurs in the catchment or distribution network can be detected and corrected before water of poor quality is delivered to the consumer. This proactive method of monitoring reduces the amount of sampling that needs to be conducted in the distribution system. In addition, processes are established for documentation, record keeping, validation and verification during the management phase.**

The WHO has published a foundational document that describes the process water suppliers must follow in order to ensure that a WSP is planned and implemented properly. These steps are illustrated in Figure 2 and have been summarized as follows:

Assemble a team that understands the water supply system and its capability to meet the water quality targets;

- **Identify where contamination could arise within the water supply, and how it could be controlled;**
- **Validate the methods employed to control hazards;**
- **Establish both a monitoring system to check that safe water is consistently supplied and agree to corrective actions in the case of deviation outside acceptable limits;**
- **Periodically verify that the WSP is being implemented correctly and is achieving the performance required to meet the water safety targets.**

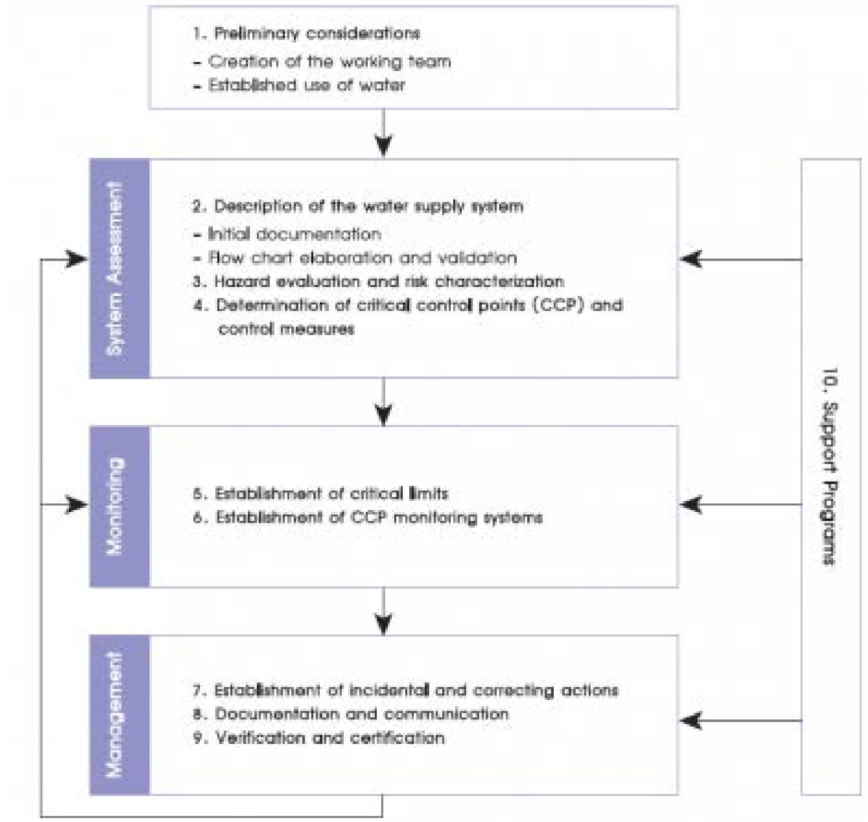

Figure 2: Steps in the development of a WSP (adapted from Davison et al., 2005)

The technology application: *An Integrated Management Strategy for Water Safety in eight Rural Water Supply Systems in Belize* will target rural communities in Belize where recurrent health problems have been detected because of poor water quality, Village Water Boards are on record for poor water delivery services, and inadequate management of water service systems are prevalent. Once proven to work in these communities, the Water Safety Plan(s) may be extended to other communities facing similar difficulties with their rudimentary water supply systems, and communities where rudimentary water infrastructure and water boards will be established in the near future (Boden, J, Jul. 2016, Principal Public Health Officer, pers. Comm.).

Technology Characteristics	
Features	The National Climate Change Adaptation Strategy (2009) for the water sector outlines five key adaptation actions, namely: 1) the establishment of an agency to execute integrated water resources management; 2) strengthening the existing institutional and human resources capacities in the water sector for improved management practice, 3) formalizing the legal mandate and operations of the National Climate Change Committee, 4) strengthening the trans-boundary relationships to cover the impacts of climate change on the water sector, and 5) increasing public awareness and education in water culture and climate change (CCCCC, 2009). Actions #3, #5 and #1 have been addressed and are partially functional, but more work is required. Action #4 has not been achieved as yet because of lack of full operationalization of Action #1. Action #2 has not been fully realized, specifically for Rural Water systems, and this is where the proposed technology transfer via the TNA project will be directed.

	Potable water for residential and commercial use in urban areas and surroundings is provided by the Belize Water Services Limited (BWS). Water is abstracted mostly from surface water sources, treated and supply to the urban centers. Water supply coverage for urban areas in Belize is nearly 100 %. With over 40,000 customers and a dedicated staff, BWS is recognized as one of the most efficiently run utilities in the region. Sanitation services for urban areas is 75 %. In rural communities, however, Village Water Boards manage the Rudimentary Water Systems and piped water. Here, the coverage nationwide is about 95 % and the water source is mostly groundwater. There are some 115 Village Water Boards and about a third of them have experienced and continue to experience water quality challenges, infrastructural and management problems in the water supply chain. The Public Health Bureau (PHB) in the Ministry of Health (MOH) is the agency primarily responsible for monitoring water quality and water related health issues in Belize. The PHB will be the agency coordinating the rural water system WSP for the target communities under the *Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize*. The targeted Rudimentary Water Systems (RWS) will be distributed as follow: three in the southern Toledo District, three in the Stann Creek District, and two in the Cayo District. Properly developed and executed WSP can be regarded as an effective climate change adaptation measure to manage, utilize and conserve the country's vital water resources, especially for vulnerable and marginalized rural communities. The components of the adaptation technology related to the Water Safety Plan will consist of: 1) An initial, then periodic assessment and monitoring of the target communities RWS during the project cycle period. This will entail assessing and maintenance of the RWS infrastructure and management in coordination with the Village Water Boards; monthly water quality sampling and analysis; water borne illness monitoring; 2) Drafting and adoption of a comprehensive Water Safety Plan for Rudimentary Water Supply Systems. An expert in the field of Public Health and Water will be required for three months to coordinate and develop the WSP. Adoption by Cabinet and operationalization by the MOH, Rural Development, and other partners will take at least eight months. 3) Following adoption of the WSP, the Public Health Bureau, along with key stakeholders such as Rural Development (Ministry of Labor, Local Government and Rural Development), Social Investment Fund (SIF), PAHO, Red Cross, National Association of Village Councils (NAVCO), etc. will operationalize the WSP in the eight target communities for the remaining two years of the technology transfer project cycle. The Government of Belize through the MOH and Ministry of Rural Development (MRD) will then take over the financial responsibility to sustain and replicate the WSP in the target communities and others. 4) Institutional strengthening will be required for the Public Health Bureau, MRD and eight Village Water Boards, training of selected members of Village Water Boards (two per Water Board, six in all for 3 years per Water Board. Total 48), strengthening of the Public Health Water Laboratory, and employment of at least seven (7) Rudimentary Water System Technicians, Two Water Quality Analyst, and one National WSP Coordinator. WSP Coordinator will be nominated from among Public

	Health personnel. Two main stakeholders need to be strengthened through capacity building, namely: The Rural Water System Support Unit (RWSSU) and Rural Community Development Officers (12 trained personnel in all). 5) One Water Consultant will be procured for three months to develop and coordinate the public consultation and adoption of the WSP.
Capital Investment Cost	US $ 440,000.00 will cover costs for hiring one Public Health and Water expert for three months, hiring two water quality analysts and seven Rudimentary Water System technicians, purchasing eight spare water pumps, two vehicles for field work, information and database equipment, and training costs.
Operating Cost	(see table below)
Maturity	Rudimentary Water System (RWS) is an established technology for rural water supply service in many communities in developing, as well as developed countries (e.g. the United States). Basically, RWS consist of a tested groundwater well, with a submersible water pump that pumps the groundwater to an elevated tank (typical capacity of about 20, 000 gallons or more). The water is treated and tested, then it is gravity fed to client's homes via water mains and small pvc pipes. Water supply may or may not be metered. However, in most cases the problem with RWS at the local level is not the water supply but rather the governance of the water supply system.
Country Specific Applicability and Potential	
Status of technology in country	About 132 villages in Belize have Rudimentary Water Systems (RWS) as their potable water supply facility, and another 38 villages have public hand pumps. A small percentage of the 197 villages in Belize have no potable water supply system. A recurrent problem with some of the RWS is the interruption of potable water supply through the system because of mis-management and infrastructure failure. Pump mal function, disruption of electrical power or broken water lines are some of the challenges afflicting water supply systems for rural communities in Belize. Villagers suffer from the lack of potable water, sometimes for months, before the system is back to normal operation. Integrated water safety plans for weak RWSs can be a means for improving the management of rural water services for vulnerable communities, especially as the stress on water supply becomes more prevalent because of climate change.
Market potential	Nearly all of the equipment, spares and chemical reagents for RWS in Belize is imported. Each RWS is legally managed by an appointed Village Water Board. The Board is governed by the Village Councils Act, and new appointments are carried out every three years after each village council election. Each Village Water Board is semi autonomous and responsible for collecting fees for the potable water service, and maintaining the systems. The Public Health Unit is responsible for ensuring water quality and system safety. Construction of the RWS is the direct responsibility of Rural Water Unit of the Ministry of Labor, Local Government and Rural Development. Spares and equipment for the RWS is the responsibility of each Village Water Board. The market for the supply of equipment and spares is generally controlled by selected or contracted importers.
Scale of	The scale of the water safety technology for rural water supply systems will be at a

Operating Cost:

No.	Items	Period	Unit Cost	No. Units	Cost
1	Retrofitting water meters & installation		$40.00 per meter	100/RWS	32,000
2	Water Lab Reagents	3 years	$8,000.00/annum		24,000
3	Chlorination	3 years	$5,000.00/annum		15,000
	Total US $				71,000

application and time horizon	pilot project level in all six districts of Belize. The time horizon for the drafting, adoption and application of the water safety plans for integrated rural water supply systems management is three years.
Institutional and Organizational requirements	The public and semi-autonomous institutions directly responsible for the operation of rudimentary water systems are established within the Public Service of Belize (i.e. Rural Development & Public Health) and cooperating agencies such as the Village Water Boards and Village Councils at the village level.
Operation and maintenance	Operation and maintenance of the eight target rural water systems will remain the responsibility of the Rural Development Department, Public Health, SIF and the Village Water Boards.
Scale/size of beneficiary group	The initial beneficiaries of this technology transfer will be villagers of the eight target Rudimentary Water Systems. A total of approximately 19,500 people will benefit from the intervention.
Acceptability to local stakeholders	Improved and reliable rural water supply systems is highly desirable in many villages that suffer extended disruption of their potable water supply.
Endorsement by experts	The experts in the field of water supply systems welcome any initiative that can help to improve the sustainable management of rural water services.
Barriers and Disadvantages	-political will to support improved rural water services -animosity and weak water governance at the local level -funds to improve infrastructure in water distribution system -insufficient technical and managerial capacity -high cost of spares and equipment - high electricity cost to run water pumps - pumps damaged frequently resulting in disruption of water supply services -fragmented and weak water quality monitoring protocol -Public Health water laboratory lacks capacity to do systematic analysis of water samples for all Rudimentary Water Systems in a consistent and timely manner. -Only two water laboratories operational in the country of Belize. The private water laboratory of Bowen and Bowen Group of Companies is well equipped and do excellent analysis, but the costs are elevated. -lack of reliable information and data on Rural water quality and supply -water authorities and public health reactive and not proactive on water supply and water quality issues. - very little study and research done on groundwater capacity, characteristics and sources pollution - some communities cannot afford the monthly basic water-use cost. - one pivotal problem "Limited institutional capacity of water boards" - limited water treatment technology available -lack of financial resources to acquire improved water treatment technology
Climate change adaptation Benefits	
Adaptation potential: **Water Safety Plans and Integrated Rural Water Supply System management/strategy when combined are highly needed for the sustainable use and conservation of water resources particularly in communities located in regions of the country vulnerable of the negative impacts of climate change and land use stress. Hence improved water supply management for rural areas has significant climate change adaptation potential.**	
Potential Development Benefits: Economic, Social, Environmental	
Economic	The economic benefits of improved rudimentary water system management

benefits	and governance is indirectly measured via improved family and community health, a healthy labor force and reduced absentee, reduced water borne disease incidence, reduced cost to the health services, increase profits for the productive sector, and reduced water supply costs.
Social benefits	The social benefits of improved rural water system management and governance is translated to healthier communities, improved food production, and higher standard of living for rural population.
Environmental benefits	Improved management of rudimentary water systems helps conserved ground water resources and reduce excessive withdrawals and waste that are detrimental to the environment. It also helps to address sources of water pollution and land degradation.

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9.

Sector: Coastal and Marine Ecosystems
Sub-Sector/Technology Option: Climate Change Adaptation Technologies
Technology Application: *Soft Engineering and Ecosystem Restauration (SEER) Technologies to Address Shoreline Erosion in three threatened Coastal Communities in Southern Belize*

Introduction:

Climate Impacts on Coastal Ecosystem Services

Climate change threatens many ecosystem services that humans derive from the sea (Doney, 2011, Munday et *al*., 2008, IPCC, 2007b). The negative impacts will have repercussions for society's dependence on the ocean for wild-caught and farmed food, recreation, nutrient cycling, waste processing, protection from natural hazards, climate regulation, and other diverse services (Doney, 2011). Climate-induced sea-level rise will put additional stress on coastal infrastructure and thus the health and safety of human communities. Natural habitats such as wetlands, mangroves, coral and oyster reefs, and sea grasses buffer coastlines from erosion and inundation, providing critical protective services. Another of the many advantages of nature-based protection is that these same habitats also provide other benefits, including nursery grounds for commercial and recreationally valued species, filtration of sediment and pollutants, and carbon storage and sequestration. The social values of these services are far-reaching, and include those reflected in markets, avoided damage costs, maintenance of human health and livelihoods, and cultural and aesthetic enrichment. Consequently, it is very important to understand how human activities and a changing climate are likely to interact, to affect the viability and delivery of these ecosystem services, as society makes decisions now that will affect the health of marine and coastal systems, and their ability to sustain future generations (Doney et *al*., 2011).

Anthropogenic activities have impacted the coastal zone and are now threatening the viability of the livelihoods in coastal communities in Belize. The Integrated Coastal Zone Management Plan for Belize, identifies a three (3) kilometer buffer around coastal communities as the "Zone of Influence" (ZOI) emphasizing that within this buffer the activities have an impact on the coastal ecosystem (CZMAI, 2016). In the Stann Creek District, the industries of agriculture, tourism and fisheries are all located within the ZOI and in addition to climate change, the interaction of these industries highlight the impact of anthropogenic activities on coastal resources. The strain on the coastal ecosystem in the district is a result of large scale agricultural production, tourist centric activities and fisheries practices (e.g. aquaculture).

This is a problem along the entire coastline of Belize and the Cayes, but this intervention will be focused over southern Belize where coastal erosion is most significant.

Inherent to addressing coastal ecosystem degradation is the development of comprehensive measures to address the activities within and adjacent to the ZOI. Based on the economic, social and environmental challenges facing the coastal communities in southern Belize, Pan American Development Foundation (PADF) developed a community-based approach project to address climate change adaptation and alternative livelihoods in Dangriga Town and Hopkins Village. Dangriga is the commercial center for the Stann Creek district, within its ZOI with large scale citrus farms, subsistence ground crops and a shrimp farm at the north; it is a connection point for tourists traveling by boat to the Cayes; and the waters off its coast are the favored location for subsistence fishers throughout the country (PADF, 2015). Shoreline erosion is major problem

in the northern and southern sectors of the town.

Hopkins is the budding tourism destination of northern Stann Creek, and within its ZOI are smaller scale citrus farms, a lagoon with encroaching tourist-centric development, and a beach largely populated with hotels and resorts providing scenic waterfront views; due to its proximity to Dangriga it also has an active, off-shore fishing grounds (PADF, 2015). Persistent and expanding beach erosion is a problem along several key sections of the shoreline in both communities.

During the course of the project community stakeholders frequently discussed Monkey River Village as another community that requires immediate intervention as a result of the shoreline erosion and beach degradation. Within Monkey River's ZOI are large scale banana and citrus farms, and a shrimp farm. Monkey River Village is frequently accessed by tourists who come by boat from nearby Placencia. As one of the many fishing communities in Belize, most villagers depend on the marine resources for their livelihood. The loss of land as a result of shoreline erosion and beach degradation within the three communities during the last 20 years vary from 50 feet to 300 feet (PADF, 2015). The coastal erosion problem in Monkey River Village has been observed to be a worst-case scenario. Over the past three decades the sea has eroded and submerged a 30 – 50 feet wide beachfront, the first row of properties/houses and street oriented parallel to the shoreline, and today is threatening the second row of properties/houses and the 2nd street of the village (Richard Pitts, Village Chairman, and Leonard Castro, Village Vice Chairman, Personal Comm. April 2016). Some effects resulting in massive shoreline erosion in Monkey River Village are land use and land use changes in the Monkey River watershed and its two tributaries, namely the Bladen and Sittee Rivers, and sea level rise generating high energy wave action.

A priority for adapting to shoreline erosion and beach degradation in these communities is the collection of data to understand the causes and symptoms of the problem. For over the last ten years, researchers from the CERMES, University of the West Indies- Cave Hill have conducted yearly beach profiles in Monkey River to better understand the sediment movement, bathymetry and hydrology. This research is the only one of its kind in the southern region of Belize and provides the appropriate foundation towards the development of comprehensive measures to address shoreline erosion and beach degradation.

The Galen University study of the beach erosion problem in Monkey River Village (GUARD, 2007), indicated that the beach erosion is not because sand is not being generated from the mountainous interior and transported through the main channels of the Swasey and Monkey Rivers, but may be attributed to other natural, climate, and anthropogenic factors. Because of the severe erosion, many villagers have abandoned the village; some because their properties have been lost to the invasive sea, and others because of the limited opportunities for economic development.

Once data is collected it is important for measures to consider soft engineering and ecosystem restoration principles to support natural ecosystem functions as oppose to altering those functions (PADF, 2015).

In terms of addressing shoreline erosion and beach degradation, permeable coastal defense structures help to support the natural hydrology and sediment movement as they allow for the movement of waves and sediment encouraging natural habitat restoration. Climate Change adaptation technologies in the form of soft engineering and ecosystem restoration techniques to address the coastal erosion in these three target communities is the focus of the technology

options recommended for this sector.	
Technology Characteristics	
Features	**Soft Engineering and Ecosystem Restorative Technologies** - Permeable coastal defense structures (gabion baskets, geotextiles) to support the hydrology and sediment movement - Coastal vegetation replanting (mangroves, sea grass beds, littoral forest species e.g. sea grapes) to restore ecosystems, wetlands and the coastal habitats **Adaptation strategies within Coastal Zone and ZOI** - Buffer Zones along water courses - Awareness on impact of farming activity and climate change adaptation measures, if any, being implemented for eco-friendly and sustainable agriculture - Reduce river mining activities and implement best practices for water abstraction by farmers - Retreat or relocating directly threatened households Selection of technology to be applied will depend on the physical and environmental characteristics of the eroding shoreline, and the subsequent social benefits it will accrue in the short and medium terms.
Capital Investment Cost	The initial costs for this technology will entail cost for a research study including the development of beach profiles, hydrological assessments along water courses and surveys of conditions in the three (3) stakeholder communities and their ZOI, over the period of a year at a cost of US $180,000.00. This will be followed by the implementation of soft engineering and ecosystem restorative techniques at costs of US $150,000 and US $75,000.00, respectively **Total Cost US $405,000.00** The existing NGOs working closely with coastal communities and coastal ecosystem protection can also provide in-kind contributions towards the application of this technology through capacity building, and monitoring and evaluation, while community participation in the restorative efforts has already been committed by village leaders.
Operating Cost	The costs to provide project management and monitoring and evaluation of this technology is estimated at US $22,500.00 per year per community or **US $112,500.00** for the three target communities for five years.
Maturity	Authorities in Belize including the Fisheries Department,

	Coastal Zone Management Authority and Institute (CZMAI), Village Councils, Fisher Folks, and NGOs are aware of the shoreline erosion problem, not only along the coastline of Belize, but also on some of the offshore islands or cayes. Recent interventions to address the problem have had some/limited success. These include: CZMAI beach restoration efforts on Goff Caye, Fisheries Department and University of Belize replanting of mangroves in northern Ambergris Caye, Southern Environmental Association beach rehabilitation project in Placencia and Barranco Village, PADF's *Community Preparedness and Resilience in Belize: Community-based Approaches to Disaster Preparedness and Climate Change Adaptation* (Target communities include Dangriga Town and Hopkins), and Sarteneja Alliance for Conservation and Development (SACD) beach control project. A number of resorts in Belize have initiated actions to control the erosion problem on their beachfront, for example the construction of groins (Placencia Hotel) and installation of geotextiles by some resort owners in the Placencia area following recommendation from a rapid beach profile study of the surroundings by Belize Environmental Technologies consultants in 2014.
Country Specific Applicability and Potential	
Status of technology in country	Soft engineering and Ecosystem Restorative techniques are conducted on a small scale and require funding to increase the scale and reach as well as to evaluate its success. Due to the strong NGO network, these activities are led by NGOs in conjunction with national, regional and international agencies.
Market potential	Shoreline and beach protection technologies both indigenous and foreign are in demand, particularly in the hotel, tourism and fisheries sectors that are being directly impacted by relentless coastal erosion. Engineers and coastal zone planners are needed in the private sector to manage and coordinate efforts to halt the shoreline erosion.
Scale of application and time horizon	The scale of the application of these technologies will devote the first year to research and stakeholder engagement; the second through the fifth years for the installation of the piloted technologies, and monitoring and evaluation.
Institutional and Organizational requirements	Such interventions necessitate a cadre of experienced and skilled researchers, practioners and community volunteers with a shared goal to assess, implement and evaluate. Given proposed ongoing pilot interventions in Dangriga and Hopkins, there is much potential to build on present implementing team's experience through additional research and consultations with all three (3) stakeholder communities.
Operation and maintenance	The Coastal Zone Management Authority and Institute (CZMAI) will be the leading agency in the operation and maintenance of this technology, in coordination with the Pan

	American Development Foundation (PADF), Forest Department, Fisheries Department, the Department of the Environment, and other local organizations within the target communities.
Scale/size of beneficiary group	Persons: 11,500 primary (14,300 secondary surrounding rural communities)
Acceptability to local stakeholders	The stakeholder communities are heavily invested in the protection of their coastal resources.
Endorsement by experts	NGOs implementing projects in the Coastal Zone are in full support of a national approach to addressing shoreline erosion and habitat restoration to build community resilience.
Barriers and Disadvantages	- National policies to monitor current agricultural and tourist-centric development practices to ensure responsible ZOI - Long term research in coastal communities - Enforcement of national regulations to protect coastal resources (human and financial resources)
Climate change adaptation Benefits	
Adaptation potential: Once implemented in the targeted communities, the methodology can be easily duplicated in coastal communities throughout the country, to strengthen and restore coastal ecosystems in response to the climate change phenomenon. Specific hydrological studies will be conducted but research, lessons learned and best practices on interventions in Belize would be readily available through the National Climate Change Office (NCCO).	
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	Investment in technologies that address shoreline erosion and habitat restoration will protect the livelihoods of the stakeholders in the coastal zone and the ZOI and encourage the sustainable growth of key coastal zone industries.
Social benefits	A district that is heavily reliant on coastal resources ensuring that these resources are protected and restored will reduce the need for population migration to communities with stronger economic growth. Waves of migration cause strain on public services and the natural resources of other communities.
Environmental benefits	Alignment with national policies, monitoring and a closer network among practioners and line ministries will support sustainable development and support stewardship of the environment.

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10.

Sector: Coastal and Marine Ecosystems
Sub-Sector/Technology Option: Coastal Rehabilitation and Early Warning
Technology Application: ***Improved Monitoring Network and Early Warning System for Belize's Coastal Zone to Increase Resilience to Climate Change***

Introduction

There is scientific consensus that the changes induced by global warming and climate change are already evident and will intensify in the future (IPCC, 2007; USAID, 2014). The effects of climate change will continue to significantly alter coastal ecosystems, coastal hazards, and lifestyle changes for fishers, coastal resource users, waterfront property owners and coastal communities. These changes will have far-reaching consequences on the marine environment and will pose complex challenges for coastal resource managers. As a result, multi-sectoral and integrated efforts are required to guide proactive adaptation actions that can benefit human and natural ecosystems for present and future generations (USAID, 2014).

The ability of marine ecosystems and habitats to adapt to climate impacts can be increased by reducing other stressors such as overfishing, land-based pollution and misguided land use changes (CZMAI, 2014). Regulating and reducing these stresses will increase the resilience or ability of the environment to adapt to future impacts, thus reducing threats to human welfare.

One of Belize's natural and greatest asset is its coastal zone (CZMAI, 2014). About 30 % of Belize's gross domestic product is directly linked to commercial activities inside its coastal zone (Cho 2005 in CZMAI, 2014). Belize's coastal zone also has important social and cultural values for its people, considering that about 40 % of the population resides along the coast and offshore areas (Statistical Institute of Belize, 2010). The past decades have seen rapid economic development and population growth within the coastal zone and inland regions of Belize. Consequently, this has led to increasing pressures on coastal and marine resources, directly affecting the livelihood of stakeholders that depend on these resources.

As Global Warming intensifies and the effects of climate change overshadows natural climate variability, the marine ecosystem will experience increasing ocean acidification and thermal stress which will continue to impact coral reefs around the world and the Caribbean, resulting in more coral bleaching events and marine ecosystem disruption (NOAA/CCCCC, 2012). It is therefore critical to systematically monitor the various parameters that impact the coral reefs in Belize, complimenting and supporting the NOAA/CCCCC Caribbean Coral Reef Early Warning System (CREWS) network and the Fisheries Department/CZMAI Marine Conservation and Climate Change Adaptation Project (MCCAP), ***Component 1: Improving the protection regime of marine and coastal ecosystems*****. Strong Climate Change Early Warning Systems improve climate risk planning, management and action and are necessary to address the impacts of Climate Change, especially coral bleaching.**

The threats to the coastal zone arise from a number of activities connected with tourism and

recreational facilities, increase in population and expansion, utility supply, dredging and minerals extraction, land clearance, pollution, waste disposal, fisheries and aquaculture, and agriculture runoff (CZMAI, 2014). Some pollution and ecosystem health indicators in the marine environment are: Water Clarity, Dissolved Oxygen, Coastal Wetland Loss, Eutrophic Condition, Sediment Contamination, Benthic Index, Fish Tissue Contaminants, and Multiple Marine Ecological Disturbances (Guefact, 2007).

Earlier in 2016 the Government of Belize adopted the "National Integrated Coastal Zone Management Plan for Belize: Creating a Blueprint for Sustainable Coastal Resources Use" (CZMAI, 2016). The Framework of the Plan consists of four (4) Strategic Objectives, namely:

1. **To ensure the sustainable use of resources within the coastal zone;**
2. **To support integrate planning and management;**
3. **To build alliances for the benefit of Belizeans; and**
4. **To manage and adapt to climate change.**

Some actions under the strategic objectives that addresses coastal/marine environment and ecosystem viability, and early warning related directly or indirectly to the effects of climate change are:

1.1 **Coastal Research and Monitoring,**
1.2 **Coastal Habitat and Species Conservation,**
2.2 Coastal Vulnerability,
3.1 Education, Awareness and Communication,
3.2 Collaboration in Enforcement and Monitoring,
3.4 A National Network for Managing the Coast,
4.1 Socio-ecological Vulnerability and Resilience, and
4.3 Prioritization of Ecosystem-based Adaptation.

The Belize Fisheries Department in the Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development (MAFFESD), in collaboration with the Coastal Zone Management Authority & Institute (CZMAI) is implementing the five-year Marine Conservation and Climate Change Adaptation Project (MCCAP Fisheries Dep, 2014).

The project has four components, specifically:
Component 1: Improving the protection regime of marine and coastal ecosystems;
Component 2: Promotion of viable alternative livelihoods;
Component 3: Raising awareness and building local capacity;
Component 4: Project Management, Monitoring and Assessment

Under component 1, the CZMAI will be installing a network of nine marine and riverine climate and environmental monitoring platforms in the lower Belize River watershed and estuary to record near real-time river and marine water quality and other environmental parameters, to assess critical levels of environmental stress and pollution on sensitive marine ecosystems in the area. The data will be used along with other information to inform decision- making and management strategies.

The Belize Fisheries Department has also been collaborating with the Caribbean Community Climate Change Center (CCCCC) and the University of Belize (UB) in the U.S. funded National Oceanographic and Atmospheric Administration's Coral Reef Early Warning System (CREWS) initiative for the Caribbean Region. Under this project, two Satellite-transmitting environmental

and marine platforms were installed at Belize's Calabash Caye in the southern Turneffe Atoll and South Water Caye in the Glovers Reef Atoll back in late 2010. However, these marine observation platforms only functioned for about two years; thereafter the onboard sensors began mal functioning, and data recording and acquisition stopped. **The Fisheries Department proposes to upgrade the Marine Monitoring and Early Warning System of Belize as a means to reduce the negative impacts of climate change on sensitive marine ecosystems, and contribute to the sustainable use and management of marine resources.**	
Technology Characteristics	
Features	*The State of the Belize Coastal Zone 2003-2013* Report (CZMAI, 2014) made a number of recommendations with respect to the effects of climate change on coastal and marine ecosystems. These included the strengthening of the environmental and marine network; conduct quantitative vulnerability studies of the coastal zone using historic and current data; use results from studies and near real-time observations to develop early warning for climate and anthropogenic impacts on marine ecosystems; and draft policy recommendations to reduce the projected impacts of climate change. Under the TNA-Belize project, the fisheries Department is proposing the climate change adaptation technology for the Coastal and Marine sector: *Improved Marine Monitoring Network and Early Warning System for Belize's Coastal Zone to Increase Resilience to Climate Change*. The technology transfer will consist of the following: 1. Eight automatic environmental/marine observation platforms (e.g. YSI EXO 2 Sonde) with sensors to record: depth, sea water temperature, pH/ORP (Oxidation/Reduction Potential), salinity, conductivity, turbidity, dissolved oxygen and Chlorophyll. Additional above water sensors will be installed to record air temperature, surface wind speed and direction, rainfall, relative humidity, and solar radiation. 2. Eight loggers with transmission facility via smart phone technology. 3. Eight Photo Voltaic solar power equipment to generate, store and energize the observation platforms. 4. Quarterly water quality sampling at four strategic sites for laboratory analysis of nitrates/nitrogen, phosphates, Fecal Coliform, E-coli, etc. during the proposed five years of the project cycle. 5. Develop protocol to retrieve, quality check, archive, and process/analyze data and information for Early Warning Bulletins for stakeholders (including policymakers).

	6. Maintain updated and accessible environmental and marine database to inform research, policy recommendation, management strategy and the annual State of the Belize Coastal Zone reports.
Capital Investment Cost	Total capital cost: **US $177,965.33** for installation of eight only Marine Environmental Monitoring stations @ US $22,245.67 per station.
Operating Cost	The cost to provide project management, monitoring and evaluation of this technology plus spares is estimated at **US $84,491.34** for five years of the project cycle. (Field operation cost @ US $8,000.00 per year plus replacement of sensors for two stations over the five-year project cycle).
Maturity	Monitoring of the marine environment and resources in Belize has been carried out since the 1980s, but lacked continuity, standard and accessibility (CZMAI, 2014). This was evident in the preparation of the recent national Integrated Coastal Zone Management Plan (ICZM), where it was pointed out that the main factor that limited the planning process was data availability and accessibility. This TNA-project initiative along with the CZMAI watershed/estuary monitoring network, should fill the much-needed data gap.
Country Specific Applicability and Potential	
Status of technology in country	In the review of the National Integrated Coastal Zone Management Plan for Belize (CZMAI, 2014), it was highlighted that the main factor that limits the coastal and marine planning process was data availability and accessibility. CZMAI and the Fisheries Department do not have the capacity to conduct primary research, hence they used older CZMAI datasets and primary data collected by their partners, and secondary data collected by others. Complete datasets were not always readily available, such as climatological and oceanographic data for the country. Some agencies that have been conducting marine ecosystems monitoring, observations and records include: The University of Belize Environmental Research Institute (ERI), World Wildlife Fund (WWF), NOAA (CREWS-Caribbean), the Smithsonian Institute, Southern Environmental Authority, among others.
Market potential	The market potential for an improved “Marine Monitoring Network and Early Warning System for Belize’s Coastal Zone to increase resilience to climate change” will be indirect. The lack of a sustainable marine resource management strategy and early warning to inform stakeholders of threats to their livelihood, is related to “costs of inaction”, which in the medium and long term can be prohibitively high. The social and economic benefits of timely and reliable data and information of the state of the marine ecosystems and resources are far-reaching for the fisheries and aquaculture industries, tourism, and coastal development.

Scale of application and time horizon	The eight Environmental and Marine observation stations will be deployed at eight critical marine management sites in the coastal zone, where Fisheries Department and Marine Reserves co-management partners/stakeholders have field operating centers with adequate security, and within range of the mobile communication network.
Institutional and Organizational requirements	Such interventions necessitate a cadre of experienced and skilled researchers, practioners and community volunteers with a shared goal to assess, implement and evaluate 'the state of the marine environment' on a continuous basis. The Fisheries Department, CZMAI, and the University of Belize Environmental Research Institute will continue to spearhead the marine environmental network. The cooperation of other key stakeholders will be encouraged.
Operation and maintenance	The Fisheries Department will be directly responsible for the daily operation and maintenance of the proposed marine environmental monitoring network, and the coastal and marine early warning.
Scale/size of beneficiary group	The scale of the Fisheries Department Marine Environmental Monitoring Network will extend across eight critical marine resource sites in the coastal zone of Belize. It will necessitate a cadre of at least four qualified technicians to monitor and maintain the marine observation stations, two additional boat captains and a Marine Research expert at least at the MSc level. The beneficiary groups will include stakeholders of the fishing and tourism industry, marine developers and policymakers. The monitoring and evaluation period will run for 5 years after successful installation of the Marine Environmental Network. There after the GOB (through the Fisheries Dep.) will take over the operation of the Marine Environmental Monitoring Network.
Acceptability to local stakeholders	The existing NGOs working closely with coastal communities and coastal ecosystem protection are fully committed to provide in-kind contributions for the coastal and marine monitoring network. Fishers have been sensitized on the benefits of Marine Protected Areas, and are cognizant of the impending impacts climate change will have on marine ecosystems. Any initiative that can contribute to reducing vulnerability to climate change is welcome by fisher folks and other local stakeholders.
Endorsement by experts	Marine scientists and researchers applaud and support the CZMAI and the Fisheries Department initiatives to improve and upgrade the coastal and marine environmental monitoring network in Belize. This initiative is also supported by costal zone managers and policymakers.
Barriers and Disadvantages	- National policies to monitor current agricultural and tourist-centric development practices to ensure viable Zone of Influence (ZOI) - Long term research in coastal communities

<table>
<tr><td></td><td>- Enforcement of national regulations to protect coastal resources
- Limited knowledge of the impacts of climate change on marine ecosystems
- Lack of reliable and current oceanographic / marine resources data</td></tr>
<tr><td colspan="2">Climate change adaptation Benefits</td></tr>
<tr><td colspan="2">Adaptation potential: Warmer sea surface temperatures and increasing ocean acidity is already impacting coastal and marine resources around the world and in the Caribbean. The National Oceanic and Atmospheric Administration (NOAA) has reported an unprecedented third straight year of global coral bleaching to target U.S. and Caribbean reefs in the summer of 2016 (Mooney, 2016). Marine resource and environmental monitoring and early warning can contribute significantly to adaptation measures necessary to address the impacts of climate change.</td></tr>
<tr><td colspan="2">Potential Development Benefits: Economic, Social, Environmental</td></tr>
<tr><td>Economic benefits:</td><td>The economic benefits of comprehensive marine early warning for key stakeholders is unequivocal to the sustainable development of the country. Timely and reliable warnings of impending impacts such as coral reef alerts, algal bloom and increasing pollution levels can help in implementing preventative measures to reduce the impacts and conserve resources.</td></tr>
<tr><td>Social benefits:</td><td>The social benefits are far reaching and will improve the livelihood security of fisher folks and fishing communities in Belize.</td></tr>
<tr><td>Environmental benefits:</td><td>Systematic and consistent monitoring of marine resources and environmental conditions is crucial to inform policies, strategies and actions necessary for integrated and sustainable management of the coastal zone, and help increase resilience of marine ecosystems to the negative impacts of global warming and climate change.</td></tr>
</table>

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