BELIZE TECHNOLOGY NEEDS ASSESSMENT

BARRIER ANALYSIS AND ENABLING FRAMEWORK

ADAPTATION

Identification of Barriers and Enabling Framework for Adaptation Technologies in Belize

Technology Needs Assessment Climate Change Adaptation

Barrier Analysis and Enabling Framework Report

National Climate Change Office

Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development

Market Square

Belmopan, Belize

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BELIZE

TECHNOLOGY NEEDS ASSESSMENT

Barrier Analysis and Enabling Framework

Adaptation Technologies

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List of Abbreviations

ASR	American Sugar Refineries
BAHA	Belize Agricultural Health Authority
BNCCC	Belize National Climate Change Committee
BSI	Belize Sugar Industry
CARDI	Caribbean Agriculture Research and Development Institute
CCD	Climate Change Department
CGIAR	Consultative Group for International Agriculture Research
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CNG	Compressed Natural Gas
COP	Conference of the Parties
CRDU	Crop Research and Development Unit
CTI	Climate Technology Initiative
CZMAI	Coastal Zone Management Authority and Institute
DRR	Disaster Risk Reduction
DTU	Technical University of Denmark
EST	Environmentally Sound Technology
EU-GCCA	European Union- Global Climate Change Alliance
FCDU	Fruit-tree and Crop Development Unit
GCF	Green Climate Fund
GEF	Global Environment Facility
Gg	Giga gram
GCM	Global Climate Models
GDP	Gross Domestic Product
GHG	Green House Gas
GPRS	Growth and Poverty Reduction Strategy
GSDS	Growth and Sustainable Development Strategy
ICT	Information and Communication Technology
IICA	Inter-American Institute for Cooperation on Agriculture
IPCC	Inter-Governmental Panel on Climate Change
IPR	Intellectual Property Rights
KAP	Knowledge, Attitude and Perception
KBA	Key Biodiversity Areas
LCDS	Low Carbon Development Strategy
LDC	Least Developed Country
LFA	Logical Framework Analysis
LULUCF	Land Use, Landuse Change and Forestry
MAFFESD	Ministry of Agriculture, Forestry, Fisheries, Environment, Sustainable Development, Climate Change & Immigration
MCDA	Multi Criteria Decision Analysis
MDG	Millennium Development Goals
MESTPU	Ministry of Energy, Science and Technology, and Public Utilities
MLLGRD	Ministry of Labour, Local Government and Rural Development
MNR	Ministry of Natural Resources

MOA	Ministry of Agriculture
MOH	Ministry of Health
MRV	Monitoring, Reporting, and Verification
NAMA	Nationally Appropriate Mitigation Action
NAPA	National Adaptation Programme of Action
NAVCO	National Association of Village Councils
NC	National Communication
NCCC	National Climate Change Committee
NCCO	National Climate Change Office
NCCPSAP	National Climate Change Policy, Strategy, and Action Plan
NDC	Nationally Determine Contribution
NEPF	National Energy Policy Framework
NMVOC	Non-Methane Volatile Organic Compound
NPSC	National Project Steering Committee
NSDS	National Sustainable Development Strategy
NSTMP	National Sustainable Tourism Master Plan
O&M	Operation and Maintenance
PAHO	Pan American Health Organization
PMCA	Participatory Market Chain Approach
PV	Solar Photovoltaic System (Generating Electricity)
RCM	Regional Climate Model
RE	Renewable Energy
REDD	Reducing Emissions from Deforestation and Degradation
RWS	Rudimentary Water System
SBSTA	Subsidiary Body for Scientific and Technological Advice
SDG	Sustainable Development Goal
SME	Small Medium-sized Enterprises
SNC	Second National Communication
SPS	Supply, Packaging and Storage
SPS	Sanitary and phytosanitary
STWG	Sector-based Technology Working Groups
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TNC	Third National Communication
TTD	Technology Transfer and Diffusion
UB	University of Belize School of Agriculture
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WHO	World Health Organization
WSP	Water Safety Plan
WTO	World Trade Organization

Glossary of Terms

Adaptation
Adaptation is a short for 'climate change adaptation', adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderate harm or exploit beneficial opportunities (IPCC, 2007). Adaptation is a process, not an outcome.

Afforestation
Direct human-induced conversion of land that has been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.

Ancillary benefits
Policies aimed at some target, e.g. climate change mitigation, may be paired with positive side effects, such as increased resource-use efficiency, reduced emissions of air pollutants associated with fossil fuel use, improved transportation, agriculture, land use practices, employment, and fuel security. **Ancillary impacts** are also used when the effects may be negative. Policies directed at abating air pollution may consider greenhouse-gas mitigation an ancillary benefit.

Barrier
Obstruction or impediment that impedes technology transfer; a reason why a target is adversely affected, including any failed or missing countermeasures that could or should have prevented the undesired effect(s).

Biofuel
Any liquid, gaseous, or solid fuel produced from plant or animal organic matter. E.g. soybean oil, alcohol from fermented sugar, black liquor from paper manufacturing process, wood as fuel, etc.

Biomass
The total mass of living organism in a given area or of a given species usually expressed as dry weight. Organic matter consisting of, or recently derived from, living organisms (especially regarded as fuel) excluding peat. Biomass includes products, by-products and waste derived from such material. **Cellulosic biomass** is biomass from cellulose, primary structural component of plants and trees.

Capital goods
Machinery and equipment used in the production of other goods, e.g. consumer goods such as boilers, motors, steel or pumps. May also mean 'producer goods'.

Carbon dioxide (CO_2)

CO_2 is a naturally occurring greenhouse gas, and a by-product of burning fossil fuels or biomass, of land-use changes and of industrial processes. It is the principal anthropogenic greenhouse gas that affects Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore it has a Global Warming Potential of 1.

Climate Change (CC)
Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and /or variability of its properties, and that persist for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Carbon price
What has to be paid (to some public authority as a tax rate, or on some emission permit exchange) for the emission of 1 ton of CO_2 into the atmosphere.

Coastal Zone
The coastal zone encompasses the full extent of the area ranging from the open sea to the beaches and into the watersheds, and diverse flora and fauna that thrives in these systems, including *Homo sapiens.* The coastal zone comprises a many of species, ecosystems, user groups, and economic, social and cultural interests.

Consumer goods
Good and products specifically intended for the mass market and purchased by (private) consumers.

Cost-benefit analysis
Monetary measurement of all negative and positive impacts associated with a given action. Costs and benefits are compared in terms of their difference and/or ratio as an indicator of how a given investment or other policy effort pays off seen from the society's point of view.

Diffusion
The process by which a technology is spread or disseminated through various channels over time in a society, where the technology is gradually adopted by more and more members of the society (people, institutions, companies, etc.).

Enabling Environment/Framework
The set of resources and conditions within which the technology and the target beneficiaries operate. The resources and conditions that are generated by structures and institutions that are beyond the immediate control of the beneficiaries should support and improve the quality and efficiency of the transfer and diffusion of technologies.

Energy
The amount of work or heat delivered. Energy is classified in a variety of types and becomes useful to human ends when it flows from one place to another or is converted from one type to another.

Fertigation
The application of fertilizers, soil amendments or other water-soluble products/inputs through an irrigation system.

Global Warming
Global warming refers to the gradual increase, observed or projected, in global surface temperature, as one of the consequences of radiative forcing caused by anthropogenic warming. Global warming refers to the global increase, observed or projected, in global average surface temperature, as one of the consequences of radiative forcing caused by anthropogenic emissions.

Greenhouse effect
Greenhouse gases effectively absorb infrared radiation, emitted from the Earth's surface, by the atmosphere itself due to the same gases and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect.

Hardware
The tangible aspects of technology, such as equipment and machinery.

Innovation
Innovation refers to both the processes of research and development and the commercialization of the technology, including its social acceptance and adoption.

Land-use
The total of arrangements, activities and inputs undertaken in a certain land-cover type (a set of human actions). The social and economic purposes for which land is managed (e.g., grazing, timber extraction, and conservation). Land-use change occurs when, e.g., forest is converted to agricultural land or to urban areas.

Low-carbon technology
A technology that over its life cycle causes less CO_2-eq. emissions than other technological options do.

Market/value chain
The chain of economic actors that own and transact a particular product as it moves from primary producer to final consumer.

Market mapping
An analytical framework for understanding market systems and an approach to market development that is both systematic and participatory.

Measures
Measures are technologies, processes, and practices that reduce GHG emissions or effects below anticipated future levels. Examples of measures are renewable energy technologies,

waste minimization processes and public transport commuting practices etc. Measures can also be factors (financial or non-financial) that enable or motivate a particular course of action or behavioural change or is a reason for preferring one choice over the alternate. Often the word 'incentive' is used synonymously, sometime with a slightly different interpretation.

Milpa system
A form of subsistent farming; slash-and-burn or shifting cultivation. Swidden agriculture.

Mitigation
Mitigation is short for 'climate change mitigation', meaning an action to decrease the concentration of greenhouse gasses, either by reducing their sources or by increasing their sinks.

National Action Plans
Plans submitted to the COP by parties outlining the steps that they have adopted to limit their anthropogenic GHG emissions. Countries must submit these plans as a condition of participating in the UNFCCC and, subsequently, must communicate their progress to the COP regularly. The National Action Plans form part of the National Communications, which include the national inventory of GHG sources and sinks.

Nitrous oxide (N_2O)
One of the six types of greenhouse gases to be curbed under the Kyoto Protocol.

Non-market goods
Goods not traded in a market.

Orgware
The institutional framework, or organizational aspects, involved in the diffusion and uptake of a technology.

Praedial larceny
The theft of agriculture produces. Is widely acknowledged in the Caribbean region as a practice that is negatively impacting the development of the agriculture sector. Illegal fishing or piracy in the Exclusive Economic Zones of respective member states is also considered praedial larceny.

Primary energy or **energy sources** is the energy embodied in natural resources (e.g. coal, crude oil, natural gas, uranium) that has not undergone any anthropogenic conversion. Primary energy is transformed into **secondary energy** by cleaning (natural gas), refining (oil into oil products) or by conversion into electricity or heat. **Final energy** is secondary energy delivered at the end-use facilities (e.g., electricity at the wall outlet), where it becomes **usable energy** (e.g., light).

Publicly provided goods
A category of technologies characterized by large investments, general public ownership, and production of good and services available for the public or a large group of persons.

Reforestation
Direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was previously forested but converted to non-forested land.

Renewable Energy
Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, biomass, wind, rain, tides, waves and geothermal heat.

Sequestration
Carbon storage in terrestrial or marine reservoirs. Biological sequestration includes direct removal of CO_2 from the atmosphere through land-use change, afforestation, carbon storage in landfills and practices that enhance soil carbon storage in agriculture.

Sinks
Any process, activity or mechanism that removes a greenhouse gas or aerosol, or a precursor of a greenhouse gas or aerosol from the atmosphere.

Stakeholder
A person, group, organization or system that affects or can be affected by an actor's actions.

Technology
Technology is a piece of equipment, technique, practical knowledge or skills for performing a particular activity. It is common to distinguish between three different elements of technology: the tangible aspect such as equipment and products (hardware); the know-how, experience and practices (software) associated with the production and use of the hardware; and the institutional framework, or organization, involved in the transfer and diffusion of a new piece of equipment or product (orgware).

Technology transfer
Technology transfer involves vertical technology transfer, which is understood as the movement of technologies from the R&D stage to the commercialization, and horizontal transfer, which involves the spatial relocation or diffusion of technologies across space.

Vulnerability
Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity and adaptive capacity.

BARRIER ANALYSIS & ENABLING FRAMEWORK REPORT: ADAPTATION TECHNOLOGIES

EXECUTIVE SUMMARY

Achieving successful technology transfer requires participation and building on indigenous knowledge. While hardware has taken centre stage in activities and interventions to reduce greenhouse gas emissions, processes and institutions are central to building capacity and resilience to the impacts of climate change.

Article 4.5 of the United Nations Framework Convention on Climate Change states: "The successful deployment and transfer of environmentally sound technologies and know how requires a country-driven, integrated approach at a national and sectoral level. This should involve co-operation among various stakeholders (the private sector, governments, the donor community, bi-lateral and multi-lateral institutions, non-governmental organizations, academic and research institutions), including activities on technological needs assessments, technology information, enabling environments, capacity building and mechanisms for technology transfer" (Tempo #67, 2008).

This report reviews the main barriers to the diffusion of six prioritized adaptation technologies for the Technology Needs Assessment Phase II process in Belize (Nygaard and Hansen, 2015), and identifies the enabling framework and 'measures' to help facilitate the smooth transfer of the proposed technologies. The latter covers the institutional and legal status in each sector that can help to promote the proposed technologies.

The vulnerable sectors selected by key stakeholders through a participatory, consultative process were: Agriculture Sector, Coastal and Marine Ecosystems, and the Water Sector.

The prioritized technologies for the Agriculture sector include:

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

For the Coastal and Marine Ecosystems sector, the prioritized technology is:

- *Improved Environmental Monitoring Network and Early Warning System for Belize's Coastal Zone to Increase Resilience to Climate Change;*

and for the Water sector, it is:

- *An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize.*

Agriculture

Although the National Food and Agriculture Policy 2002-2020 is still the official guiding policy for Agriculture in Belize, the yet-to-be adopted National Agriculture and Food Policy 2015-2030 (GOB/MOA/FAO, 2015) is referred to for matters that address more-in-depth the challenges related to global warming and climate change, disaster risk reduction issues, and sustainable agriculture not adequately covered in the first policy.

Since there has not been an updated "Agriculture Development, Management and Operational Strategy 2003A" (ADMOS) (GOB/MOA/FAO, 2003), some components of ADMOS 2003 are still being used. Recently, the Department drafted a strategy matrix for program coordination for grain and potato crops, respectively. An update of the ADMOS is still a work in progress in the Ministry of Agriculture (R. Thompson, Project Coordinator, MOA; Personal comm. August, 2017).

The general focus of the MOA is captured in the National Food and Agriculture Policy 2015-2030 which states " **…** *engender a conducive environment for the development of an Agriculture and Food Sector that is competitive, diversified and sustainable, enhances food security and nutrition, and contributes to the achievement of the socio-economic development goals of Belize*."

The Agriculture Sector has a focus on a value chain approach to production with emphasis on productivity and competitiveness, in order to penetrate export markets and meet the basic food security needs of the country. Small-scale farmers in developing countries still largely rely on the public sector for technology transfer, especially if they cultivate crops that do not interest private firms (Piñero, 2007).

Some of the critical or non-starter (killer) barriers tabled and discussed among senior personnel of the Ministry of Agriculture, other stakeholders, and members of the Sector-based Technology Working Groups (STWG), that may impede the smooth transfer and diffusion of the four prioritized technologies for the Agriculture Sector under the TNA initiatives were considered under the following classification: Economic and financial, and Non-financial.

- *Economic and Financial*. High upfront or capital costs of technology equipment, spares, and ancillary components, is a killer or non-starter barrier which may easily

discourage potential investors and other stakeholders/farmers, investing in a new or improved technology. High operational and maintenance costs were also categorized as critical barriers to the diffusion of any technology, if other factors such as increased yields and favourable markets are not realized in favour of small and medium-scale producers.

Non-financial.

- *Enabling policy environment*: Investment in new technologies and technology transfer and diffusion, requires conducive and favourable policy environment for successfully streamlining the technology and its socioeconomic benefits within the developmental framework of a country and society. Subsidies and tariff reduction (lower import duties and taxes, zero-rated import category, etc) should be considered on certain equipment and components that form an integral part of the technology transfer and diffusion process, at least for the start-up phase. Market policies (import/export and restrictions, etc.), correspondence banking, rate of exchange, interest rates, and general investment climate (investment risks, credit lines, transparency, political stability, etc.) are key factors that can impede the transfer of technology.
- *Technical capacity*: A critical barrier to cost-effective transfer and diffusion of technology in the Agriculture and related sectors is the limited technical capacity that exist to operate and efficiently maintain new and improved technologies. It is often stated that it is the lack of funds for maintenance that results in the technology ending in disrepair. The barrier may be a combination of both inadequate funds and the limited technical capacity and innovation skills that prevail. Nevertheless, networking with partners and experts in the Private sector and industry, and specialized training programmes in innovative technology, are measures that can help to build capacity and strengthen institutions in the Public sector such as Agriculture.
- *Level of technical and organizational capacity of farmers*: A significant proportion of small and medium-scale farmers have limited technical capacity and skills in technology operation. Language and literacy level are barriers that may affect their uptake of new information and skill development.
- *Incumbent technology:* The incumbent technology can be a major hurdle to the transfer and diffusion of cost-effective and beneficial, improved technology. Farmers and other stakeholders may be comfortable with the incumbent and not interested in upgrading; the incumbent may be part of a monopoly, often controlled by self interest parties in places of authority; users may simply be satisfied with the incumbent and cannot affore investing in a new technology. There may be other reasons that should be examined and addressed.
- *Information Barriers:* Reliable information exists on technologies being considered for transfer and diffusion. However, information barriers arise when the information is not disseminated correctly and hence, does not reach potential users or clients. Additionally, should the information reach potential users, the mis-interpretation and misuse of technical information becomes a barrier, if technology awareness and education is not conducted to guide users, such as farmers and producers.

The IPPC (2000) indicated that the ‘enabling environment’ or ‘enabling framework’ for facilitating the transfer of climate change technology is the entire range of institutional, regulatory and political conditions that are conducive to promote and facilitate the transfer and diffusion of technologies (Nygaard and Hansen, 2015).

The Ministry of Agriculture partners with several local, regional and international institutions to promote sustainable agriculture in Belize. The agriculture sector policy and institutional framework guides the climate change adaptation strategy, and will determine decisions to be made, and the most suitable entities to implement the proposed TNA prioritized adaptation technologies for the sector.

Specific actions or critical measures identified during the barrier analysis included, but not limited to the following:

- Expand access to local and external finance.
- Lobby for reduced import Tax on equipment and seeds.
- Provide technology companies & suppliers with concession to service specific areas or groups of clients at reduced service costs (Public-private partnership).
- Set up local assembling industry where feasible.
- Improve access to products and services. Grow the market for new technology.
- Implement policies & regulations for lucrative markets.
- Improve policy and enabling environment (e.g. seed policy, market liberalisation, protectionism, monopoly of incumbent technology).
- Establish regulatory agency for standards, testing and certification (equipment, seeds, etc.).
- Strengthen regulatory framework (e.g. implementation & penalty)
- Enhance networking for certified seed production/ improved drip irrigation / potato cultivation chain actors.
- Strengthen research, development and demonstration of new technology.
- Strengthen Cooperative Dep. and form an association of farmer's cooperatives.
- Establish a programme to increase local and regional farmer's networking, utilizin mass media and ICT.
- Establish management programme and education/awareness campaign among key stakeholders for new technology.
- Establish training component in technology diffusion programme

Coastal and Marine ecosystems and environment

Analysis of prominent barriers to technology transfer and diffusion in the Coastal and Marine Ecosystem sector for an environmental monitoring network and early warning system, are presented in the Report. The following is a summary of non-starter and critical barriers in key component of the technology transfer process:

- *Economic and financial* High capital costs for marine environmental monitoring equipment and spares is a critical barrier that may easily discourage potential investors. High operational and maintenance costs were also identified as critical barriers to the diffusion of any technology, especially a modern environmental monitoring network of marine station/platforms comprising of sensitive instruments that requires continuous maintenance and replacement of components (e.g. cable, sensors, batteries/solar energy panels, communication spares etc.).

Non-financial

- Organisational/regulatory: Many organization operate in the Coastal Zone but some work in isolation. Coordination and synergy among some key stakeholders is lacking. Fisheries regulations are in place and are arduously being implemented, but there are those stakeholders that maintain that measures are too restrictive and affect their livelihood. Hence non-cooperating stakeholders can restrict the optimization of an efficient, marine monitoring network and early warning, that is for the benefit of all stakeholders operating in the Coastal Zone.
- *Weak Enabling policy environments for establishment of adequate Marine Environmental Monitoring Network:* Currently, marine environmental monitoring is being done for water quality and other physical impacts along the coastline and the barrier reef. However, the data collection covers only small sections of the marine environment and historical data is fragmented or periodic, and key indicators/parameters are missing. The Coastal Zone Development and Management Plan makes provision for comprehensive marine environmental monitoring, but capacity, professional human resources, and financing are major barriers for an improved and extended marine environmental monitoring network.
- *Incumbent technology:* Investments in marine environmental monitoring platforms and network have been carried out in the past through many projects and scientific research programme. However, sustainability has proven to be a major problem as funding dries up and plans to maintain the monitoring network fall apart for lack of finance, decreased institutional capacity and phasing out of old technology by new, improved and faster systems. This can be a major hurdle in the establishment of a modern, high technology marine monitoring network for the long haul, and workable measures must be implemented for sustainability and safeguarding the capital investment.
- *Information barrier:* Information on the most reliable, high precision, durable and affordable marine monitoring platforms or sensors is available. In formation on

environmental monitoring systems is not a barrier per se; however, the use and its interpretation can be a barrier by the inexperience technicians, clients or environmental officers.

- *Technical barriers*: Operation and maintenance of an efficient marine environmental monitoring network requires technically skilled technicians. Most of these skilled persons are in the private sector, but many are available in the public sector. Capacity in the Fisheries and CZMAI is limited, but personnel can be trained to operate the marine monitoring network.

Some actions or measures identified in the analysis for the Coastal and Marine Ecosystem technology transfer included, but not limited to the following:

- Fisheries Department in coordination with partners will continue strengthening the technical capacity of its personnel, thereby increasing the number of specialized expertise/trained staff;
- Through its regulatory mandate, Fisheries & CZMAI will continue work on implementation of legislative/regulatory framework;
- Fisheries Department, in coordination with partners will maintain public campaigns, awareness drives and advocacy for high priority given to marine ecosystem conservation by GOB & stakeholders;
- Fisheries will operationalize a coordinated and effective marine monitoring network and early warning;
- Fisheries and CZMAI will strengthen human and institutional capacity to write bankable project proposals and continue to identify potential international funding opportunities.

Water Sector

Provision of safe and wholesome water for domestic use is a human right and is vitally important for the health and well being of the rural population in Belize. The disruption of Rudimentary Water System (RWS) services in some villages is the result not of water availability, but the poor governance of the service, which includes the monitoring and technical operation/maintenance of the system, including the water treatment process and protection of the water source. This prioritized technology for the water Sector is to establish: *An Integrated Management Strategy for Water Safety for Eight Rural Water Supply Systems in Belize.* The essence of the technology transfer for threatened RWSs is the implementation of Water Safety Plans as recommended by WHO, comprising of: System Assessment and Operation; Monitoring; and Management and Communication.

The critical barriers that hinder the transfer of this technology are analysed in the Report, but a brief summary of the prevailing issues per key components of the technology transfer process is the following:

Economic and financial

- Financial management in the operation of Rudimentary Water Systems (RWS) is key for a successful water delivery service and its sustainability. Weak or none-cost recovery and service fee collection imperils successful operation of RWS in many communities. The high cost of spares such as water pumps, pvc pipes, fittings, meters, chemicals, etc., and general maintenance costs are also barrier for implementation of water safety plans for the successful operation of RWS.

Non-financial

- Organisational/regulatory: Members of Village Water Boards are politically assigned or nominated. Many of the political appointees do not have the capacity or commitment to do the job. The Village Council Act that governs the Village Water Boards must be reviewed, and amendments made to address this issue.
- *Weak Enabling policy environments for establishment of adequate Marine Environmental Monitoring Network:* Stakeholders in the water sector and community members contacted during the consultative process indicated that the policy regarding Village Water Board needs to be revised so that qualified personnel committed to the work can be hired or contracted. Thus, advocacy in this regard should be increased at the community and decision-making levels
- *Incumbent technology:* The incumbent technology is the absence of a Rudimentary Water System (RWS) for rural communities. RWS have worked in many parts of the world including Belize. Investments in this technology for delivery of safe water supply to rural communities will continue. The technology is becoming automated, including the water purification component. Solar PV technology is also being introduced to run the water pumps. However, the main problem is governance of these system. The technology transfer for threatened RWSs is the implementation of Water Safety Plans as recommended by WHO, comprising of: System Assessment and Operation; Monitoring; Management and Communication.
- *Information barrier:* Relevant information on components of RWS is lodged in the offices of the Rural Development Department in the Ministry of Labour, Local Government and Rural Development, in the Public Health Bureau, and at the Social Investment Fund (SIF). Technical and managerial capacity to run the daily operations of a RWS successfully is the critical barrier identified by stakeholders. Most members of Village Water Boards have no technical or managerial skills.
- *Technical barriers*: Committed and skilled persons are required to operate, manage and maintain RWS in accordance with an adopted Water Safety Plan. The technology transfer for the *Management and Operation for Water Safety of eight Rural Water Supply Systems* will include measures to overcome the technical deficiency for a sustainable and safe water delivery systems for the target communities

Measures identified with stakeholders' input in the Water sector included:

- Public Health Bureau develops and implement a timely, water-quality monitoring protocol for target Rudimentary Water Systems. This can be executed as part of the technology transfer for RWS Water Safety Plans. The budget for this activity will form part of the capital costs.
- Public Health Bureau and Rural Water Department spearhead the efforts to procure capital finance for the *Management and Operation for Water Safety of eight Rural Water Supply Systems.*
- Capital cost will include training for Village Water Boards in Business-oriented RWS operation and management
- Village Water Boards in coordination with Rural Water Department will procure and install water meters for RWS services that are not metered.
- Village Water Boards in coordination with Rural Water Department will identify operational funds and ensure regular audit be conducted for their RWS by a reputable auditing firm. Funding for this will come from Operational costs.
- Ministry of Labour, Local Government and Rural Water will revisit the appointment policy for Village Water Boards with intent of making recommendations for revision.

The focus of technology transfer should be on how technologies are received and mainstreamed into the development process (Tempo #67, 2008). Technologies must meet collectively identified adaptation needs and instil a sense of ownership by developing the software and orgware elements necessary to adopt and manage the hardware. The technology transfer should also be in synergy with current and planned intervention in adaptation and mitigation to climate variability and change in the target sectors. Adaptation therefore, becomes a form of sustainable development that supports self-defined positive and progressive change for communities and the society at large.

CHAPTER 1. Process for the identification of barriers and measures

1.1 Objective and Methodology for the Barrier Analysis

The objectives of the Barrier Analysis (BA) in the TNA process were to:

- Categorize the prioritized technologies and identify generic barriers and measures, using the literature and other supporting material;
- Identify the economic/non-economic barriers for each technology through a participatory consultative process;
- Prioritise barriers to select two/three critical barriers;
- Identify root causes and possible measures for the critical barriers prioritised; and
- Outline an enabling framework to overcome the barriers.

The TNA guidebook series "Overcoming Barriers to the Transfer and Diffusion of Climate Technologies" (Nygaard and Hansen 2015), UNEP-DTU training videos, and resource material from the desktop literature review provided guidelines for conducting the barrier analysis. The process followed included: background reviews; sector-based, small group stakeholder consultations; and field visits.

Literature Review

The consultant began the process with a desktop review of the relevant literature, including existing national policies, regulations, plans, strategies, annual reports and case studies from other countries and Belize. The information gathered from this review was complimented with informal interviews (face to face, telephone, email), input from sector small group stakeholders, other institutional experts, policymakers and end users. An initial list of possible barriers was prepared by the consultant, guided by the background research. Barriers in the initial list were grouped into two main categories: economic/financial barriers and non-financial barriers. Non-financial barriers included the following sub-categories: policy/legislative/regulations, institutional/technology capacity, social and cultural tendencies, and information/awareness of technologies. The lists were then presented to the sector-based technical working groups (including Agriculture, Coastal and Marine Ecosystem, the Water sector and other market actors and interests groups) on different occasions for their review, refinement, and prioritisation/decomposition of critical or key barriers. The prioritized barriers were then examined using the recommended logical framework analysis including "problem/solution tree" evaluation and basic economic analysis for the agriculture sector technologies.

Field Visits

The consultant in the company of the agronomist/grain seed development expert and his assistant, visited the Ministry of Agriculture/Taiwanese Mission rice-seed breeding site at

Central Farm to investigate the process for grain-seed cultivation and production. Next, the team visited the site of the grain storage facility, that has been inoperable for some time, to check the technical specification of the cold storage equipment and discuss the grain-seed production initiatives of the Ministry of Agriculture Crop and Grain Production Unit. On several other occasions the Lead Consultant visited the office of the MOA Crop Research and Development Unit to discuss the status of drip and centre-pivot sprinkler irrigation systems, and operational use of tropical greenhouses and locally constructed crop protection Bel-houses.

Other visits were conducted by the Consultant to the Coastal Zone Management Authority and Institute database unit and the Fisheries Department to investigate how the data gathered from CZMAI small array of water quality monitoring sites are collected and processed. On a later occasion, the consultant visited the Public Health Bureau main office in Belmopan, to further discuss with the Director, the management and technical problems faced by some Rudimentary Water System (RWS), which often results in a complete shut-down of these village water services.

Face-to-face discussion were also held with officers of the Agriculture Extension Service (MOA), the Coordinator of Projects (MOA), Agro-forestry technician from the Forest Department, the director for Prosolar (A renewable energy company), and the director of GoGreenBelize.

Sector-based Technology Working Groups

Sector-based Technology Working Groups (STWGs) were formed to work on the BA for each technology. Each group consisted of four to five participants and met on several occasions to review the prioritized technologies, barriers and measures. Separate lists of these stakeholders are included in Annex III. The consultant, in collaboration with the TNA team, identified stakeholders for each STWG based on their related interests with respect to the sector technologies (Table 1). Participants included representatives from government, non-governmental organisations and the user community, namely: the Agronomist of the Grain & Fruit-tree Production Unit of the MOA, Director and Assistant from the Crop Research and Development Unit (CRDU-MOA), Director/Agronomist from CARDI, technical personnel from Fisheries and CZMAI, Director and Water Quality technician from Public Health (MOH) and personnel Rural Development Unit (Ministry of Labour, Local Government and Rural Development), and a technical representative from Prosolar and Chen Tech Limited.

Table 1 is a list of the key stakeholder agencies/departments in the Agriculture sector.

Table 1: Categorization of Key Stakeholder Agencies in the Agriculture Sector

Sector: Agriculture	**Interests**					**Remarks**
	Economic/ Financial	Political	Adaptation & Environment	Sustainable Development	Livelihood Security	
- Crop & Grain Production Unit, MOA			√	√		Crop and certified seed production and sale to farmers
- Crop Research & Development Unit, MOA			√	√	√	R & D and training in irrigation, crop production, water harvesting and crop cover structures
- CARDI	√			√	√	Field test peppers, grains and tubers
- Grain Growers Representative	√			√		Four grain producer cooperatives/groups
- Extension Service MOA		√	√	√		MOA
- DFC	√					Low interest loan for Agriculture & RE
- BETTRAIDE				√		Technical support and investment guidance
- PROSOLAR	√					Solar PV & Cooling system provider & services
- Chen Tech & Company	√					Technical support & irrigation component supplier
- FAO			√	√		Donor, Technical support
- IICA			√	√	√	Technical Support
- UNDP			√	√	√	Implementer / facilitator, focused on SDGs
- Partners in R&D			√	√		CREI, SIRDI, etc.
- UB Plant propagation facility	√		√	√	√	Propagatingsugar cane seedlings to BSI/ASR

Table 2 and Table 3 contain the list of some of the other key stakeholders were contacted and participated in the Barrier Analysis process for the Marine and Coastal Zone sector and the Water sector, respectfully.

Table 2: Categorization of Key Stakeholder Agencies in the Marine and Coastal Zone Sector

Sector: Marine & Coastal Zone	Interests					Remarks
	Economic/ Financial	Political	Adaptation & Environment	Sustainable Development	Livelihood Security	
- Fisheries Dept.			√	√	√	Leading GOB Department for Fisheries sector
- CZMAI			√	√	√	Addresses issues on Coastal Zone management
- MAFFESD		√				Umbrella Ministry for Fisheries Dep and CZMAI
- Fishers	√				√	There are about 1,500 fisherfolks
- Investors in Tourist Sector	√					Tourism sector and coastal development
- Caribbean Fishery Management Council		√		√		Creation of management plans for fishery resources
- UB-ERI & Marine Researchers			√	√		University of Belize Environmental Research Institute
- PROSOLAR	√					RE supplier, technical support
- Shrimp Farmers	√			√		Eight major shrimp farms
- BTIA	√	√		√		The tourism association promotes tourism in Belize, the leading industry for foreign exchange & GDP
- BELTRAIDE	√			√		Facilitate investment ventures in Agriculture and RE, tourism and industry
- Partners in Coastal Zone Management & SD, Research and Advocacy			√	√	√	WWF, NGOs Coral Reef protection, Smithsonian Institute, Oceana, UNDP, etc.

Table 3: Categorization of Key Stakeholder Agencies in the Water Sector

Sector: Water	Interests					Remarks
	Economic/ Financial	Political	Adaptation & Environment	Sustainable Development	Livelihood Security	
- Rural Development Department		√		√		Along with SIF, the Rural Development Department (MLLGRD) coordinate establishment of RWS
- Public Health Bureau MOH				√	√	GOB Water Quality laboratory & database
- Social Investment Fund (SIF)	√			√		Financial mechanism of GOB for poverty alleviation & basic rural infrastructure & social services
- Village Councils		√				Governance
- Village Water Board Association	√	√				Management of RWS
- NAVCO		√				National umbrella association for Village Councils
- Hydrology Dept.			√	√		Monitoring, abstraction and regulation of water resources
- PAHO				√		Public Health issues, including potable water
- PROSOLAR	√					RE supplier, technical support & services
- Chen Tech Ltd.	√					Technical support & irrigation component supplier

1.1.1 Prioritisation of Barriers

Brainstorming barriers: The STWGs met by sector (Agriculture, Coastal and Marine Ecosystems, and Water) at different occasions to reviewed and modified/added to the initial list of possible economic/financial and non-economic barriers. Each barrier was carefully analysed and screened to retain only the essential ones based on stakeholders' knowledge in the area, experience acquired and lessons learned from local, incumbent technology that haven been in used for several years in Belize.

Selection and categorization: Using a qualitative measure of relative importance such as a Likert-type Scale, barriers were classified as: 1. critical/killer/non-starter; 2. Crucial; 3. Important; 4. Less important; and 5. Insignificant. This was necessary since all barriers were not considered at an equal level or highly important.

Ranking barriers: Using the Likert scale 1 to 5, with 1 as 'non-starter' or killer barriers, and 5 'insignificant'; the barriers were ranked for further analysis. Based on the rationale to decompose only the 'killer/critical' barriers, it was decided that the two highest ranked barriers should be decomposed using the logical framework analysis (LFA). Table 4 below shows an example of the categorisation and ranking applied.

Table 4: Categorisation and Prioritisation Process for Barriers

No.	**Barriers**	**Criteria and Importance of Barriers for Technology 1**					
	Economic & Financial	**1. Critical (Killer, non-starter)**	**2. Crucial**	**3. Important**	**4. Less important**	**5. Insignificant (easy starter)**	**Rank**
1	Barrier A		x				2
2	Barrier B	x					1
	Non-financial						
3	Barrier C				x		4
4	Barrier D	x					1

Each critical or 'killer/non-starter' barrier was decomposed to find the causal relations and their resulting effects. See problem/objective trees for each identified focal problem/objective. The LFA was very useful in bringing together all the key elements of a problem and guide systematic and logical analysis of inter-linked key elements. According to the TNA guidelines, barriers may be decomposed at four levels:

1. Broad categories of barriers (e.g., economic and financial)
2. Barriers within a category (e.g., high cost of capital)
3. Elements of barriers (e.g., high interest rate).

4. Dimensions of barrier elements (e.g. an interest rate of 15% per annum for households).

Following the decomposition of the barriers to identify root causes, possible measures were identified to address those causes and overcome the barriers. Overlapping or cross-cutting barriers for each sector were identified to show the linkages among the barriers across the technologies. In this assessment of linkages, all barriers across the technologies for each sector, financial and non-financial were considered, with a focus on the critical barriers. This allowed for a wider range of measures to be captured in the enabling framework for the technologies.

1.2 Category of Prioritized Technologies for the TNA process in Belize

Annex 1 shows a schematic diagram and a corresponding Table for the categorization of the prioritized technologies for the TNA process in Belize, including those for the Agriculture sector (adopted after Nygaard and Hansen, 2015; Schumacher, 1973). A summary of the categories is presented in Table 5 below.

In accordance with Table 5 the four prioritized technologies for the Agriculture Sector under the TNA process fall under Market Goods, in the sub-category of Consumer Goods. These technologies target the mass market, households, businesses and institutions. The general characteristics of such market goods are: number of potential consumers for goods is high; interactions with existing markets; supply chain can be large and complex; barriers may exist in all steps of the supply chain; and demands depends on consumer awareness and preferences.

Table 5 also shows that “The environmental and coastal/marine monitoring network for a marine early warning system”, and “Integrated management plans for water safety in eight rural communities” fall under “Other non-market goods”, and specifically, in the sub-category of “Technologies provided by public institutions’.

Table 6 shows a sample of improved ‘Consumer Goods’ and ‘Capital Goods’, and some corresponding incumbent consumer goods technologies and related barriers. Focusing on ‘Consumer Goods’, requirements and impacts for successful diffusion may include: cost-benefit analysis and market surveys, review of tariffs and import duties/taxes on technology components, investment climate, demands and market conditions, technical training, and job opportunities for people that may help stimulate the local economy. Listed are some barriers to procurement, long-term sustainability, implementation, achieving change, market goods and services, and some key measures to facilitate the transfer and diffusion of the ‘market goods’ technologies.

Table A1-3 (Annex A1) is a summary of "Non-market Goods" and "Other Non-Market Goods", adopted from Nygaard and Hansen, (2015). Table 6 and Table A1-3 were presented to key stakeholders as a general perspective on technology transfer and diffusion, and related barriers and measures to help define and evaluate the transfer/development of 'goods' connected with the prioritized technologies.

In the literature (Hecker et al. 2011, Nygaard and Hansen, 2015, Schumacher, 1973), "Non-market goods" are subdivided into "Publicly provided goods" and "Other non-market goods", as shown in Table 5 and Table A1-3. Publicly provided goods consist of large infrastructure projects requiring large investments, and generally publicly owned, and implemented/coordinated at the government level. Other requirement is an in depth socio-economic Cost-benefit Analysis (CBA) and an Environmental Social Impact Assessment (ESIA), notwithstanding the procurement of capital financing.

Furthermore, "Other non-market goods" is subdivided into: **i)** "Technologies provided by public institutions"; ii**)** "Institutional change: Improved rural livelihood'; and **iii)** "Behavioural change at the individual level (i.e. change of practice)".

Examples of technologies categorized under "Other non-market goods − Technologies provided by public institutions", include: Early warning system for drought; Environmental Monitoring Network & Early Warning System for Coastal and Marine Resources, Integrated Ecosystems Management and Resource Use; Seasonal Weather Forecasts, etc. Barriers identified are listed as barriers to procurement, long-term sustainability, implementation, achieving change, market goods and services; while some key measures to facilitate the transfer and diffusion of 'other non-market goods' are listed for review (see Table A1-3, Annex 1A). As indicated earlier, the prioritized technology in Coastal and Marine Ecosystem sector and the Water sector are categorized under "Other non-market goods − Technologies provided by public institutions".

Table 5: Category of prioritized technologies

Goods	Category	Description	Market characteristics	Prioritized Technology
Market Goods	**Consumer goods**	-Goods targeting the mass market; households, businesses and institutions.	– a high number of potential consumers – interaction with existing markets with extended and complicated supply chains – barriers may exist in all steps in the supply chain – demand depends on consumer awareness and preferences, marketing and promotional efforts	– *Heat and drought resistant variety of open-pollinating corn and bean seeds for reproduction and marketing.* – *Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement.* – *In-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties.* – *Rehabilitation of crop*

				cover structure cooling systems
	Capital goods	Machinery and equipment used in the production of goods, e.g. consumer goods or electricity or agro-processing products	- a limited number of potential sites/consumers - relatively large capital investment simpler market chain - demand is profit-driven and depends on demand for the products the capital goods are used to make	
Non-market Goods	**Publicly provided goods**	Technologies in this category are often (although not always) publicly owned, and production of goods and services are available (free or paid) to the public or to a large group of persons	– very few sites – large investment, government/donor funding – public ownership – simple market chain; technology procured through national or international tenders. – investments in large-scale technologies tend to be decided at the government level	
	Other non-market goods	Non-tradable technologies transferred and diffused under non-market conditions, whether by governments, public or non-profit institutions, international donors or NGOs	- technologies are not transferred as part of a market but within a public, non-commercial domain. Serves overall political objectives, such as energy saving and poverty alleviation – donor or government funding	- *Improved environmental monitoring network and early warning system for Belize's coastal zone to increase resilience to climate change.* - *An integrated management strategy for water safety for rural water supply systems in Belize*

(Source: adopted from Nygaard and Hansen, 2015)

Table 6: Sample of technologies and related barriers for Market Goods

Market Goods			
	Consumer Goods	**Capital Goods**	**Competing Consumer Goods Technologies**
Examples	- Solar water pumps - Improved drip irrigation - Climate resilient grain seed varieties - Plant micro propagation of heat/drought resistant varieties - Crop cover-structure/greenhouse cooling systems - Mini hydro plant for renewable energy generation for small, farming households, communities, and water supply systems	- Cement factory - Agro processing and consumer goods production - Flood protection barriers - Coastal protection infrastructure, etc -	- Diesel/gasoline or direct current powered water pumps - Manually operated irrigation; old, incumbent drip irrigation systems - GMO or hybrid grain varieties - Annually imported potato seeds that are not climate resilient - Small diesel generator (50 – 75 kWh) - Inadequately designed

			greenhouses/cover structures for tropical regions
Requirements and Impacts	- CBA and market survey often precedes initial investment - Tariffs and import duties/taxes for import of technology components - Demands and market conditions - Technical training and job opportunities for people - Help stimulate local economy	- CBA and ESIA precede capital investment -Tariffs, import duties and taxes, incentives/subsidy - Supply and demand, marketing opportunities (local / regional/international) - Legal and regulatory environment for investment - Enhance institutional and organization capacity in country - Provide job opportunities and stimulate the national economy	- Initial or capital investment - Import duties/taxes - Subsidies
Barriers to procurement	- High initial cost for improved technology (Cost improved technology minus cost incumbent technology) - Clash with incumbent technology - Uneven playing field - Few and inadequate suppliers of auxiliary goods and services - Legal and regulatory framework restricted - Poor technology quality/performance -Difficulty assessing finance -High interest rates	- High capital costs - Monopoly and protection of incumbent technology - Investment may be considered risky - Market controlled by incumbent technology -Uneven playing field arising from subsidies on competing technologies -Political influence -Legal and regulatory framework not favourable -Difficulty assessing finance and guarantee for loan	- Not considered; incumbent technology already in operation and use… -
Barriers to long- term sustainability	- High operational / maintenance costs - Volatility of markets - High interest rates	- High operational costs - High interest rates on loans - Unpredictable markets	- -
Barriers to implementation	- Low in country technical and institutional capacity - No incentives, high import duties and taxes - Weak connectivity between actors -Incumbent technology favoured -	- Enabling business environment unstable - Cost and risk may supersede benefits - -	- Initial cost of production and risks - -
Barriers to achieving change	-Mis-leading perception that traditional/incumbent technology is better - General lack of interest among stakeholders because of mis-information or little information	- Unfavourable social and cultural status - Market too small or limited - Social and environmental impacts may out weigh benefits in the long term	- Negative attitude of customers - Low market demands -

	- Local self-service interests and monopoly -	-	
Barriers to market goods & services	- Market volatility and small, limited market share -Unsatisfactory services because of limited knowledge of new technology and old equipment - Limited stock of spares and components - Exchange rates and correspondence banking issues, e.g. high risks	- Monopoly of incumbent technology -Unskilled technical workforce - Consumer preferences and social/cultural biases -	- Protectionism and monopoly - Limited knowledge of benefits
Proposed measures	- Develop awareness and education campaign on the benefits and advantages of new technology - Government and statutory bodies redress constraints in investment climate - Key stakeholder agencies (public and private) develop or improve mechanisms and identify market to attract investment in new technology - Ministry of Agriculture, Coastal Zone Management Authorities/Fisheries, and Water Sector /Public Health agencies implement short and medium term strategic plans to facilitate technology transfer	- Government and partner institutions (e.g. BELTRAIDE, DFC, others) should amend laws, policies and regulations to facilitate investment/trade facilities - Government introduces bill to provide incentives. Subsidies/tax reduction for establishment phase of new technology - Government/strategic partners guarantee market for new technology, as case may be - Government/strategic partners ensure policies and regulations in place for 'an even' playing field, and close loop holes against corruption	- Remove restriction to introduction of technology and services - Public awareness campaign by proponents -

(Source: adopted from Nygaard and Hansen, 2015, with input from stakeholders in the Agriculture, Coastal Zone and Water sectors, May - August 2017)

CHAPTER 2. Agriculture sector

The focus of any technology transfer should be on how technologies are received and mainstreamed into the development process (Tempo #67, 2008). It is paramount therefore, that the technology transfer should also be in synergy with current and planned intervention in adaptation and mitigation to climate variability and change in the target sectors being considered. The prioritized technologies in the Agriculture sector are:

1. Heat and drought resistant variety of open-pollinating corn and bean seeds for reproduction and marketing.
2. Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement.
3. In-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties.
4. Rehabilitation of crop cover structure cooling systems

The aims of these technologies transfer are the following: 1) Introduce climate resilient varieties of grain seeds and other crops among farming communities to ensure food security and stimulate the local economy; 2) Expand the use of improved drip irrigation and fertigation using solar powered water pumps and various forms of rainwater harvesting; 3) Utilized and expand the plant micro propagation facilities of the University of Belize to replicate fast-reproducing potato seedlings for more small farmers to participate in potato cultivation; and 4) Rehabilitate greenhouses/crop cover structures with efficient, solar powered cooling systems to help modify the elevated temperature and create a more comfortable environment conducive for the farmers and crop development. .

This chapter discusses the preliminary targets for the transfer and diffusion of the prioritised technologies, the barriers which are likely to hinder/prevent their deployment/uptake and the possible enabling measures to overcome those barriers. The analysis will examine linkages among the barriers and identify possible solutions to create an enabling framework

2.1 Preliminary targets for technology transfer and diffusion in Agriculture

An overview of the targets of the technologies for the Agriculture sector and the potential benefits to stakeholders that are likely to be affected by climate change is presented in this section. The last agriculture census in Belize indicted that there were approximately 12,000 farmers; 24% of farmers had less than 5 acres, 33% between 5 and 20 acres, and 74% of farms

are less than 50 acres in size (FAO, 2011). The majority of land used for agriculture (37%) was classified as shifting agriculture and unimproved pastures, followed by mechanized agriculture for grains practices primarily by the bigger, Mennonite farmers, who cultivate most hybrid varieties. The targets for the technologies are aimed at the majority of small farmers who are more vulnerable to the vagaries of the climate, the instability of the markets and externalities. The targets of technology transfer and diffusion in the agriculture sector include:

1) *Production of heat and drought resistant varieties of open-pollinating corn and beans certified seeds*. The target beneficiaries are small famers involve in the seasonal cultivation of corn and beans. It is estimated that there are over 7,000 small farmers cultivating 10 acres of less of rainfed grains seasonally. The climate resilient varieties of corn and beans 'breeder' seeds will be imported by the Ministry of Agriculture and partitioned among four certified grain producing cooperatives and the MOA Crop/Seed Production Unit. Each certified seed production group will have received 400 lbs for the first year and 200 lbs for the second year. The certified seed production groups will then cultivate these varieties under controlled conditions for the production of certified seeds as exemplify in the schematic below. The certified seeds will then be packaged in units of 25 lbs. and marketed to 200 small farmers in the six districts for a minimal price to cover purchase and production costs. The funds will then be reused for purchasing of new breeder seed varieties in the fourth year to commence the cycle once again. Farmers will also be able to use some of their grain seeds as planting material in the second and third year. The cycle recommenced in the fourth and fifth year, when new breeder seeds are purchased from abroad to strengthen and replenish the variety.

2) *Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement.* The target for this technology aims at improving and expanding drip irrigation technology among 150 small farmers to enhance yields in horticulture and vegetable productions for the local market. Improved drip irrigation/fertigation system demonstration centres will be upgraded in all districts, including the agriculture training facility at the National Agriculture Showgrounds in Belmopan. Initial acquisition of the improved drip/fertigation irrigation system and training of groups of farmers (25 farmers/district) will be an integral part of this piloted technology transfer.

3) *In-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties.* Potato is currently produced by small-scale farmers in San Antonio, Upper and Lower Barton Creek, Springfield village, La Gracia, and El Progresso in the Cayo District. Smaller quantities are cultivated in the Orange Walk, Corozal and Stann Creek districts. Potato varieties cultivated require cool conditions for tuber development, and these farming communities have the required conditions for growing these varieties during the cool period of November to February. The Red la Roche, Red la Soda and Red Pontiac potato varieties are the varieties mostly planted in Belize. There are approximately 15 main potato-farming communities in Belize (MOA

factsheet for Potato seed importers, 2014-15). In 2016, the production of potato was 2,173,000 lbs on 245 acres (yield 8,869 lb/acre or 21,915.8 lbs/ha). This annual production was low compared with the peak production of 2,231,100 lbs on 108 acres in 2013 resulting in a yield 20,658 lb/acre (51,047.0 lbs/ha). See Crop production table in Annex III for detail. The estimated production for 2017-18 potato-growing season that ended in February was: 3.7 million lbs, with a breakdown of 2.8 million lbs in the Cayo District, 588,000 in the Corozal District, 286,000 lbs in the Orange Walk District and 45,000 lbs in the Stann Creek District (MOA Press Release, January 24, 2018). The technology to reproduce climate resilient varieties of potato for tropical region in Belize, via plant micro propagation technology (University of Belize, School of Agriculture in Central Farm), is aimed at micro propagating these improved varieties in Belize in larger proportions for eventual redistribution of clean, certified potato seed tuber, certified seed tubers to an expanded number of potato-growing farmers. The funds from the sales will be used to improve the micro-propagation process and buy new seeds after a period of 4 years.

4) *Rehabilitation of crop cover structure cooling systems.* The Government of Belize, through project funding, bought a total of 30 greenhouses at unit rate of BZ$ 30,000.00 back in 2010. Some of these greenhouses are still in operation but the majority have fallen in disrepair and abandoned. Over the years the CRDU has also been refining the construction of Bel Tunnel cover structures, similar in design to the Tropical Greenhouse, but smaller in size. The technology transfer aims at installing improved cooling systems in at least eight (8) crop cover structures (greenhouses) in operational use around the country, with the capacity to address the inefficient cooling systems for other crop cover structures as demands for this service increases. The beneficiaries will be both small and medium-size farmers utilizing crop cover structures.

Table 7 below is a summary of technology targets for the agriculture sector and cost – benefit evaluation. See Annex II for a preliminary economic analysis for the of interventions.

Table 7: Targets and possibility of attainment of agriculture technology diffusion

Sector: Technology	Targets	Too Ambitious	Conservative
Agriculture			
1. Climate resilient open-pollinated certified corn & bean seeds	Small farmers cooperatives and farmers groups, and individual farmers in all six districts. The estimate is at least 50 small & medium-scale farmers per district purchasing certified, climate	No. Majority of small farmers cultivate non-resilient grains and/or hybrids under rainfed agriculture system.	GOB & certified grain seed producers can procure funds to cover initial cost of breeder seeds. Sources are: CIAT in Colombia, and CIMMYI in Mexico. Cost of seed production for 3 seed-producing cooperatives and the

	resilient grain seeds.		MOA Grain Unit cultivating six acres: estimated **Capital cost:** US$ 170,000 including drip irrigation and solar pumps (Annex 1). **Operational costs:** US$ 23,000.00. CBA for grain seed production per hectare: Capital cost per hectare for certified seed production US$ 421.50/ha Operational Costs (inputs) for farmers to cultivate one-hectare incumbent: US$ 399.00/ha
2. Improved drip irrigation & fertigation	Sixty small/medium-size farmers countrywide (20 per district). Farmers will be trained to setup and operate improved drip/ fertigation irrigation systems, coupled with water harvesting and RE solar-powered water pumps where needed.	No. Many farming cooperatives or farmer's groups, and individual farmers are utilizing the incumbent, low-efficient drip irrigation technology.	The focus is to upgrade the technology, incorporating fertigation, water harvesting and/or RE technology for water pumps. Incentives and import tax exemptions can be requested, in addition to low- interest loan facilities for small farmers (e.g. from DFC, Credit Unions, National Bank, etc.). Preliminary estimate of **Capital costs:** US$ 126,800.00, with solar energy-driven pumps. **Operational costs**: US$ 45,000.00
3. In-country micro-propagation of clean stock, climate resilient	Country-propagated certified, clean stock climate resilient, potato seeds for	Might be too ambitious. Initial cost to establish a potato micro-	Not too conservative. Initial costs for improving the plant micro-propagation

	Irish Potato seeds	current population of 25 potato-growing farmers, plus another 50 from the six (6) districts in Belize.	propagation programme from procurement of clean tubers to certified tubers for sale to famers is high within a timeframe about 5-years. (see Annex IV)	laboratory and producing certified seeds is high. Requires a comprehensive CBA. **Estimated capital** cost US$ 337,000; **Operating costs** (5-year period): US$ 625,000.
4.	Improved cooling system for Crop cover structures (Tropical Greenhouses	Refurbishing cooling systems for at least 7 crop covered structures. The intention is to develop a business for rehabilitation of existing covered structure cooling system as demands for installation increase.	Initial cost for cooling system components could be high for individual small farmers.	Yes. **Capital Costs:** US$ 109,500.00 for cooling system refurbishment of (7) Bell Tunnel Covered structures. **Operational costs:** US$ 28,000.00 for three years (spares & maintenance).

2.1.1 Institutional framework

In Belize, the Ministry of Agriculture, Fisheries, Forestry, The Environment, and Sustainable Development (MAFFESD) is the Ministry responsible for the coordination and implementation of Sustainable Development and Climate Change policies in Belize. The National Climate Change Office (NCCO) under this Ministry plays a leading role in coordinating the work of the National Climate Change Committee (NCCC), which has wide representation from the public and private sectors and has the mandate to spearhead climate change actions at the local, regional and international levels. The NCCC is organized into sub-groups to address the various aspects of climate change.

The Ministry of Agriculture partners with several local, regional and international institutions to promote sustainable agriculture in Belize.

The agriculture sector policy and institutional framework guides the climate change adaptation strategy, and will determine decisions to be made, and the most suitable entities to implement the proposed TNA prioritized adaptation technologies for the sector. The proposed Technology Action Plan (TAP) will be the strategic mechanism to facilitate the sourcing of funds for the technology transfer at the national, regional and international levels. The availability of the necessary human and material resources, what measures/interventions have already been

initiated, complementarity and partnering needs, supportive proposed and/or adopted policies and systems, jurisdiction, improvement needs and remaining barriers to be properly addressed to facilitate the technology transfer, will all be considered per technology in the TAP.

2.1.2 Ministry of Agriculture

The Ministry of Agriculture is guided by the National Agriculture and Food Policy (NAFP) 2015-2030, with the strategic objective of increasing agricultural production, productivity, competitiveness, and market opportunities. Emphasis is being placed on innovation, research and development, and partnerships to capitalize on available opportunities that have a comparative advantage.

Vision: "A transformed/modern sector that is fully competitive, diversified and sustainable".

Mission: "To continue as the economic pillar of Belize, ensuring food security, generating income and foreign exchange, creating employment, and conserving natural resources, in order to grow the economy, reduce poverty and empower the local population for sustainable development".

Strategic Goal: "Contribute to the overall GDP growth and national household incomes and growth in export earnings".

Strategic objectives for the Agriculture Sector in Belize are to:

- Stimulate and facilitate agricultural and fisheries sector growth and reduce rural poverty;
- Create the enabling and favourable environment to increase the efficiency, productivity, profitability and competitiveness of the agriculture, fisheries and cooperative sectors;
- Accelerate the diversification in production, processing and exports;
- Improve and conserve the natural and productive resource base to ensure long-term sustainable productivity and viability;
- Improve access to productive resources and services and create economic opportunities for small/young farmers, women and indigenous people, particularly in poor, marginal areas;
- Strengthen the institutional capacities to provide effective support in marketing and trade, research and extension, as well as relevant education and training;
- Increase food production, enhance food security and improve the nutritional status of the population, as well as increasing farm incomes; and
- Strengthen inter-sectoral linkages, in particular with the social sectors of health and education, as well as with the strategy and action plan for poverty eradication, (www.agriculture.gov.bz, retrieved June, 2017).

The over-arching goal of the NAFP 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 that contributes to the achievement of the socio-economic development goals of Belize" (GOB, 2015).

Short-term strategic plan for corn and beans cultivation

Program: Crops and fruit trees

This strategic plan is derived from the workplans submitted by the different units of the Crops Section.

Thematic area: Diversification

Objective: To facilitate agricultural diversification through the promotion of viable crop and fruit tree commodities that contribute to economic development and opportunities of rural producers.

Timeframe: 2017 -2020

Strategy matrix: Table 8 shows the short-term strategy proposed by MOA for corn and beans production. It is recommended that future initiatives or technology transfer in climate resilient, certified grain seed production should be streamlined with the MOA's short to medium-term strategy and actions.

Table 8: Strategic matrix for corn and beans production

Target Commodity	Objective	Components (how? Strategy)	Deliverables (2017-18)	Location	Lead Person	Partners
Corn (*Zea mays*)	Support corn production among rural producers for food security and income generation.	1. Maintain a reliable supply of Open Pollinated (OP) stock seed for rural producers. 2. Strengthen the selection of climate resilient germplasm (local or introduced) that is tolerant to pest and diseases. 3. Promote biofortified varieties of corn to enhance nutrition. 4. Develop and implement an integrated pest and disease mgmt. for corn production. 5. Strengthen production systems for seed and grain to be cost effective, sustainable and climate resilient.	1. A report on the demand for yellow and white OP quality seed on a seasonal and yearly basis. 2. Trained selected producers in quality corn seed production. 3. Four acres of yellow OP corn established for seed production in four districts with producer groups. 4. 20,000 lbs of yellow OP corn seed with 95% germination rate produced at C/Farm. 5. A protocol for the production and quality assessment of OP corn seed. 6. A report on bio-fortified and heat/drought tolerant varieties available regionally.	Central Farm Central Farm OW, Cayo, S/C, Toledo	M. Trujillo M. Trujillo M. Trujillo	CARDI producers Extension CIMMYT, INIAS,
Beans (*Phaseolus*	Support production	1. Maintain a reliable supply of quality seed	1. 5000 lbs of small red bean seed with	Central Farm	M. Trujillo	CARDI

vulgaris)	of pulses among rural producers for food security and income generation.	of small red and black beans. 2. Strengthen the selection of climate resilient germplasm (local or introduced) that is tolerant to pest and diseases. 3. Promote biofortified varieties of pulses to enhance nutrition. 4. Develop and implement an integrated pest and disease mgmt. for coconuts 5. Strengthen production systems to be cost effective, sustainable and climate resilient. 6. Promote good post-harvesting practices among producers.	95% germination rate produced. 2. 5000 lbs of black bean seed with 95% germination rate produced. 3. Four acres of small red beans established for seed production in four districts with producer groups 4. Four acres of small black beans established for seed production in four districts with producer groups 5. A report on the demand for yellow and white OP quality seed indicating seasonal and yearly demand. 6. A protocol for the production and quality assessment bean seed. 7. A report on bio-fortified and heat/drought tolerant varieties available regionally.	OW, CYO, S/C, Tol OW, CYO, S/C, Tol	M. Trujillo M. Trujillo	Extension Extension CIAT, INIAS, etc.

(Source: Strategic action plan 2017-2020. Ministry of Agriculture, July 2017)

Some short and medium-term measures contributing to an enabling environment as proposed by MOA

With respect to the proposed technologies in the Agriculture sector, stakeholders at the policy level and others in consultative small group meetings, pointed out that some measures that may contribute to current and future enabling environment for technology transfer in the sector are:

1. Strengthen technical cooperation and cooperation with regional institutions such as: CARDI, IICA, INFAP, Mexican Scientific and Technical Cooperation (AMEXCID).
2. Accelerate the initiative to strengthen MOA's Research and Extension Service, including a greater emphasis in the use of ICT.
3. Implement programme with the IDB, to improve and systematize its agriculture data and information in a way that is readily accessible for decision making.
4. Fast-track, at policy level, technical cooperation projects with FAO, CDB, IFAD, and other partners, etc.
5. Advocate at policy level, the adoption of the National Agriculture and Food Policy 2015-2030, and the drafting and adoption of an updated Agriculture Development, Management and Operational Strategy (ADMOS), that will both help to steer sustainable agricultural development in Belize for the short and medium term.

2.1.3 Overview of barriers to the diffusion of technologies in the Agriculture Sector

Stakeholders in the Agriculture Sector both at the policy and technical levels, and partners in the sector, listed a series of barriers to consider in technology transfer of heat and drought resistant varieties of open-pollinated corn and beans seeds, other climate resilient crops; micro-propagated, climate resilient potato seed tubers; improved drip irrigation & fertigation systems; and improved technology for crop cover structures (e.g. Cooling system and solar PV components). The preliminary list of barriers included:

- Inadequate and incoherent policy incentive frameworks e.g. absence of a seed policy.
- No national seed/crop certification mechanism and unit.
- Limited capacity in crop research and development.
- Weak governance systems and mechanisms−monitoring and evaluation systems are still in infancy stages; regulations that support contract farming or provide a fair operating field for producers and buyers is not available.
- Local market opportunities are limited (i.e. agricultural storage and service centres) not well developed, still in infancy).
- 'Value added' not fully embraced among small producers and agro-processors.
- Poor infrastructure, including SPS standards, food safety monitoring.
- Affordable credit and financing not easily accessible to small producers.
- Low levels of productivity and high production costs especially fuel, agro-inputs.
- Limited research and deficient extension services to support rural producers.
- Limited or lack of relevant information on technologies−their advantages, costs and benefits to improve yields and reduce impacts on the environment.
- Limited technologies and usage.
- High up-front cost for new technologies.
- Limited resilience capacity to risks and natural disasters.
- Institutional conflicts and overlapping roles, (turf protection).
- Striking a balance between increased land use change for agricultural expansion and a healthy and secured biodiversity for present and future generations.
- Limited and accessible financial mechanisms for small farmers.
- Land tenure issues.
- Elevated financial risks arising from extreme climatic events and unfavourable market conditions.
- Poor infrastructure in remote localities.
- Rising cost of fuel for operation and transport.
- Younger generation not fully interested or engaged in agriculture.
- Limited technical capacity in the agriculture sector, especially among small farmers.
- Increased praedial larceny.
- Increasing costs of agriculture inputs.
- Majority of small farmers have limited education.
- Competition with incumbent technologies and interest groups.

The barriers were further classified under “Economic/financial” and “Non-financial” barriers and were arranged according to key components for these technologies as illustrated below.

- **Economic and Financial Barriers**

High up-front costs for establishment of a sustainable and profitable ‘certified’ corn and beans seed production system will discourage grain producers in making this investment, as market may be too small. Elevated import duties and taxes on components of solar PV systems and cooling fans, tropical greenhouses, water pumps, and miscellaneous agro technology equipment. Cost of maintenance of improved agro-technology systems can also be high fpr individual small or medium-scale farmers, for example: grain cold storage systems/facilities, multilple crop cover structure cooling systems, expanded plant micro propagation laboratory facilities, farm mechanization, etc. Also, elevated financial risks resulting from crop failure, and limited, attractive, low-interest financial mechanisms for small producers are constraints that discourages inestments. Unfavourable market environment can also discourage farmers from investing in large-scale production of certain crops (e.g. corn, beans, potato, onions, etc.). because of unpredictable importation of such commodities flooding the market, low prices at harvest time, and inadequate storage technology and facilities.

Non-financial barriers.

- **Organizational/regulatory Barriers**

Several departments and partner organizations including: MOA Fruit Trees and Grain Production Unit, the Crop Research and Development Unit (CRDU), farmers groups/cooperatives, research units in industry and academia, e.g. CARDI, CREI, UB and others, tend to work in isolation, with limited coordination and sharing of information. Regulatory framework for R&D in crop production/marketing etc. may exist but not fully implemented.

- **Enabling policy environments for Drip/Sprinkler irrigation systems and Solar PV**

Currently, duty is paid on components of drip/sprinkler irrigation/fertigation systems, and Solar PV at the same rate as imports of other hardware equipment, construction and building components. Inadequate and incoherent policy incentive frameworks e.g. absence of a National Seed policy, establishment of a Seed/Crop Certification Unit/Institution and adopting and implementing the draft irrigation policy and strategy (GOB/FAO, 2015) are barriers that can be addressed to help facilitate the transfer and diffusion of climate resilient grains and crops that can help farmers adapt to climate change, improve their livelihood and ensure food security.

- **Incumbent Technology**

Agro-businesses and more progressive farmers in Belize have been using older technologies and applications in drip/sprinkler irrigation systems, hybrids varieties of corn and other grains beans, over-heated tropical greenhouses and cool-season potato varieties for some time now, so investing in new technologies may appear difficult and costly. Moreover, the incumbent

technology may be profitable under current conditions, and farmers may be very familiar with operations and maintenance, so switching to a new, unfamiliar technology appears risky, and too costly for small farmers who would want the improved technologies.

- **Information Barriers**

Information barriers include limited access to relevant information on technologies, which could provide potential customers with a knowledge on the viability of investing in new technologies. Prices and quality of complete drip irrigation units, grain cool storage units and cooling fans and electric water pumps, solar PV components and miscellaneous parts for the various technologies can vary, so customers need to know which model will yield better return on their investments. Information barriers may arise due to poor extension services, lack of information dissemination and training, and limited coordination among key actors in the market chain (manufacturers/primary producers, importers and large-scale processors, retailors, service providers and maintenance, and market end users/clients).

- **Technical Barriers**

Few skilled persons can properly install and maintain improved drip/sprinkler irrigation systems, cooling systems for crop cover structures, “certified” grain seed production and storage, and plant micro-propagation technology, certified and commercial seed production, and marketing. In Belize, this is usually done by Agronomists and Horticulture technicians at CARDI, Ministry of Agriculture (MOA) Fruit-tree and Grain Production Unit, MOA Crop Research and Development Unit (CRDU), agrobusiness technicians, and other professional groups/companies who technical service for installation and maintenance of complex electrical equipment and renewable energy systems. Improper installations, lack of adequate maintenance, or inferior model/brand of equipment may result in accidents and failure. This may lead to delayed of returns on investments or a loss of investments, and unprofitable yields that may discourage agro-businesses and farmers in the usage of the new technology.

2.2 Barrier analysis and possible enabling measures for heat and drought resistant varieties of open-pollinating corn and beans seeds

The recommendation from stakeholders on climate resilient crops indicates that 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 (R. Thompson, Agriculture Officer responsible for Projects, personal communication, September 2017). Thus, the technology will encompass not only the new varieties of open pollinated corn and bean 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.

2.2.1 General description of heat and drought resistant varieties of corn and beans seeds

The proposed technology transfer to produce heat and drought resistant variety of open-pollinated corn and 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 beans seeds for supplying to small farmers, and four farming cooperatives to produce corn and black bean grain for the local market. The intervention will run for three years.

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:

1) *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.
2) *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.
3) *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.
4) *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 San Carlos 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 systems. The San Carlos Farmers Cooperative plans to increase their yellow and white corn, and black beans production to supply the local market demand.

The Ministry of Agriculture Crop Production Unit (Central Farm Group) is involved in seed production of grain crops such as corn, beans and rice. This group will also participate in this intervention. The Crop Unit will be provided with an improved 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. A simplified production chain for quality corn and black bean seed and other grain is illustrated in the following schematic:

Schematic of production chain for quality corn and bean seeds

It is envisioned that with an efficient drip irrigation or sprinkler irrigation system, the San Carlos Group can attain yields of corn in the order of 5000 lbs./acre which would be exceptional and profitable.

Table 9 shows the recent yields in grain and potato cultivation in Belize. The records are for the period 2010 to 2016, for both *milpa* and mechanized production.

Focusing on the mechanized and semi-mechanized production one can observe yields of 0.74 tons per hectare for black beans, 3.86 tons per hectare for yellow corn, 2.69 tons per hectare for white corn, and 11.87 tons per hectare for semi-mechanized potato cultivation. A table with the detail production and yields can be seen in Annex 1B. Cost estimates for cultivation of one acre of grain and potato are contained Annex II for review. The estimates were used evaluate the Net Present Value (NPV) for such crops, as a means to highlight the economic barriers for climate resilient varieties of grain and potato seedling technology transfer and diffusion.

Table 9: Recent average yields in grain and potato production in Belize for the period 2010-2016
(Source: MOA Marketing Information Unit, 2017)

PRODUCTS	Average Yields	
GRAINS, BEANS	(lbs)/acre	tons/ha
BLACK BEANS		
Mechanized		
Production (lbs)	734,525	333.18
Acres	1,106.6	447.84
Yield (lb)	**663.77**	**0.74**
Milpa		
Production (lbs)	2,917,459.63	1,323.35
Acres	3,392.66	1,373.01
Yield	**859.93**	**0.96**
CORN Yellow		
Milpa:		
Production (lbs)	6,364,300.43	2,886.83
Acres	5,064.29	2,049.52
Yield (lb)	**1,256.70**	**1.41**
Mechanized:		
Production (lbs)	117,853,165.29	53,457.85
Acres	34,220.14	13,848.89
Yield (lb)	**3,443.97**	**3.86**
CORN White		
Milpa:		
Production (lbs)	8,349,154.14	3,787.15
Acres	6,125.57	2,479.02
Yield (lb)	**1,363.00**	**1.53**
Mechanized:		
Production (lbs)	8,225,090.00	3,730.88
Acres	3,431.43	1,388.70
Yield (lb)	**2,396.99**	**2.69**
Irish Potato	(lbs)/acre	tons/ha
Production (lbs)	2,331,505.29	1,057.56
Acres	220.14	89.09
Yields	10,590.87	11.87

International Centre for Tropical Agriculture (CIAT- Colombia)

Since its foundation on 17 October 1967, the CIAT has collaborated closely with its host country, Colombia, focusing on the shared conviction that agriculture research is an important tool for generating new technologies, methods, and knowledge that enable farmers, particularly low-income smallholders, to make their production more eco-efficient: that is, competitive, profitable, sustainable, and resilient. Among its achievements are: more than 90 improved varieties of four key crops− rice (48), tropical forage (11), common bean (16), and cassava (18) (CIAT information sheet retrieved from www.ciat.cgiar.org/, Nov. 2017). CIAT's 50-years of research has provided the Centre with a strong platform from which to project its work through cooperative ventures, to the rest of Latin America and the Caribbean. CIAT is one of the regional processors of climate-resilient breeder beans seeds.

International Maize and Wheat Improvement Centre (CIMMYT – Mexico)

The International Maize and Wheat Improvement Centre operates in the developing world to improve livelihood and promote more productive, sustainable maize and wheat farming. The Centre's portfolio targets critical challenges, such as food insecurity and malnutrition, climate change and environmental degradation. Through collaborate research, partnerships, and training, the Centre contributes to the building and strengthening of a new generation of national agricultural research and extension services in maize- and wheat- growing nations. As a member of the CGIAR Research System composed of 15 agriculture research centres, CIMMYT leads the CGIAR Research Program in Maize and Wheat, which is streamlined into the agriculture

development programme of more than 500 partners around the world (CIMMYT information sheet retrieved from www.ciat.cgiar.org/, Nov. 2017).

It all starts with seed. CIMMYT crop-breeding research begins with its Germplasm Bank, consisting of a unique catalogue of genetic diversity comprising over 28,000 unique seed collections of maize and wheat. From the breeding program, CIMMYT sends half a million seed packages to about 600 partners in 100 countries. With the collaboration of researchers and farmers, the Centre also develops and promotes more productive and precise maize and wheat farming methods and tools that help save money and resources such as soil, water, and fertilizer.

Box 1: FAO "Seed for Development – A bright future for Open-pollinated corn

FAO 'Seed for Development' Project – A Bright Future for Open-Pollinated Corn
Published on August 1, 2014 in Issue 26 of the **Belize Ag Report**.

Experimental seed development project sponsored by the Food and Agriculture Organization (FAO) and carried out by Cayo farmers under the direction of Lead Extension Officer, William Can, of the Ministry of Natural Resources and Agriculture (MNRA), is a resounding success! The project objective was to evaluate and multiply seeds of three improved corn varieties, two of which were white corn and one yellow, that adapted to weather and soil conditions of the Cayo District from the previous year's experiment. The slogan that evolved is *Good seed = Good yield*. The success of the corn seed production trials hinged on a strong support for the plans in training and assisting corn farmers to address their most pressing issues such as:

- Production and selection of quality seeds to increase yields.
- Good agronomic practices to increase yields.
- Good post-harvest practices.
- Marketing.
- New technologies to increase yields per unit area by increasing plant density.
- Good management practices of the crop.
- Formation and organization of corn farmer groups to maximize production success.

Ms. Fay Garnett, District Agriculture Coordinator (Cayo) /Organic Program Coordinator of MNRA indicated that NB-6 seeds should be available to farmers for the next growing season from seed plots in Valley of Peace. The varieties currently planted are: Icta-B1, NB-6, CARDI yc-001.

According to William Can, 12 acres were being planted for seed purposes in the Toledo district. The varieties were Icta-B1, NB-6, CARDI yc-001, one local white and one local yellow. All these varieties were to be harvested and sold as seeds in the Toledo district. More details on the corn trials can be seen in *The Belize Ag Report, Issue 26*.

1.2.2 Identification of barriers for heat and drought resistant varieties of corn and beans seeds

Following consultation with key stakeholders connected with the production of certified grain seeds in the Agriculture sector, a list of general barriers that may likely impede the transfer and diffusion of climate resilient grain seeds were identified. These were:

- Costs to procure and run field trials of breeder seeds;
- Initial cost to purchase certified seeds and to prepare land for planting commercial grain;
- Land tenure issues;
- Lack of a functional Cool Storage facility for harvested grain crop;
- Lack of a workable marketing strategy;
- Lack of interest among some farmers;
- Limited knowledge about the impacts of Climate Change and the need to conserve water, soil, biodiversity, and reduce emissions;
- Lack of finance for maintenance and rehabilitation of cool storage facility;
- Inadequate recurrent budget and institutional support to run 'certified' seed production and training;
- Limited use of climate resilient, certified grain seeds;
- Inadequate financing facilities/mechanism for small farmers;
- Elevated financial risks arising from extreme climatic events and unfavourable market
- Weak coordination and synergy among certified grain producing groups.
- Absence of a National Seed policy;
- No national seed/crop certification mechanism and unit.
- Incumbent technology of non-climate resilient varieties still holds sway some users and larger farmers
- Patented breeder, lines or stock seed limits importation amount and distribution for field testing and reproduction

The list of the main barriers was then short listed in accordance with their degree of importance and rank as illustrated in Table 10 below. Those barriers ranking 1 and 2 on the Likert scale were then further analysed using the LFW methodology of "problem tree" and corresponding "solution tree".

Table 10: Criteria and importance of barriers for climate resilient grains

No.	Barriers	Criteria and Importance of Barriers for Technology 1					
	Economic & Financial	**1. Critical (killer, non-starter)**	**2. Crucial**	**3. Important**	**4. Less important**	**5. Insignificant (easy starter)**	**Rank**
1	Initial costs for seeds and field trials		x				2
2	Cost for cultivating certified/ commercial grains	x					1
3	Limited low-interest financing			x			
4	High taxes and limited subsidies			x			3
5	Unfavourable market status at harvest		x				2
6	Financial risks due crop failure			x			3
	Non-financial						
7	Land tenure issues			x			3
8	Limited use of climate resilient crops	x					1
9	Incumbent technology in grain production still widely used		x				2
10	Absence of a national seed policy			x			
11	Weak coordination among certified grain					x	5

	producers						
12	Lack of drying and cool storage facilities				x		4
13	Limited quantity of patented breeder, lines or stock seeds					x	5
14	Weak institutional capacity in extension services and R&D		x				
15	Mis-trust among small farmers in new technology and with MOA				x		3
16	Animosity of small farmers towards larger producers					x	4
17	Water scarcity during dry season			x			3
18	Limited knowledge of impacts of climate change			x			
19	In effective strategic plan to build climate resilience in agriculture		x				2

Figure 1 below is a problem tree analysis conducted with stakeholder's input on the barrier or focal problem: "Limited use of climate resilient crops among small farmers".

The causes and effects arising from this focal problem are clearly highlighted in the diagram. Stakeholders have pointed out that this is the reality in the sector and are compatible with the main identified barriers for production and dissemination of climate resilient varieties of open pollinated corn and bean seeds in Belize. The economic barriers are further addressed in the following section.

Figure 1: Problem tree for low cultivation of climate resilient grains among small farmers

Other critical barriers identified from the selection process above in Table 10 were:

- Initial cost for stock seeds and trials.
- Cost to cultivate certified/commercial seeds (by famers).
- Unfavourable market climate at harvest.
- Incumbent technology still widely in use.
- Weak institutional capacity in extension services and R & D.
- In effective strategic plan to build climate resilience in agriculture.

2.2.2.1 Economic and financial barriers

According to the literature (Nygaard and Hansen, 2015), one of the main constraints or barrier to the transfer and diffusion of a new or improved technology is the difference in cost of the technology in its development/demonstration phase and the cost of the baseline or incumbent technology, or the absence of the technology. For example, an improved, highly automated drip/fertigation systems being tested and the inefficient, manual drip irrigation in use, or the absence of drip or sprinkler irrigation systems in crop production. In the case of the introduction of climate resilient grains into a farming system, this economic barrier would be the cost of procuring the breeder/lines or stock seed varieties from Grain Research Centres such as CIAT or CIMMTY; doing extensive and controlled field trials, testing for the preferred varieties for climate resilience, robustness and high-yielding, and palatability. The cost also includes inputs and reproduction of the varieties for certified/commercial seed production for sale to farmers as planting material (M. Trujillo, Agronomist and National Crop Coordinator, MOA, personal comm. 14 November, 2017).

Figure 2 and Figure 3, and Table 11 illustrate the economic disparity between the new technology and the baseline (incumbent) for the production of one acre of Yellow Corn and Black/Small Red Beans. This also holds true for improved drip irrigation & fertigation, micro-propagation of climate resilient potato seedlings and for refurbishing crop cover structures with improved, and efficient cooling systems. Detailed cost estimates and monetary benefits for grains, laboratory micro-propagation of climate resilient potato propagules (seed tubers) and drip irrigation can be reviewed in Annex I C.

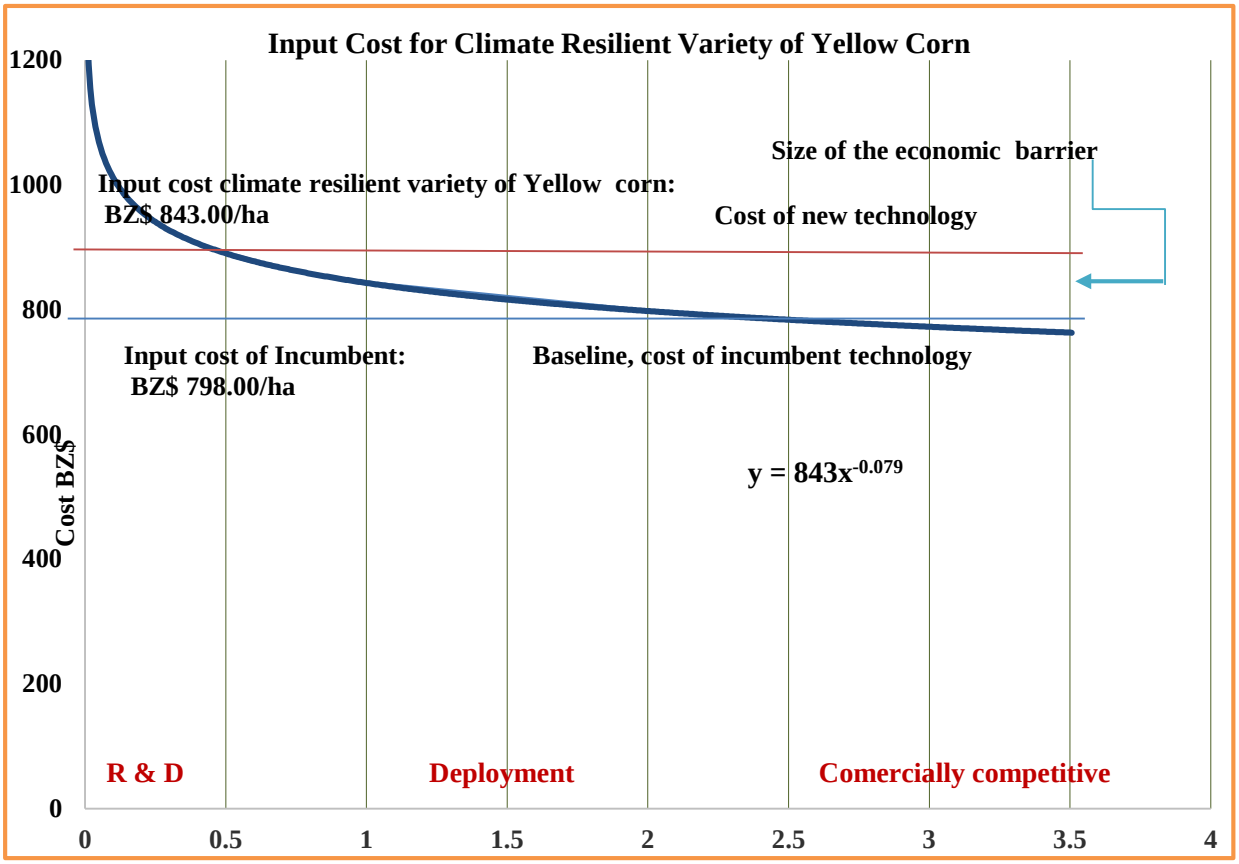


Figure 2: Size of economic barrier for climate resilient variety of yellow corn
(After Nygaard and Hansen, 2015)

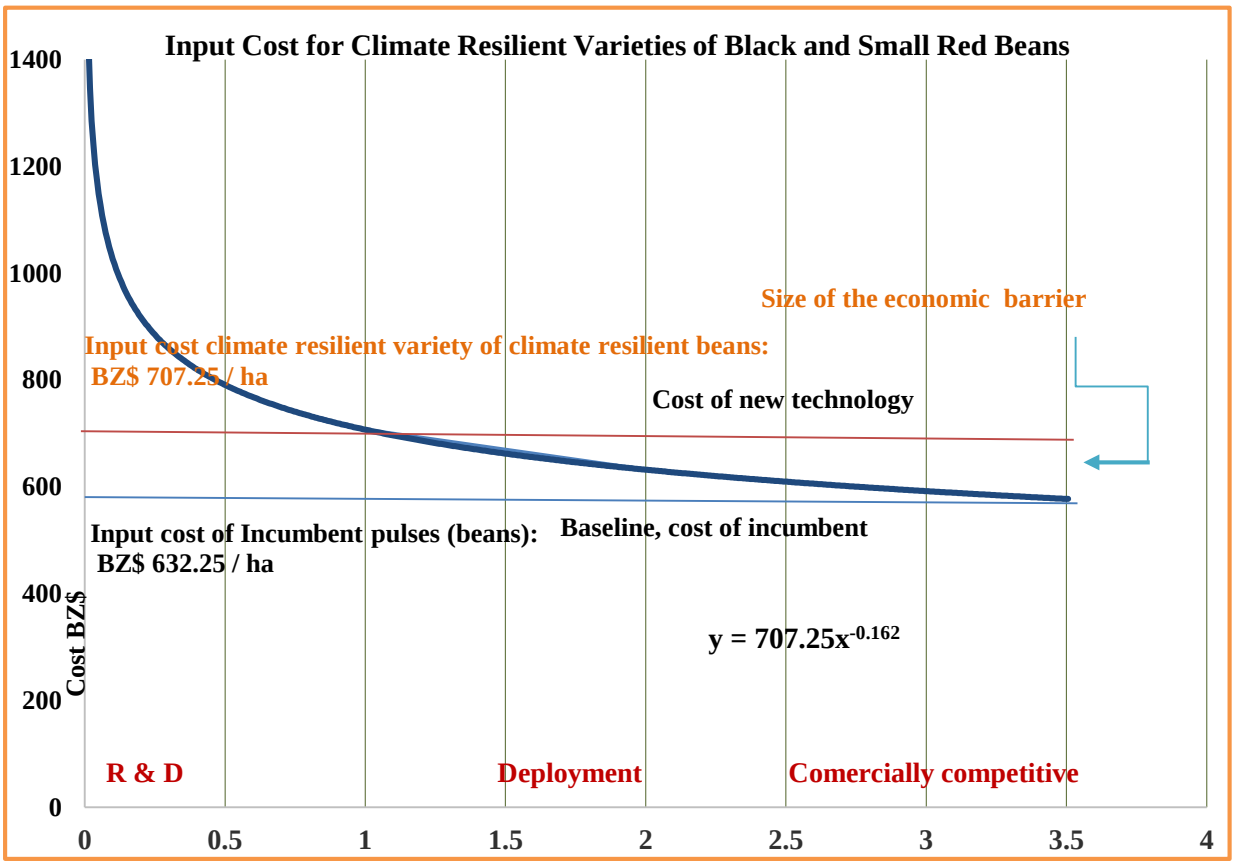


Figure 3: Size of economic barrier for new varieties of Black and Small Red beans
(After Nygaard and Hansen, 2015)

Cost Benefits analysis for cultivation of one and fifteen acres of the incumbent Grains

Table 11 is a summary of the Cost-Benefit analysis for cultivation of one and fifteen hectares of incumbent grain seed at the January, 2017 market price.

Cost of inputs included subsidized seeds at BZ$ 1.50 per pound. The production cost for the climate resilient seeds is assumed to be double the price per pound of the incumbent seed (Annex 1-B: Grain and Potato Production Statistics, 2010 – 1016), hence the cost for input will be higher (i.e. the cost barrier), but the benefits will be improved yields and better market prices, once the other facilities in the market chain are established and market conditions become favourable for small producers.

Table 11: Cost-Benefit Analysis for cultivation of one hectare of yellow corn and beans

Cost Benefit Analysis for One Hectare of Incumbent Variety of Yellow Corn				
		Wholesale		
Dry Weight Corn (14%)	**Av. Yield lbs/Ac**	**Price/lb**	**Total Sales**	**Remarks**
	2000.00	$ 1.50	$ 3,000.00	
Cost of production from planting to storage			$ 798.00	From CBA, Annex 1B
Net Profit			**$ 2,202.00**	
Cost of Producing 15 acres of corn	**Yield for 15 acres of Corn**	**Price/lb of corn seed**		**Projected Sales for 15 acres**
	30000	$ 1.50		$ 45,000.00
Cost of production for 15 acres @ BZ$ 798.00				$ 11,970.00
per acre				
Net Profit				**$ 33,030.00**
Cost Benefit Analysis Incumbent Varieties of Black and Small Red Beans				
	Av. Yield lbs/Ac	**Price/lb**	**Total**	**Remarks**
	1000	$1.50	$ 1,500.00	
Cost of production			$ 632.25	From CBA in Annex IB
Net Profit/acre			**$ 867.75**	
	Yield lbs for 15 acres of beans	**Price/lb**		**Project Sales for 15 acres**
	15000	$1.50		$ 22,500.00
	Cost per acre	Acres Planted		Total Cost of Production
Cost of Production/acre	$632.25	15		$ 9,483.75
Net Profit				13016.25

(Source: M. Truijillo, Agronomist, MOA, Jan. 2018)

Decomposition Critical Barriers

Figure 4 show the decomposition of key barriers limiting the transfer and diffusion of new technologies in the agriculture sector. The broad categories were: Economic and financial, market failures, and non-financial barriers. These were decomposed into: barriers identified within categories, elements and dimensions of barriers, as proposed by Nygaard and Hansen (2015). The decomposition of these barriers for the agriculture sector, in particular, helps stakeholders to understand their significance, and provide the baseline for identifying and implement appropriate measures to overcome or reduce the effects of the barriers.

For example: under 'capital cost', one element of this barrier identified by stakeholders was 'high interest rates'; another was 'high import duties on equipment'; and a third was 'high cost of specialized services and programmes'. The corresponding dimensions of these barrier elements under 'capital cost', include: 'interest rates per annum could be 15% or higher for certain processes in the market chain' (e.g. rentals or land taxes); 'high risks of default on loan (depending on assessment of NPV, IRR, and/or payback period, etc.), and 'high transaction cost for technology transfer/diffusion' (e.g. could be as high as US$ 2,500, depending on the size of the loan). Measures to address the latter can then be proposed and implemented to counter the economic barriers.

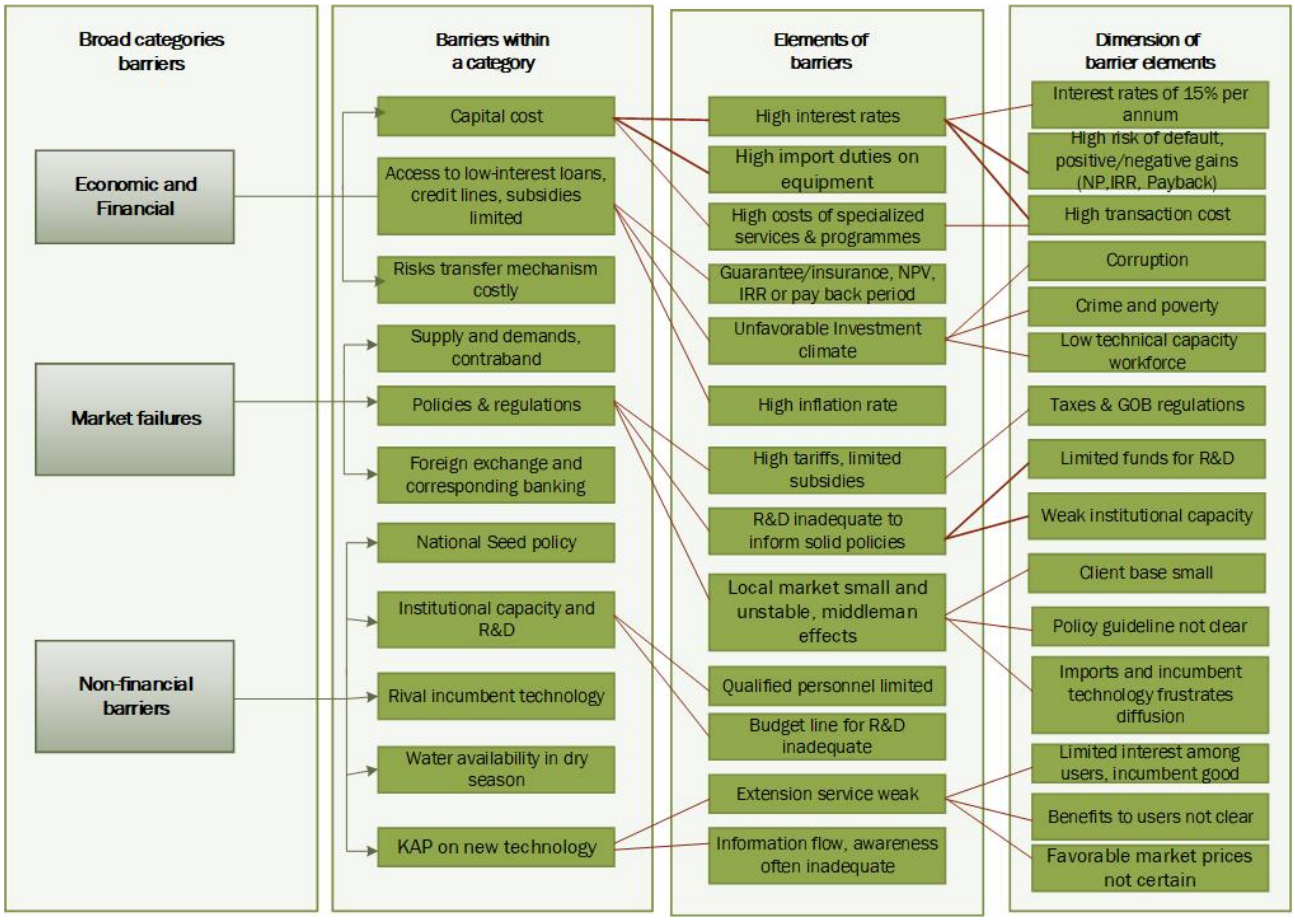


Figure 4: Decomposition of key barriers to the diffusion of technologies in Agriculture

In small economies of many developing countries, most of these 'critical, or non-starter' barriers are cross-cutting for most or all sectors vulnerable to the negative impacts of climate change. Actors sometimes operate in more than one sector or sub-sector, such as: Agriculture; Water Resource; the Coastal Zone and Marine Ecosystem; Aqua-culture; and Land Use, Land use Change and Agro-forestry. This is the case in the Greater Belize River watershed, that drains the central region of the country, and where rapid and poorly planned development is on the rise (e.g. the period 2012-2018), such as in agriculture and tourism, are occurring, and impacting the marine environment (Boles, E. in CZMAI, 2014). Hence, policies and regulations for sustainable use of resources and planned development, become barriers for technology transfer, when not implemented properly or stakeholders do not comply, or where policies/regulations become ineffective, or outdated, or do not exist.

2.2.3 Identified measures

Figure 5 is the Objective tree analysis of the focal problem identified earlier by the small group of stakeholders, centred on the objective: "Extensive use of climate resilient crops among small farmers". One option for a strategic pathway of measures and results to attain the said objective is contained in the green-shaded boxes in the diagram. This option for a solution of the problem and attainment of the objective is further developed in Table 12.

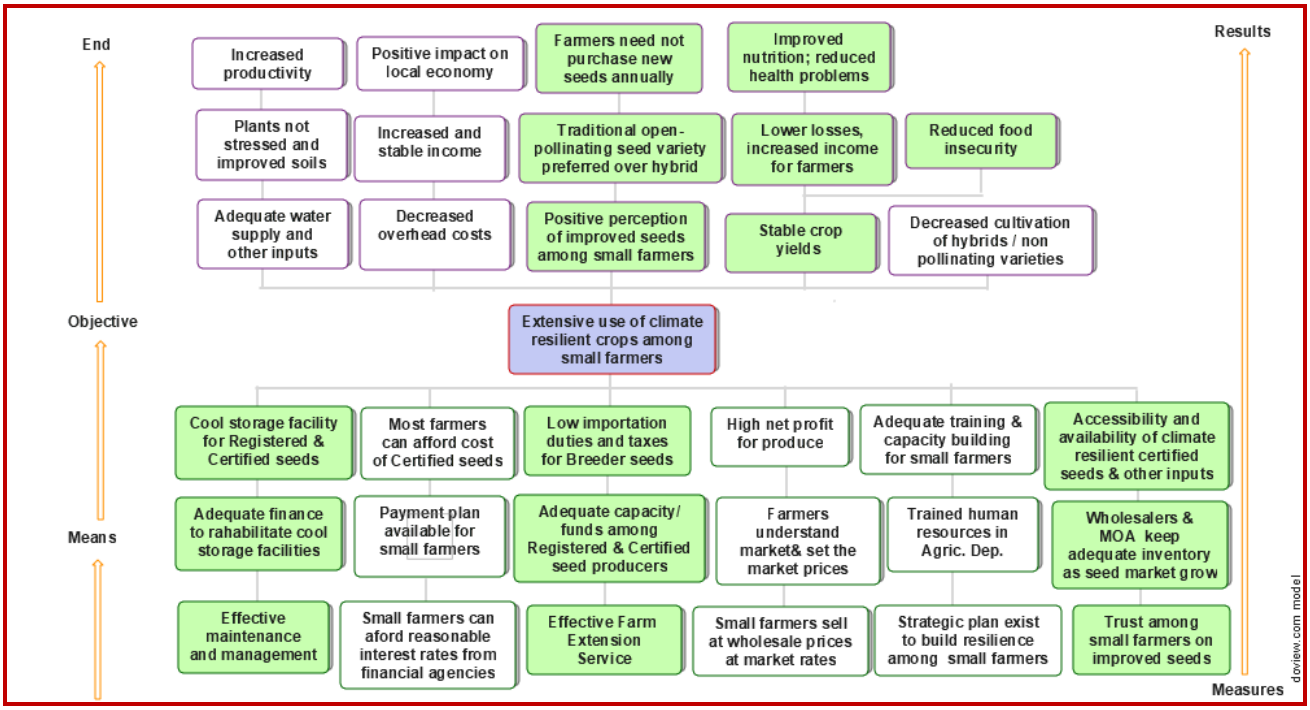


Figure 5: Objective tree for cultivation of climate resilient grains among small farm

Table 12: Proposed strategic pathway for objective – 'Extensive use of climate resilient crops/grains among small farmers'

Objective	Measures	Results	Timeframe & Actors
Extensive use of climate resilient crops/grains among small farmers	Crop Development Unit (MOA) and Farmers groups will ensure that climate resilient certified seeds & other inputs will be available, Finance for this measures will come from capital costs.	Positive perception of climate resilient, open-pollinated corn and beans varieties among farmers. Food insecurity reduced.	*Medium term. - MOA, specialized grain/crop seed importers
	Wholesalers & MOA will keep in cool	Stable/high crop yields and more income for	*Medium/long term. - Importers /

	storage, adequate inventory of certified seeds, as seed market grows.	small/medium-size farmers.	wholesalers. MOA grain prediction Unit
	MOA will implement and coordinate efficient & effective technology diffusion programme and Extension Service.	Traditional open-pollinated varieties preferred over hybrid. Technical capacity of farmers improved.	Medium/long term - MOA Extension Service, policymakers & administrators
	Through technology diffusion programme, MOA will build trust for technology among small and medium-scale farmers.	Farmers need not purchase seeds annually, some harvested grain seed used for planting.	Medium/long term - Extension service MOA
	Policy Unit and partners will advocate for lower import duties and taxes for Breeder seeds and equipment (e.g. for grain storage, spares/components, building material, and inputs).	Lower costs for 'certified' seeds; lower losses, higher yields; increased income for farmers.	Medium/long term - MOA and private sector stakeholders
	Training/capacity building and demonstrations for Registered and Certified seed-producers will be conducted and financed through capital costs.	Stimulate local economy.	Medium term - MOA CRDU, FCPU, CARDI, & others
	Procure and erect at least 2-cool storage facilities for registered and certified grain-seed storage, financed through capital costs.	Marketing of grains controlled. Farmers can sell when prices are good.	*Short/medium/long term. - MOA; private sector
	Establish effective maintenance and management programme for breeder grain seed production chain during early phase of project	Increased yields, jobs, food security and livelihood;	Medium/long term. - MOA & Certified seed producers including CARDI

	(MOA & Certified seed producers). This will be financed through operational costs.		
	High-level training and capacity building programme through MOA CRDU will be conducted for certified seed producers and small/medium-scale farmers	More progressive, business-oriented and environmentally-sensitive farming communities. Increased resiliency and climate smart agriculture.	Medium/long term. - MOA Extension Service, CARDI, Manufacturers
	Upgrade MOA commodity and production database, and market information which will be available to producers / policymakers, & others. Capital finance will cover this measure	-Farmers understand market, have some control of market prices, and have good returns on investments -Farmers reuse land, improve soil fertility and reduced impacts of extreme climate	Medium/long term. - MOA Policy Unit, Extension Service, Partners.
	Through other intervention MOA will step up 'added value' and marketing training to produce, thereby expanding commodity (grain production) and reduced imports.	-Stemmed foreign exchange loss & reduce food insecurity; -Stimulate local economy	Medium/long term. - MOA CRDU, FCPU, Partners

**Short term:* Within one year; *Medium term*: Within three to five years; Long term > five years

Using Cost-Benefit model results to assess measures on diffusion of improved Yellow Corn Seeds

Table 13 is a summary of the Cost-Benefit Analysis (CBA) model results to evaluate some recommended measures to facilitate the diffusion of climate change adaptation technologies in agriculture. The technologies include the procurement and production of climate resilient Yellow Corn seeds, production of Black and Small Red Beans seeds, and production of micro-propagated climate resilient Irish potato, certified seed-tubers.

Table 13: Cost-benefit results to assess measures for diffusion of climate resilient grains and Potato seed-tubers

Products	10-year Discount Rate	NPV	Benefits–increased Production (1000 tonnes)
Yellow Corn	10%	31.3	86.1
Black & Small Red Beans	10%	31.2	14.0
Climate Resilient Irish Potato seeds	10%	31.0	76.0

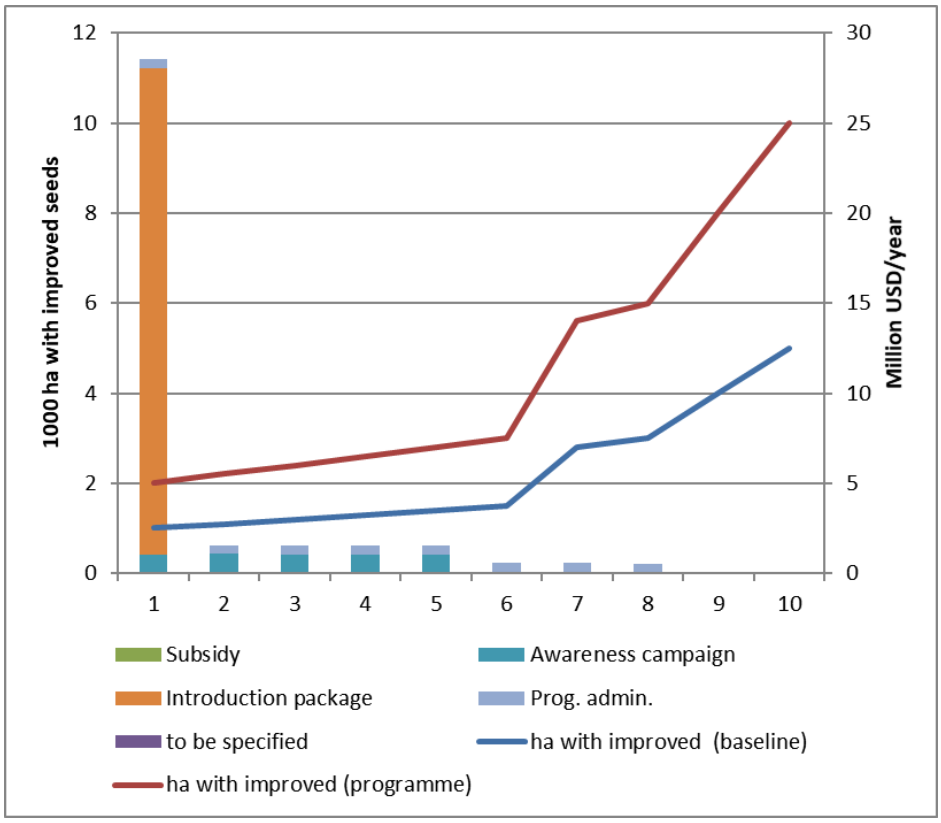
The measures considered in the CBA included: Subsidy on seeds per hectare, Introduction Package, Awareness Campaign, and Programme Administration. The model outputs are contained in Annex I-D. The results showed Net Present Value (NPV) increased gain on investment in a 10-year period, assuming 10 % discount rate, which could be lower during the period under consideration. The results show that the investments are viable. Table 14 and Figure 6 show the CBA model output results for various measures related to the production of Yellow Corn with baseline and programmed improved seed variety. As indicated above, similar results and plots are contained in Annex I-D for reference.

Table 14: Assessing sets of measures for improved corn seed production

Assessing sets of measures for improved maize seeds						INPUT CELLS IN YELLOW						
Assumptions	Increased yield		3.86	tonne/ha		Disc. rate		0.1				
Text	Unit	Total 10 years	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
Impact												
ha with improved (baseline)	1000	22.3	1	1.1	1.2	1.3	1.4	1.5	2.8	3	4	5
ha with improved (programme)	1000	44.6	2	2.2	2.4	2.6	2.8	3	5.6	6	8	10
Effect (ha with improved seeds)	1000	22.3	1	1.1	1.2	1.3	1.4	1.5	2.8	3	4	5
Programme costs		NPV										
Subsidty on seeds per ha	USD		30	30	25	20	20	20	10	5	0	0
Subsidy on seeds	M USD	0.3	0.06	0.066	0.06	0.052	0.056	0.06	0.056	0.03	0	0
Introduction package	M USD	24.5	27	0	0	0	0	0	0	0	0	0
Awareness campaign	M USD	3.8	1	1	1	1	1	0	0	0	0	0
to be specified												
Program administration	M USD	2.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0
Total programme cost (NPV)	M USD	31.3	28.56	1.566	1.56	1.552	1.556	0.56	0.556	0.53	0	0
Benefits	1000											
Increased production	tonnes	86.1	3.86	4.246	4.632	5.018	5.404	5.79	10.808	11.58	15.44	19.3
Cost vs. benefits												
Programme costs/tonne of extra yield		363.7	USD/tonne maize		Market price for maize					110	USD/tonne	

(After Nygaard and Hansen, 2015)

Figure 6: CBA model results plots for measures related to Yellow Corn seed production



(After Nygaard and Hansen, 2015)

Table 15 is a summary of critical and significant barriers and related measures for the diffusion of climate resilient varieties of grain seeds for: Economic and financial category of barriers; Market conditions; Legal and regulatory framework; Network Structures; and Others. The summary also highlights if the measures/interventions are Legal or Other, and if probable funding sources can be procured in-country or from external sources.

Table 15: Summary of market and non-market barriers and corresponding measures for improved varieties of grain seeds

Categories	Identified Barriers	Measures to overcome barriers	Intervention		Funding Sources	
			Legal	Other	National	External
Economic and financial	− High initial investment − Limited subsidies for technology components − High cost of installation	−Expand and secure access to finance (Grants, low interest loans, project funds) −Lobby for reduced import Tax on equipment and seeds −Provide technology companies & suppliers with concession to service specific areas or groups of	√	√	√ √	√ √

		clients at reduced service costs (e.g. Public-private partnership)				
	− Gaps in technology value chain	− Set up local assembling industry (small industry, job creation initiative etc.)		√	√	
Market conditions	− Local hardware stores often low in stocks of spares & components	− Improve access to products and services. Grow the market for new technology		√	√	√
	− Unstable, monopoly, special interest groups	− Implement policies & regulations for favourable market climate to help level playing field	√		√	
	− Inadequate policy and regulatory framework	− Improve policy and enabling environment (e.g. seed policy, market liberalisation, protectionism, monopoly of incumbent technology)	√		√	
Legal and regulatory	− No office of testing and certification	− Establish regulatory agency for standards, testing and certification (for equipment, seeds, etc.)	√		√	√
	− Import of cheaper, inferior-quality equipment/products	− Strengthen regulatory framework (e.g. implementation & penalty)	√		√	
	− Networking among professionals and agencies weak and ineffective	− Enhance networking for certified seed production/ improved drip irrigation / potato cultivation chain actors.		√	√	√
Network structures		− Strengthen research, development and demonstration of new technology				
	− Farmers cooperatives generally work in insolation (crop specific)	− Strengthen Cooperative Department and form an association of farmer's cooperatives	√		√	
	− Limited farmer to farmer visits	− Increase local and regional farmer's networking		√	√	√
Others	− Limited awareness and knowledge of	− Establish management programme and		√		√

	new technology	education/awareness campaign among key stakeholders for new technology		
	−Low technical capacity	− Establish effective and on-going training component in technology diffusion programme	√	√
	−Farming communities and farmers suspicious and afraid of change	− Through technology diffusion programme address social, cultural and behavioural issues; improve KAP* among users of new technologies	√	√

(* KAP: Knowledge, Attitude and Perception)

2.2.3.1 Economic and financial measures

Economic and financial measures for the transfer of climate resilient, open-pollinated varieties of corn and beans 'certified' seeds as noted by stakeholders during deliberation of barriers and related measures are summarised in Table 15 above and include:

- Expand access to finance.
- Lobby for reduced import duties/tax on equipment and seeds.
- Provide technology companies & suppliers with concession to service specific areas or groups of clients at reduced service costs (Public-private partnership).
- Technology transfer programmed should consider capacity development in "value added' for producers and beneficiaries, and market evaluation, iderntifying market opportunities and niche markets.

Box 2 is an overview of specific measures or actions related to the economic measures outlined above that can be considered by partner in the technology transfer and diffusion. The key actors enabling these measures/actions include: The Fruit Tree and Crop Development Unit in the Ministry of Agriculture, CARDI, BAHA, Grain Seed Production Cooperatives, and farmers willing to participate.

Box 2: Specific actions related to the economic measures for the transfer and diffusion of climate resilient grain seed production and dissemination

- Procurement of capital funds to purchase at least two, well-equipped cool storage facilities running on RE energy with diesel generator backup or grid connection.
- Request from GOB/Farmers cooperatives an adequate recurrent budget for maintenance and operation initially.
- Develop an effective Business Plan to market locally produced 'certified' grain seeds for local and regional markets.
- Facilitate low-interest loans for farmers for grain production from DFC, the National Bank, Credit Unions, and other local /regional, financial institutions.
- Conduct a feasibility study for establishing a "Multi-peril Crop Insurance" programme to cover the widest range of risks that impacts farmers, including grain-producers.
- Develop a marketing programme for promulgating 'value added' for local produce, grain production, etc.
- Establish a revolving fund/subsidy for Research and Development to be instituted among key crop research agencies such as MOA's Crop Research & Development Unit, Fruit-trees and Crop Development Unit, CARDI, the University of Belize, the Mennonite Community, Seed Production Cooperatives, and others. Initial 'seed money' will be procured through a grant or soft loan of US$ 40,000.00 from local or international donor agencies.

2.2.3.2 Non-financial measures

Non-financial measures for the transfer of climate resilient, open-pollinated varieties of corn and beans 'certified' seeds as discussed and prioritized by stakeholders during deliberation of barriers and related measures are also summarised in Table 15 above and include:

- GOB through Ministry of Trade and Industry, MOA, other strategic line ministries and partners will enhance the legal and economic framework to continue to grow the market for high-demand agriculture produce and new technologies.
- Where necessary, GOB through MOA and Partners will conduct policy & regulation reviews for favourable market environment (e.g. seed policy, market liberalisation, protectionism, monopoly of incumbent technology, water resource management, risk management, etc.), and Strenghten regulatory framework (e.g. implementation & penalty).
- GOB through MOA and the Bureau of Standards will procure necessary resources and human capacity to establish a regulatory agency for standards, testing and certification (equipment, seeds, etc.)
- Capital cost for intervention will cover programme to strengthen research, development and demonstration of new technology through the CRDU (Agriculture Innovation Centre).

- Through capital cost of the proposed intervention, MOA will establish management programme and education/awareness campaign among key stakeholders for facilitating diffusion of improved technology.
- MOA will address social, cultural and behavioural issues; improve KAP among stakeholders through technology diffusion programme.

Similar *cross-cutting* measures are applicable for other technologies in the Agriculture and Water Sectors.

Box 3 is an overview of specific measures or actions related to non-financial measures outlined above that can be considered by partner in the technology transfer and diffusion.

Box 3: Specific actions related to non-financial measures for the transfer and diffusion of climate resilient grain seed production and dissemination

- Farmers must be encouraged to return to open-pollinated varieties of grains, instead of the continued use of expensive, hybrid varieties that have some good traits, but are not sustainable and ecologically friendly. The justification is that even though hybrids are generally high yielding, the inputs can be high, and they are not environmentally friendly and climate resilient.
- Extension Service will train farmers in their own language, about the ecological and financial benefits of Climate Smart Agriculture. (A current intervention being implemented for the Agriculture Sector by the MOA/World Bank/Partners).
- Build trust among small farmers on the far-reaching benefits of climate resilient varieties of corn and bean seeds.
- Upgrade and expand agricultural R&D. Limited capacity, lack of opportunities and an adequate budget-line stifles R&D in the Agriculture Sector in Belize.
- Strengthen partnership among crop research agencies and promulgate farmer-to-farmer exchange programme for related technologies such as improved drip irrigation systems, micro-propagation of potato seed tubers and potato cultivation, and improving designs of crop cover structures for pest control and optimizing yields.

2.3 Barrier analysis and possible enabling measures for improved drip irrigation / fertigation systems

The Agriculture Research and Development Unit (Research, Development and Innovation Centre) 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 CRDU provides services and training to farmers in drip and sprinkler irrigation systems and cover structure installation. The

proposed, improved drip irrigation/fertigation systems for cultivation under crop covered structures and small open field plots, will integrate water harvesting and fertigation technology. One major constraints with crop covered structure technology in Belize is the elevated temperatures that develop in these greenhouses during long, hot, sunny days in tropical climate, which limits the number of working hours inside the cover Structures (Oscar Salazar, CRDU Central Farm, personal comm. June 2017).

The justifications cited for expanded use of irrigation technology, such as improved drip irrigation is: water use efficiency, reduction of climate footprint, and addressing 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 (GOB/FAO, 2011; GOB/FAO, 2015); and is a recommended climate change adaptation technology to reduce stress on water resources, soil and forest resources. Some limiting factors include: initial cost per unit for drip/sprinkler irrigation systems; water availability and reliability during the dry season; maintenance costs; availability of spares; energy source for water pumps; import duties on spares; limited; technical capacity of farmers; and inability of most small famers to finance the capital cost for procurement and installation of an improved, drip irrigation/fertigation system.

Farmers, manufacturers of irrigation equipment, importers and retailers of irrigation systems, and policymakers should understand the conditions under which a specific technology, such as drip irrigation, is desirable and likely to be adopted, as well as externalities that may affect its diffusion. Understanding the adoption patterns of improved drip irrigation technology is critical for the formulation of water, energy, and land management policies (Shrestha and Gopalakrishhnm, 1993). Additionally, it is not sufficient to know whether drip irrigation is likely to be adopted in a particular field; but equally important is the ability to determine to what extent the technology will be effectively utilized, pending on other factors, such as availability of spares, operational costs, reliable market(s) for produce, ability to pay back, risk transfer mechanisms, sufficient water for irrigation, needs of other water users, among other factors.

2.3.1 General description of improved drip irrigation/fertigation systems

The proposed improved irrigation technology intervention is intended to support the work of the MOA's 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 proposed for training and demonstration, will target small farmer's groups/cooperatives engaged in vegetable and horticulture cultivation under cover structure, which is practiced by farmers in all six districts. Six improved drip irrigation/water harvesting & fertigation systems are being considered for

this adaptation technology transfer; and shall be 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 14 is a summary of applied irrigation as per agriculture productive system in Belize (Chung, 2011 in GOB/CDB/FAO, 2015). Except for wetland (flood) irrigated rice and drip irrigated banana, the percent of total cultivated area with applied irrigation is small for most other crops.

Table 16: 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).

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. Corn and grain legumes or pulses (beans), and tubers (such as Irish Potato and Sweet Potato) cultivation is mostly rainfed.

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's 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/FAO/CDB. 2015). Note that the "Target" and the degree of the intervention, that is: "Too Ambitious" or "Conservative" is summarized in Table 7 above.

Box 4 is a summary of the proceedings from a Climate Change and Agriculture Forum held in February, 2016, where partners in the Agriculture Sector deliberated on the impacts of climate change on agricultural operations and production. A series of adaptation measures or actions were recommended for increasing frequency of excessive rainfall and floods, droughts, and climate variability/seasonal changes in rainfall pattern, and temperature increase.

Some of the measures/actions proposed for droughts, climate variability and temperature increase relevant to technology transfer in the Agriculture Sector included: drip irrigation; increased use of renewable energy; selection of heat-tolerant crops, pasture varieties and livestock breeds, with emphasis on indigenous genetic diversity; and heat-alleviating

infrastructure or appropriately ventilated housing designs for poultry, pigs, sheep and goats, and crop cover structures.

Box 4: Climate change impacts on Agriculture: Summary of proceedings from the February, 2016 Forum

Climate Change Impact on Agriculture

Published on May 10, 2016 in Issue 32 by D. Feucht, ***Belize Ag Report***

Adaptation measures to climate change and variability were the focus of a forum in February, 2016 when the stakeholders of the agriculture sector and livestock producers met with representatives of the Ministry of Agriculture, Forest, Fisheries, the Environment and Sustainable Development (MAFFESD); Inter-American Institute for Cooperation on Agriculture (IICA); and National Climate Change Office (NCCO).

The measures recommended included:

For excessive rainfall and flooding	For recurrent droughts	For climate variability and temperature increase
- Drainage infrastructure, systems and mechanisms	- Irrigation, including drip irrigation	- Seasonal production
- Well-designed and drained road infrastructure	- Use of renewable energy sources	- Timely, specific, and localized weather forecasts
- Available rainfall forecasts	- Watershed management	- Selection of heat-tolerant crops, pasture varieties and livestock breeds with emphasis on indigenous genetic diversity
- Relocation of animals and annual crops	-Water harvesting and storage	- Irrigation to alleviate heat stress on plants
- Risk reduction measures & risk transfer mechanism for farmers	- Promote climate-resilient pasture management	-Agro-Silvo-pastoral systems
		- Heat alleviating infrastructure or appropriately ventilated housing designs for poultry, pigs, sheep and goats, and crop cover structures.

2.3.2 Identification of barriers for improved drip irrigation/fertigation systems

The Sector-base Technology Working Group (STWG) met on several occasions to review and evaluate the main barriers for the smooth transfer and diffusion of improved drip irrigation/fertigation technology. The list of barriers presented and analysed in random order included:

- Lack of technical capacity among small farmers and a majority of medium-scale farmers.
- Limited availability of favourable market for producers, especially for small farmers.
- Lack of insurance or crop risk transfer mechanism for losses arising from climate extremes (flood, droughts and fires), praedial larceny, vandalism, etc.
- Non-reliability of water for irrigation during dry season*.
- Energy to run water pump to get water into the irrigation system. (Most localities will require some sort of solar power or other form of Renewable Energy, or a small capacity diesel generator e.g. 4 Hp).
- Extension Service limited in Personnel/Farmer ratio, and human technical capacity.
- Difficulty exist in organizing, attracting and training farmers.
- High initial cost of establishing an improved irrigation system.
- Low stocks and elevated cost of spares.
- Import duties and taxes for components of irrigation systems, fertigation and water harvesting are relatively high. The costs are passed down to clients.
- Limited subsidies and incentives.
- Access to low-interest finance and reasonable payment plans for small farmers not always available.
- Frustrating land tenure issues.
- A large proportion of younger folks not interested in agriculture.
- Constraints on drip irrigation market due to economies of scale.
- Costs of fuel and lubricants rising.
- Transportation costs also rising.

* Water sources: Surface water catchments, rivers and streams, rainwater catchment, ponds, reservoirs, elevated tanks or springs/other ground water sources.

Selection and decomposition of critical barriers for diffusion of improved drip irrigation

The short-list of barriers and the decomposition of "killer" or non-starters are summarised in Table 17. The decomposition of killer barriers is based on the more detailed decomposition of such agriculture technology diffusion barriers presented in Figure 4 above.

Table 17: Criteria and Importance of Barriers for improved drip irrigation and fertigation

No.	Barriers	Criteria and Importance of Barriers for improved drip irrigation					
	Economic & Financial	**1. Critical (killer, non-starter)**	**2. Crucial**	**3. Important**	**4. Less important**	**5. Insignificant (easy starter)**	**Rank**
1	- High Initial costs for irrigation systems & setup	x					1

2	- Credits and limited low-interest financing, and unfavourable payment plans		x				1
3	- High import taxes and limited subsidies		x				2
4	- Unfavourable market status at harvest discourage farmers to invest	x					3
5	- Elevated financial risks due to crop failure		x				2
6	- Lack of risks transfer mechanism			x			3
7	- Foreign exchange and corresponding banking issues				x		4
	Non-financial						
7	- Frustrating land tenure issues			x			3
8	- Limited use of drip irrigation byfarmers	x					1
9	- Limited subsidies and incentives		x				2
10	- Constraints on drip irrigation market due to local economies-of-scale.		x				2
11	- Extension Service limited in technical capacity		x				2
12	- Limited technical capacity among small farmers			x			3
13	- Rising fuel costs		x				2
14	- Rising costs of transportation			x			3

Table 18 is a summary of the ‘Critical’ (killer or non-starter) and ‘Crucial’ barriers by category, as selected with a Likert scale, with 1 scored as ‘Critical’ and 5 ‘Insignificant’ (easy starter).

Table 18: Selected list of key barriers to the diffusion of improved drip irrigation

Category of Barriers	1. Critical (killer, non-starter)	2. Crucial	Elements of killer or non-starters	Dimension of barrier elements
Economic & Financial	- High Initial costs for irrigation systems	- Credits and limited low-interest financing facilities not too attractive for small farmers - High import taxes and limited subsidies for irrigation components/spares - Elevated financial risks due to crop failure - Rising fuel prices	- High interest rates - High import duties of components - Elevated cost of specialized services -	- 12 – 15 % on certain components - Service cost could be as high as 15 % of capital cost - Interest rates could be 6 to 12 % per annum
Market failures	- Unfavourable market status at harvest discourage farmers to invest	- Constraints on drip irrigation market due to local economies of scale.	- Unstable markets - Incumbent and monopoly have greater slice of market - Supply greater than demands	- Market policy and strategy not clear ad focus - Middleman strongly influence prices, returns for producers often not equitable - Imports, contraband and monopoly skew market against local producers
Non-financial	- Limited use of drip irrigation by farmers	- Limited subsidies and incentives - Extension Service limited in technical capacity - Imported equipment not of the best quality	- Limited knowledge and technical capacity among farmers - Cannot afford installation cost - Bad experience with mal-functioning system	- Farmer's income not sufficient and stable to make investment - Training selective and does not reach most farmers - Inadequate design and poor material

Figure 7 is a problem tree analysis for the limited use of improved drip/fertigation systems among small and medium-scale farmers in Belize. The main or focal problem is the limited use or non-use of drip irrigation and fertigation cultivation systems by small and medium size farmers. The over-arching "cause" is the *Limited knowledge and technical skills of drip irrigation/fertigation among small famers*. This stems from *Limited training for small farmers* and generally *Limited personnel and inadequate, specialized capacity in the farm extension services*. The analysis also outlines other related 'causes' as can be observed in the problem tree.

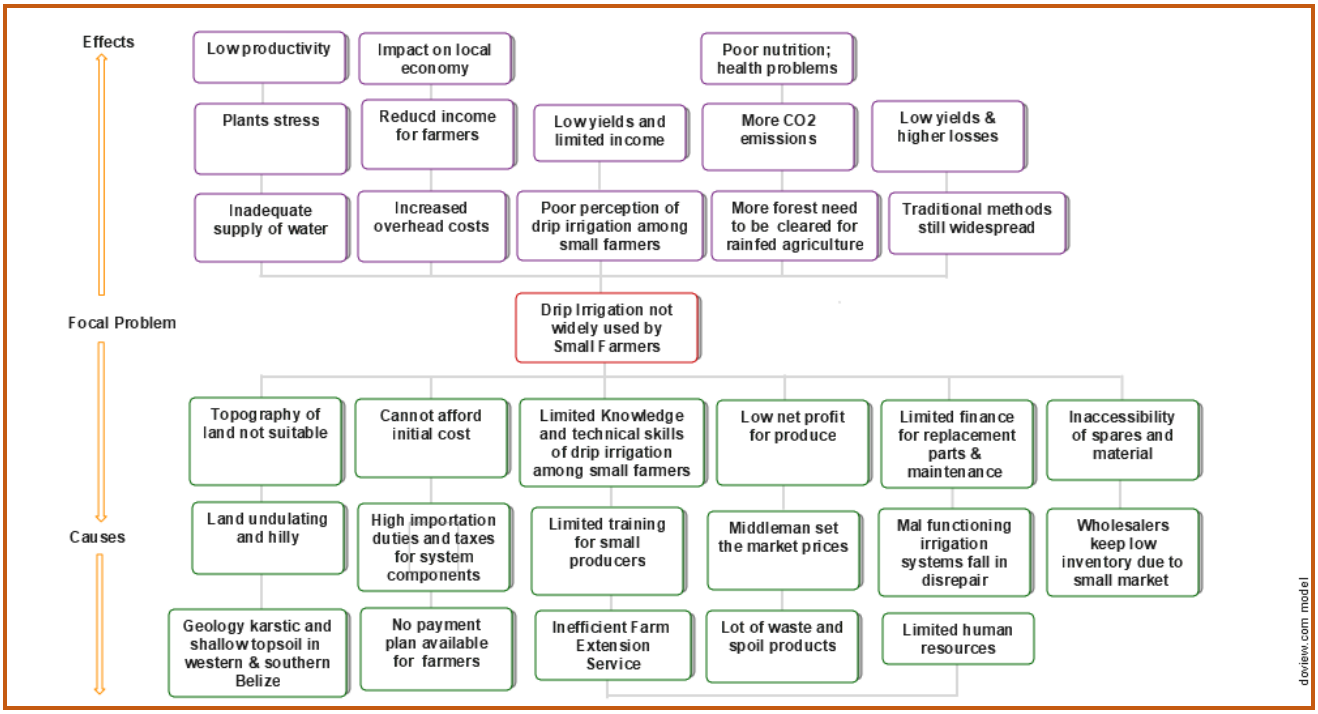


Figure 7: Problem tree for "not-widely use of drip irrigation/fertigation among small farmers."

The main, corresponding 'effects' threads through *Poor perception of drip irrigation / fertigation among small farmers; lower yields and limited income for individual farmers and communities; more forest needed to be cleared for rain-dependent agriculture;* and *more CO_2 emissions, lower yields/higher losses due to pest/diseases/extreme weather;* and *lower productivity; poor nutrition and increased health problems* in farming/rural communities. Low productivity translates to lower income, reduced stimulation of the local economy and poorer farmers.

2.3.2.1 Economic and financial barriers

Summary for Economic Evaluation of proposed drip irrigation systems

Market Mapping

A simplified market mapping (adapted from Nygaard and Hansen, 2015) for the transfer and diffusion of improved drip irrigation and fertigation systems is presented in Annex II E2.

Summary, barriers and gaps:

Reference the market mapping schematic for improved drip irrigation in Annex II.

i. *Exporters/manufacturers of drip irrigation system & components/spares:* Procured from foreign manufacturers/outlets etc. by local importers & retailers of agro-technology equipment. Funds for procurement of irrigation equipment and components from importers/retailers will come from capital costs. Farmers may purchase from importers/retailers, or if they preferred, directly from the manufacturer/franchise.

ii. *Import duties/taxes and subsidies:* Taxes may apply, but subsidies may be granted to importers which can be passed down to the farmers and institutions at the other end of the market chain.

iii. *Importers and Retailers:* Equipment and spares for irrigation, fertigation, cover structures, nurseries, harvesting, cool storage facilities, solar-powered water pumps, and water tanks shall be imported from manufacturers or their outlets, and stocks will be made available for retailers and clients. Import taxes are mostly zero rated for irrigation and solar PV systems, but taxes may apply for certain components such as inverters, batteries, pvc pipes/fittings, and material to manufacture water tanks, etc.

iv. *Input and Service Providers:* Inputs for crop protection, fertilizers, etc., and Service Providers for RE system installation (i.e. Solar PV, dryers, and cold storage facilities for grains) are available. The Research and Development Unit provides service and training for installing drip irrigation systems. Technology information and demonstration are made available to famers, but there is more to be done for expanded dissemination of relevant information and training of new technologies. Also, information and training in market principles and basic economics is limited, as is the need to utilize social media as a form for networking among producers, service providers/assemblers and importers. Another limitation or barrier is the limited level of education of many small and medium-scale farmers. Language barriers also exist in some instances.

v. *Enabling Business Environment:* MOA and partners (CARDI, BELTRAIDE, IICA, DFC Agro-businesses, and others) are available to provide guidance and advise to farmers on issues related to affordable loans, other financing opportunities, market fluctuations and opportunities, and policy changes. The gap here seems to be limited networking among main actors. The leadership role here is the MOA, whose Extension Service and Policy Unit are closest to farmer's interests. The Extension Service plays a crucial role and must be empowered (through training, increased capacity and public relations guidance) to continue the good work of improving production and climate smart agriculture among the small and medium scale farmers. On their own, most small famers, and to a lesser extent, medium-scale farmers, do not have the capital to invest on a medium-size (5 – 10 acres)

irrigation system. Large farmers impact the environment to a greater extent, A gap exist here that requires the joint cooperation of key actors in the Sector to address with sustainable development programmes and outreach.

vi. Policies and medium-term strategies must be updated and adopted to respond to the advances in technologies and changing market conditions, that if properly managed and use, can significantly improve yields of high quality, competitive products, with minimal impacts on the environment.

vii. Training at specific links of the drip irrigation market change (e.g. Service Providers, MOA CRDU, Extension Service and at the Farm level) is paramount for successful operation. Farmer's outreach programme and MOA's Public Relations activities have room for improvement and expansion. Funds for capacity building and networking should be allocated from the operational budget.

viii. Another gap identified is an Agriculture Testing/Certification Centre that can certify the quality of equipment, spares, inputs, seeds etc. The status of testing or certification is mainly for Phyto-sanitary, biosafety and risk analysis for import/export of organisms/products through BAHA, while the Pesticides Control Board is responsible for the safe use and control of pesticides.

ix. The economic and technical capacity of many small farmers to procure and operate an improved drip/fertigation irrigation system is generally limited. Medium-scale farmers would be the favoured target group in the market chain for this technology diffusion (L. Gladden, Chief, NCO, personal comm. Mar. 2018).

x. The Policy and Strategy for drainage and irrigation should be reviewed and implemented. The issue of integrated water resource management and irrigation becomes crucial, as the stress on this vital resource increases as a result of anthropogenic impacts in the watersheds, coupled with the increasing negative impacts of climate change on the rainfall regime. Spearheading this initiative should be the Water Management and Climate Change Unit of the Ministry of Agriculture.

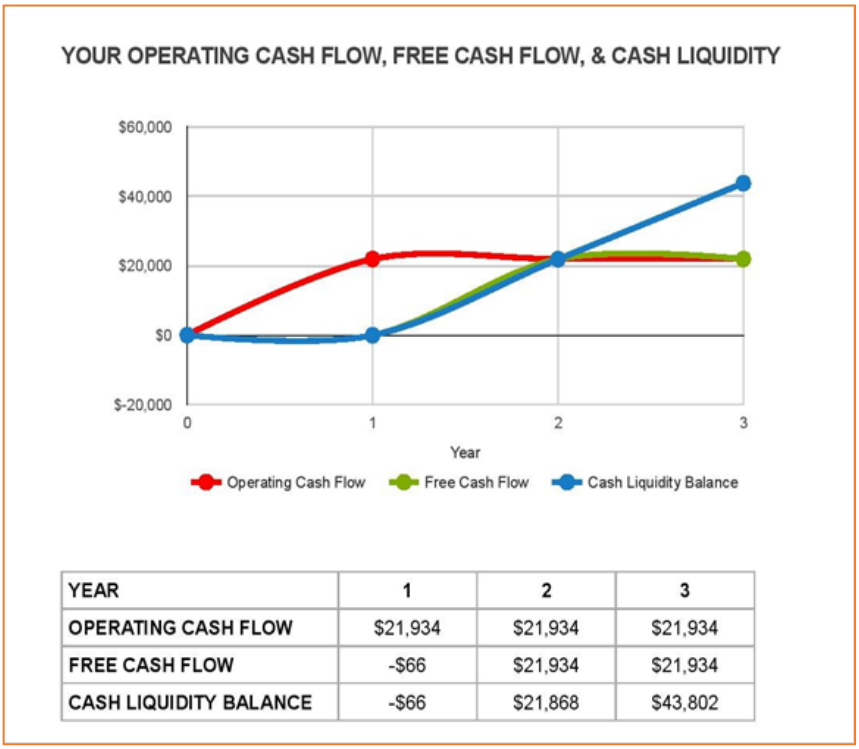
Economic evaluation

a) Drip Irrigation Systems
   Technology Application: *Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement for five farmers groups plus a training centre at Central Farm*

Table 19 and Figure 8 show a simplified investment cost estimate and the cash flow analysis for the proposed six improved, drip irrigation systems with fertigation. Feasibility of implementation of the proposed improved irrigation technology intervention was calculated on the basis of tomato cultivation.

Table 19: Investment cost for six only improved drip irrigation systems

Capital Investment Cost	1) 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** 2) Six pumps @ US $1,200.00 (3,000.00 solar) **Cost** **US$ 7,200.00 (18,000.00)** 3) Six wells @ US $7,000.00 **Cost** **US$ 42,000.00** 4) Six 2,000 gallons Water Tanks @ US$ 800.00 each **Cost** **US$ 4,800.00** 5) Training extension personnel and four farmers groups @ US$ 5,000.00 **Cost** **US$ 20,000.00** **Total Cost** **US$ 116,000.00 (126,800)**
Operating Cost	Spares and maintenance per year US$ 15,000.00 **Total Cost** **US$ 45,000.00**



YEAR	1	2	3
OPERATING CASH FLOW	$21,934	$21,934	$21,934
FREE CASH FLOW	-$66	$21,934	$21,934
CASH LIQUIDITY BALANCE	-$66	$21,868	$43,802

NPV: 213,300.00 US$.
IRR: 200.4%

(Source: Tobias, 2017)

Figure 8: Operating cash flow for proposed Drip Irrigation system

Implementation of an improved irrigation system is economically feasible as it increases the yields by approximately 40 percent. The commonly used water pumps fuelled with gasoline or diesel shall be exchanged with solar water pumps. The estimate is for six solar pumps for 6 units of 1 acre each.

Preliminary economic evaluation for the other prioritized technologies for the Agriculture sector are presented in Annex II of this Report.

The non-starter and crucial economic barriers prioritized during the stakeholder discussions were:

- Elevated initial cost to small farmers who would like to improve and expand their personal drip irrigation systems.
- Cost per unit of Drip/Sprinkler irrigation systems remains high.
- Cost of 'inputs' continue to rise. Middleman makes the profits, some small farmers barely break even, especially in the adverse economic climate.
- Credit and low-interest financing facilities not too attractive for small farmers.
- Maintenance cost could be beyond the means of many small operators.
- High import taxes and limited subsidies on spares and irrigation systems, including Solar PV components. (Not zero rated for importers).
- Elevated financial risks due to crop failure and other unforeseen events are high, in the absence of an establish and affordable insurance or risks transfer scheme. For example, an affordable portfolio for a 'multi-peril' crop insurance programme to cover the widest range of risks that could impact farmers and producers.

2.3.2.2 Non-financial barriers

Some key, non-financial barriers identified by stakeholders limiting increased used of improved drip irrigation and fertigation systems among farmers are:

- Farmers are still sceptical of their ability and resources to keep irrigation system functioning.
- Some farmers complain about the lack of effective support from local extension services.
- Farmers complain about 'too much politics' when dealing with Government Ministries.
- Extreme climatic events like floods and drought impacts becoming more frequent.
- General lack of knowledge on issues related to global warming, climate change and land degradation.
- Imported equipment not of the best quality.
- Unfavourable market status at harvest discourage farmers to invest.
- Constraints on drip irrigation market due to local economies-of-scale.

- Limited use of drip irrigation by farmers, particularly small-scale farmers.
- Technical capacity of Extension Service needs to be strengthened
- Land tenure issues.
- Rising fuel costs for operations and transportation cuts across all productive sectors and increases the unit cost of production.

2.3.3 Identified measures

Key measures or actions to address the main problem and related causes and effects highlighted in the 'Problem Tree' analysis earlier, are highlighted in the 'Solution or Objective Tree' depicted in Figure 9 below.

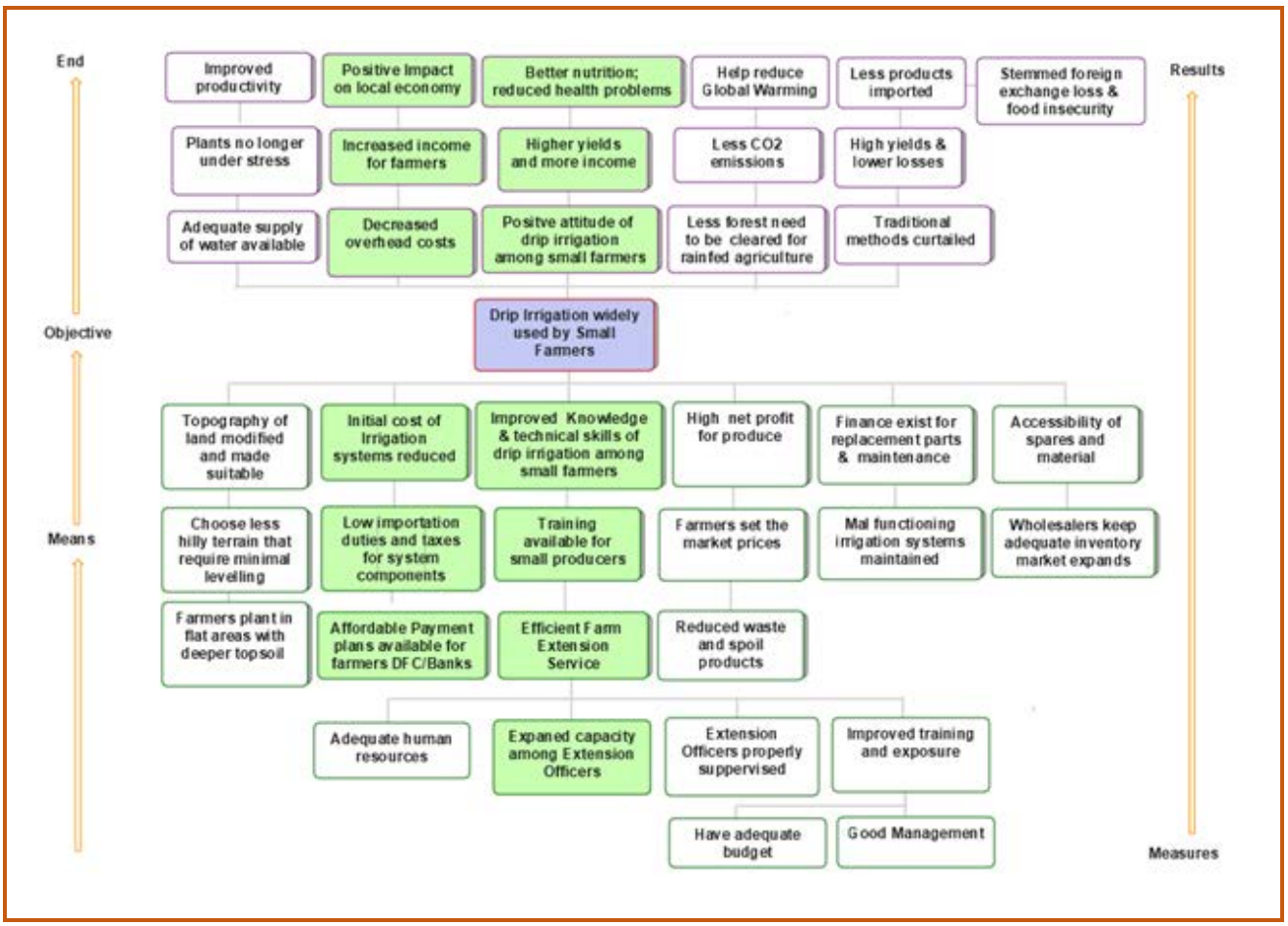


Figure 9: Objective tree for improved drip irrigation/fertigation use among small farmers

The measures, if implemented in a timely and cost-effective manner, should help realized the general objective: "Drip irrigation is widely used by small farmers".

The green, shaded boxes tracks one of several strategic pathways for solving the main problem '*Drip irrigation/fertigation not widely used by small farmers'*. This strategic pathway is further visualized in Table 20 below.

Table 20: Proposed strategic pathway for objective: 'Drip Irrigation widely used by small farmers'

Objective	Measures	Results	Timeframe
Drip irrigation widely used by small farmers	Enhance the knowledge & technical skills of small and medium-scale farmers in drip irrigation & fertigation technology, through improved and timely training and demonstration programme.	- Positive attitude of drip irrigation among small farmers. - Increased sales and use of irrigation technology - Increased yields and income - Improved livelihood and food security status	Short to medium term. Main actors: MOA CRDU, CARDI, Extension Service, etc. Funding from capital cost.
		- Higher yields and more income	Short to medium term
	Conduct programme of specialized training and demonstrations to increase efficiency of Farm Extension Service personnel. Training shall be made available at the local level and regional institutions.	- Efficient operation of irrigation systems - Increased production & yields - Improved market opportunities and business environment	Medium term. Main actors: CRDU and experts in drip irrigation/fertigation technology and agronomy. Funding from capital and operational costs
		- Increased technical skills among farmers - Professional service to producers and farmers	Medium term
	Increased lobby, where necessary, for lower importation duties, taxes, subsidies for system components. Promote public awareness and education on technology and related matters with programme on the benefits of drip irrigation, fertigation, water & soil management, water harvesting, among farming communities and other stakeholders	- Initial cost of Irrigation systems & operations reduced -Increased income for farmers which help stimulate local economy. - Subsidies passed on to small and medium-size producers	Short to medium term. Main actors: policymakers in MOA, NGOs, Farming Cooperatives, other partners in agriculture.
		- Availability of spares countrywide at reasonable cost for farmers & others - KAP of irrigation and climate smart	Medium to long term. Main actors: MOA CRDU, Extension Service, Donor agency (FAO, others). Funding

		agriculture increased among farmers -Reduced M&O costs - Less systems in disrepair - Positive Impact on local economy	likely from capital costs
	Identify and secure affordable loans and payment plans for farmers through DFC/National Bank, other Banks, Credit Unions, special project grants, project funds etc.	- Stemmed foreign exchange loss & food insecurity - Farmers encouraged to invest in irrigation and fertigation techniology in open filed and under PCSs. - Improved pest management and yields - Enhanced eco-agriculture practices	Medium/long term. Key actors: MOA CRDU/Innovation Centre, Partners. Internal funds to conduct research, networking and interviews.

2.3.3.1 Economic and financial measures

The economic and financial measures identified include:

- Increase lobby (petitions, cabinet papers, advocacy actions, etc.) for lower importation duties and taxes for system components and other spares by key actors.
- Identify/develop lucrative markets for small producers. Cut out the middleman where necessary.
- Allocate adequate funds to strengthen the institutional and technical capacity of the Extension Services and R&D Unit to service the irrigation/fertigation systems for small and medium-scale farmers. Operations and Maintenance (O&M) costs could be beyond the means of many small operators
- Identify affordable guarantees and/or insurance for loans available in the short term; for the medium and long term, the establishment of a multi-peril crop insurance or risks transfer mechanism is proposed through financial establishments such as DFC, the National Bank, Credit Unions, etc.

2.3.3.2 Non-financial measures

The non-financial measures identified by stakeholders were:

- Institute training programme to enhance knowledge and technical skills of small and medium-scale farmers in installation and O&M of improve irrigation and fertigation systems.
- Promote public awareness and education programme on the benefits of drip irrigation among farming communities and other stakeholders.
- MOA R&D Innovation Centre spearheads advocacy drive to improve Agriculture Technology network among key actors and sectors such as: Agro Processing Sub-sector, BELTRAIDE, Credit Unions, the National Bank and other financial entities in the Private Sector, Mennonite community, Tourism sector, Commerce and Trade, including foreign manufacturers of agricultural equipment.

Table 21: Summary of market and non-market barriers and corresponding measures for improved drip irrigation/fertigation system

Categories	Identified Barriers	Measures to overcome barriers	Intervention		Funding Sources	
			Legal	Other	National	External
Economic and financial	− High initial investment of drip irrigation system	− Identify and secure affordable loans and payment plans for farmers through DFC/National Bank, other Banks, Credit Unions, special project grants, project funds etc.		√	√	√
	− Limited subsidies for technology components	−Lobby for reduced import tax duties on equipment and irrigation system components (Solar powered pumps, solar panel components, fertigation and water harvesting equipment)	√		√	
	− Cost of installation and operation may be beyond the reach of small operators	−Provide technology companies & suppliers with concession to service specific areas or groups of clients at reduced service costs (e.g. Public-private partnership)		√		√
Market conditions	− Gaps in technology value chain (supply and	− Set up local assembling industry (small industry, job creation initiative etc.)		√	√	

	demand) -Market too small	− Establish demonstration programme to help grow market for drip irrigation.				
	− Local hardware stores often low in stocks of irrigation spares & components	− Improve access to products and services through subsidies that mat be pass on to farmers. Expand the market for new technology and crop production in support of drip irrigation		√	√	√
	− Incumbent monopoly in some areas; special interest groups; or none use of drip irrigation	− Implement policies & regulations for favourable market environmenr to help level playing field	√		√	
	− Inadequate policy and regulatory framework	− Recommend policy review and actions to improve enabling environment (e.g. seed policy, market liberalisation, reduce protectionism and monopoly of incumbent technology)	√		√	
Legal and regulatory	− No office of testing and certification	− Establish regulatory agency for standards, testing and certification (for equipment, seeds, etc.)	√		√	√
	− Import of cheaper, inferior-quality equipment/products	− Strengthen regulatory framework (e.g. implementation & penalty)	√		√	
	− Networking among professionals and agencies weak and ineffective	− Enhance networking for improved drip irrigation / potato cultivation market chain actors (e.g. importers/retailors, assemblers and clients)		√	√	√
Network structures		− Strengthen research, development and demonstration of new technology (e.g. through CRDU, MOA, Farmer's groups, CARDI, etc.)				
	− Farmers cooperatives	− Strengthen Cooperative Department and form an	√		√	

	generally work in insolation (crop specific)	national association of farmer's cooperatives			
	− Limited farmer-to-farmer visits and interactions	− Increase local and regional farmer's networking. Use ICT and social media.	√	√	√
	− Limited awareness and knowledge of new technology	− Promote public awareness and education on technology and related matters with programme on the benefits of drip irrigation, fertigation, water & soil management, water harvesting, among farming communities and other stakeholders	√		√
Others	−Low technical capacity	− Develop integrated and on-going, specialized training component in the technology diffusion programme using capital funds, targeting Extension Service and farmer's groups.	√		√
	− Farming communities and farmers suspicious and afraid of change	− Through technology diffusion programme address social, cultural and behavioural issues; improve KAP* among users of new technologies	√		√
	− Water scarcity	- Develop and demonstrate guidelines on water management and rainwater harvesting technologies	√	√	

A brief list of the outcomes of these measures are:

- Increased knowledge & technical skills of improved drip irrigation & fertigation technology among small farmers through technology diffusion programme.
- Highly trained cadre of Extension Service officers working with an adequate budget line.
- Improved synergies with other productive sectors such as Tourism sector, Commerce and Trade; Agro Processing Sub-sector, BELTRAIDE, Credit Unions, the National Bank and other financial entities in the Private Sector.

- Improve perception and knowledge of small and medium-size farmers on economic, environmental and social benefits that can be derived from improved drip irrigation / fertigation / water harvesting and renewable energy.
- Although most small and medium-scale farmers prefer traditional rainfed cultivation; their trust in the benefits of improved drip irrigation technology increases.
- Remove the politics/preference/favouritism in rendering aid/opportunities of farming groups, farming communities and individual farmers.
- Address issues related to land tenure and sustainable Land use and Land use change.
- Sustainable water use and water management amount stakeholders

2.4 Barrier analysis and possible enabling measures for crop covered structure cooling systems

2.4.1 General description of crop covered structure 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 rainfalls, direct solar radiation, disease, insects and birds. High relative humidity and ambient temperature microclimate in a tropical greenhouse, create a complicated dynamic system that is strongly influenced by changes of external conditions, making it a challenging environmental control task (Shamshin & Wan Ismael, 2013). The central problem with tropical greenhouses or Protective Cropping or Covered Structures (PCSs) is the high, uncomfortable internal temperatures that develop during warm, sunny days, limiting the number of working hours inside these structures.

Protective Covered Structures were introduced in Belize under the 9th European Development Fund (EDF) financed Agriculture Enterprise Development project (AED), and was well received by vegetable farmers. Some structures have been properly managed and several 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 produce 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).

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

- Natural Passive Ventilation (Air exchange) and shading systems;
- Mechanical Active Ventilation powered with a small diesel generator;
- 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 favourable 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.

2.4.1.1 Preliminary targets for technology transfer and diffusion

Rehabilitation of Protective Covered Structure cooling systems: The Government of Belize, through project funding, bought a total of 30 greenhouses at the rate of BZ$ 30,000.00 back in 2010. Some of these greenhouses are still in use but the majority have fallen into disrepair and abandoned. Over the years the CRDU has also been refining the construction of Bel Tunnel cover structures, similar in design to the Tropical Greenhouse, but smaller in size. The technology transfer aims at installing improved cooling systems in at least eight (8) crop PCSs (tropical greenhouses) in operational use around the country, with the capacity to address the inefficient cooling systems for other crop cover structures as demands for this service increases. The beneficiaries will be both small and medium-scale farmers who routinely utilize crop cover structures.

Table 21 below is a summary of this technology transfer targets, including a simplified cost – benefit evaluation. See Table 7 and Annex II for review of targets and economic analysis for related technologies in the Agriculture sector.

Table 22: Targets and possibility of attainment of technology transfer for improved cooling systems for tropical greenhouses, Bubble Houses and/or BEL Houses

Sector: Technology	Targets	Too Ambitious	Conservative
Agriculture			
5. Improved cooling system for Crop cover structures (Tropical Greenhouses /Bel Houses)	Refurbishing cooling systems for at least 8 crop cover structures. Intention is to develop a business for rehabilitation of existing cover structure cooling system as demands for installation increases and maintenance rises	Initial cost for cooling system components could be high for individual small farmers.	Yes. **Capital Costs:** US$ 109,500.00 for cooling system refurbishment of (8) Tropical Greenhouses and Bell Tunnel Covered structures. **Operational costs:** US$ 28,000.00 for three years (spares & maintenance).

Spearheading this intervention is the Ministry of Agriculture's Crop Research and Development Unit (CRDU). The objective is to build technical capacity in the CRDU to initially improve the cooling system of the target eight (8) PCS, then provide similar installation and maintenance service to farmers and agro-industry enterprises, interested in upgrading their PCS cooling systems at an affordable cost.

2.4.2 Identification of barriers for protective covered structure cooling systems

The key barriers identified in random order by the Sector-based Technology Working Group (STWG) for upgrading the cooling systems of tropical greenhouses or PCS were:

- No specific budget and resources to rehabilitate PCS cooling systems.
- General lack of interest to invest in the refurbishment of cover structures.
- Limited knowledge and technical skills among user groups and farmers.
- Limited institutional capacity to address the problem with PCS cooling system.
- Initial cost for rehabilitation of PCS can be high for small and medium-scale farmers.
- Poorly designed tropical greenhouses.
- Very limited finance for replacement and maintenance.
- Inaccessibility to spares and material.

- Unfavourable market conditions at harvest discourages farmers to invest.
- Small market for cover structure technology because of limited use and supply.
- Lack of business strategy/plan for expansion of cover structure technology.
- Low-interest loans for purchasing new tropical greenhouses, or rehabilitating cooling system of incumbent PCS often not available for small producers.
- Local market for crop protective covered structure technology is small or non-existent.
- Water for drip irrigation system in PCS limited, especially during dry season.
- Energy to operate water pumps for irrigation water from rivers/streams, lagoons or wells, to an elevated tank not available at many locations.
- Farmers and operators complain about over-heated tropical greenhouses/PCSs
- High risk of losing investment during extreme weather events. PSCs that are not properly anchored are lost to high winds during passage of tropical cyclones or floods.
- Low prices for produce during harvest time – little export market opportunities.
- Generally small economies of scale related to PCSs rehabilitation/construction.
- Vandalism and praedial larceny affects investment in PCS technology and another expensive agro-technology equipment.
- Rising cost of fuel for operational use and transportation.
- Cost of importing modern tropical greenhouses with modern technology cooling system is high, and out of reach for most small and medium-scale producers.

Selection and decomposition of critical barriers for diffusion of PCS cooling systems

The selection of killer (non-starter) and crucial barriers are summarised in Table 22, following an open selective process by members of the STWG using a Likert scale. Only barriers with score of 1 and 2 were considered for farther decomposition and evaluation as presented in Table 23.

Table 23: Criteria and Importance of Barriers for the diffusion of PCS cooling systems

No.	Barriers	Criteria and Importance of Barriers for Technology 2					
	Economic & Financial	**1. Critical (killer, non-starter)**	**2. Crucial**	**3. Important**	**4. Less important**	**5. Insignificant (easy starter)**	**Rank**
1	- High Initial costs for rehabilitating PCS cooling systems (e.g. with solar powered fans)	x					1
2	- Inaccessibility to credits and limited low-interest financing, and non-favourable payment plans		x				2
3	- High import taxes		x				2

	and limited subsidies on components						
4	- Unpredictable market status at harvest time discourages farmers to invest			x			3
5	- Rising cost of fuel for operational use			x			3
6	- Lack of risks transfer mechanism (e.g. multi-peril crop insurance, etc.)			x			3
7	- High cost of importing and buying modern tropical green-houses with high-tech cooling systems				x		4
	- Lack of business strategy to expand PCS technology locally			x			3
	- Finance/budget line unavailable for effective O&M, including for PCS	x					1
	Non-financial						
7	-Farmers and operators complain about over-heated tropical green-houses/PCSs	x					1
8	- General lack of interest to invest			x			1
9	- Limited subsidies and incentives		x				2
10	- Generally small economies of scale related to PCSs and production for markets	x					1
11	- Extension Service		x				2

	limited in technical capacity						
12	- Limited technical capacity among technicians & small farmers in effective PCS cooling system			x			3
13	- Rising fuel costs		x				2
14	- Limited institutional capacity and market-driven opportunities to address dilemma of PCS cooling system		x				2
15	- Small economies of scale related to PCSs and production for market			x			3
16	- Limited use of PCS by small farmers		x				

Selection of critical (killer or non-starter) barriers.

Table 24: Preliminary decomposition of killer or non-starter barriers to the diffusion of PCS cooling system technology

Category of Barriers	1. Critical (killer, non-starter)	2. Crucial	Elements of killer or non-starters	Dimension of barrier elements
Economic & Financial	- Initial cost for rehabilitation of PCS can be high - Very limited finance for replacement and general O&M - Inaccessibility to low-interest financing and suitable payment plans	- Inaccessibility to credits and limited low-interest financing facilities not too attractive for small farmers - High import taxes and limited subsidies for components and spares - Finance unavailable for effective O&M, including for PCS - Elevated financial risks due to crop failure - Rising fuel prices	- High interest rates - High import duties on components - Elevated cost of specialized services to rehabilitate and maintain PCS cooling systems - Key components might not be in stock in country	- 12 – 15 % on certain components - Service costs could be as high as 15 % of capital cost - Interest rates could be 7 to 12 % per annum
Market failures	- Generally small economies of scale related to PCSs	- Limited institutional capacity and market-driven opportunities to address dilemma of PCS cooling system	- Unstable and emerging market for PCS by majority of small farmers - Incumbent and monopoly have greater slice of market - Low demands	- Market policy and strategy not clear and focused - Imports, contraband and monopoly skew market against local producers using PCS and irrigation - Rainfed farming system (incumbent) still widely practiced
Non-financial	- Farmers and operators complain about over-heated tropical green-houses/Protective Covered Structure - Limited use of	- Limited subsidies and incentives - Extension Service limited in technical capacity - Imported equipment not of the best quality - Limited use of PCS	- Limited knowledge and technical capacity among farmers to address dilemma - Cannot afford re-designed cooling system costs - Bad experience	- Farmer's income not sufficient and stable to make investment - Training selective, and does not reach most farmers - Inadequate design and poor material

	PCS's by medium and small farmers - Extension Services limited in technical capacity	by small farmers	with mal-functioning system	- Technical capacity in R&D unit limited for Task; may require specialized service providers

Figure 10 is a Problem tree analysis use in conjunction with stakeholders input to study the focal problem posed by participants in the small group meetings. The focal problem that was identified was: "Over heated crop protective cover structures/greenhouses"

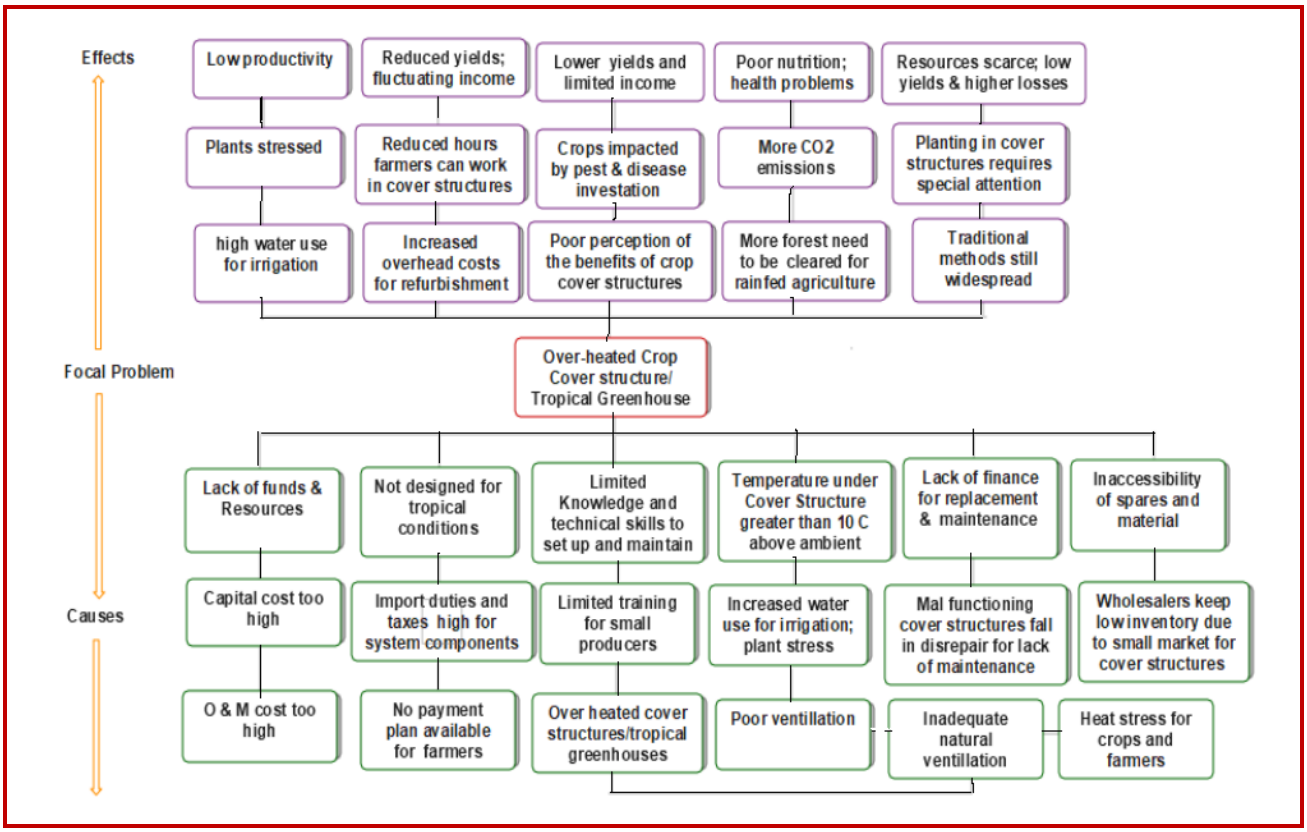


Figure 10: Problem tree for over-heated crop cover structure/tropical greenhouse

The main causes and effects related to this problem are highlighted in the analysis. Some of the main effects arising from the use of overheated tropical greenhouses in Belize are: Poor perception of the benefits of adequately ventilated crop cover structures among small farmers, traditional methods of cultivation still widespread, more forest is cut down to make way for rainfed agriculture, increasing overhead costs for refurbishment of some existing cover structures by some farmers and horticulturists, low yields due to pest and disease infestation, and reduced hours farmers can work under cover structures, low yields under heat-stressed environment, to name a few.

2.4.2.1 Economic and financial barriers

The economic barriers identified were:

- Initial high cost for refurbishment of cover structures.
- High cost to small famers for spares and maintenance.
- Small or limited inventory of spares by importers.
- High import duties and taxes on RE system components and spares (Solar PV);
- Financing for agriculture equipment and upgrades available (e.g. DFC, National Banks, Credit Unions, etc.); but interests on loans may not be at the reach of small farmers.

2.4.2.2 Non-financial barriers

The crucial non-financial barriers identified by the stakeholders were:

- Limited use of crop cover structures by small farmers in some districts.
- Limited institutional capacity and market-driven opportunities to address dilemma of PCS cooling system.
- Subsidies and incentives to invest on PCS not attractive.
- Extension Service have limited in technical capacity on improve PCS cooling system.
- Imported equipment not of the best quality.

Other non-financial barriers to consider are:

- Small farmers still mis-trust new technologies, especially those they cannot maintain.
- Limited or total lack of capacity to install and profitably operate a crop cover structure with adequate cooling system.
- Lack of adequate training and guidance to small farmers;
- Farmers may have one or two cover structures, but they cannot expand production with more cover structure because of limited resources and capacity.
- Cooling system technologies for cover structures are a bit complex and the local resources, knowledge and capacity to install the most efficient is unavailable because of the low in-country demands.

2.4.3 Identified measures

The measures to overcome barriers and facilitate the smooth implementation of improved Protective Covered Structure cooling system technology, were identified using the Logical Problem Analysis (LPA) tool, namely an Objective tree. Stakeholders participation in this

exercise was crucial, particularly the input of the Crop Research and Development Unit (CRDU) and personnel from CARDI.

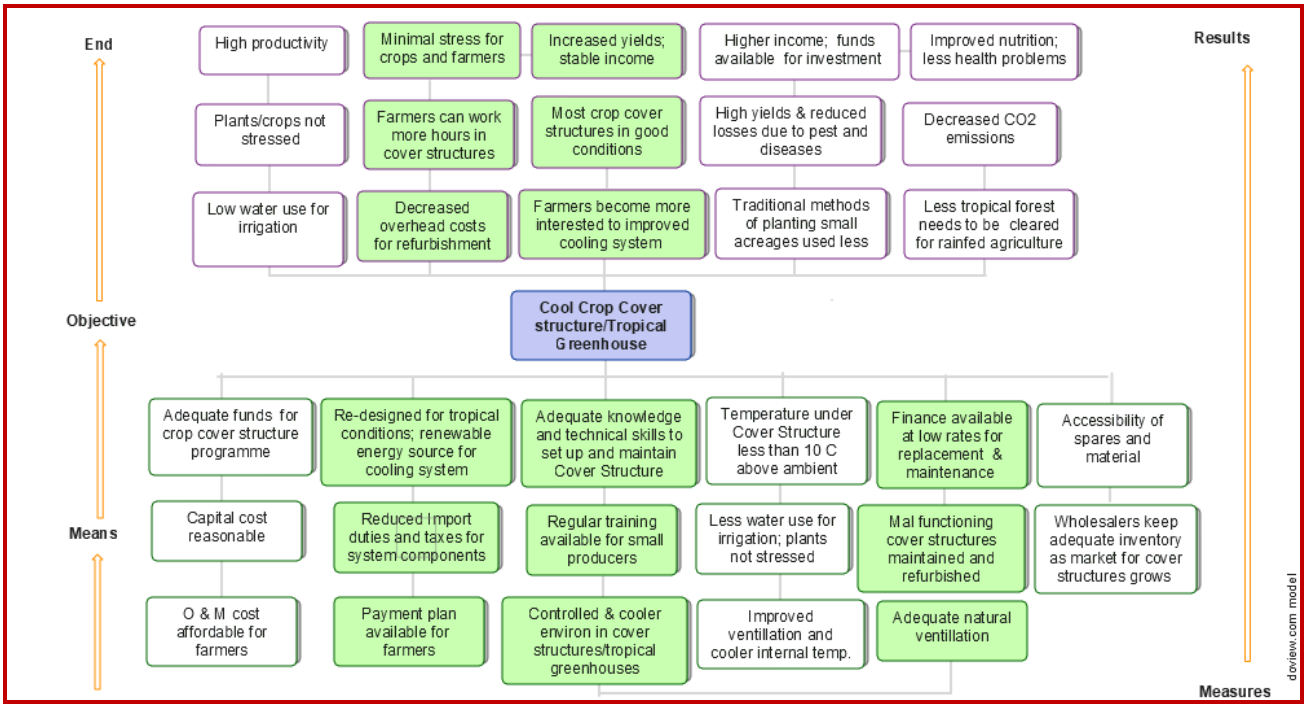


Figure 11: Objective tree for the redesigned of cooler crop protective covered structure or tropical greenhouse

The general Objective proposed for the problem of "Over Heated Crop Cover/Tropical Greenhouses" was: "Cool Crop Covered Structure/Tropical Greenhouses". The green shaded boxes of 'measures' and 'results' is one of the proposed strategic pathways to help achieve this objective. Table 24 is a summary of the preliminary measures and results derived from the solution tree analysis. Other pathways from the Objective tree analysis can be traced or followed to help achieve the same general objective.

Table 25: Proposed strategic pathway for objective, 'Cool crop covered structure / tropical greenhouse'

Objective	Measures	Results	Timeframe & Actors
Cool crop cover structures/tropical greenhouses	Procure local or external finance to organise and run training programme for rehabilitation of PCS cooling systems.	-Technical capacity and skills of CRDU technicians/officers improved -Farmers become more interested to improved cooling systems	Short to medium term. Electrical engineers will be contracted to facilitate training and demonstrations.
	Procure finance (local or external) for refurbishment of PCS cooling systems powered with RE	-Most of the targeted PCSs in good operational conditions, and conducive for productive work	Short to medium term. R&D technicians highly trained to service PCS and install new crop Protective

		- Controlled & cooler environment in cover structure/tropical greenhouse	Covered Structures
		-Less heat stress for crops. Increase yields and stable or higher income	Short/Medium term
	CRDU redesigns PCS for tropical conditions using Renewable Energy (solar PV) for cooling systems	Farmers/operators can work more hours in crop cover structures / Bel houses.	Medium/long term. MOA CRDU
	Stakeholders lobby for reduced import duties & taxes for system components	Importers keep a reliable inventory/stock of spares and components as market for Cover Structure grows.	Medium term. Policymakers, farmers, and partners
		Positive Impact on local economy	Medium term
	Financial institutions offer affordable payment plans available for farmers (DFC / Credit Unions / National Bank etc.).	Decreased overhead costs for refurbishment	Medium/long term. MOA Policy Unit, Extension Service, farmers
	Finance is made available at low interest rates, for initial cost, and for operation and maintenance	Traditional methods of planting smaller acreage used less, and vermi-culture encouraged for organic cultivation	Short/medium term
	Importers and Retailers keep adequate stocks of spares and material for PCSs	Redesign enhances cooler working conditions	Short/medium term. Importers, retailers, CRDU, partners
		Reduced losses due to pest and diseases; enhances adaptation to Climate Change and food security	Medium/long term

2.4.3.1 Economic and financial measures

Some financial measures were:

- Facilitate reduced prices of equipment and spares for refurbishment;
- Request reduction on import duties and taxes for agriculture technology components (e.g. Cooling fans, humidifiers, Solar PV, other.);
- Facilitate accessibility to small interest loans by small farmers and affordable payment plans
- Provide market mechanism for small farmers to receive reasonable prices for farm produce
- Request increased budget for R&D& extension Services in Agriculture Sector.
- Identify niche markets for cover structure-cultivated, organically grown vegetables such as celery, sweet peppers, garlic, parsley, mushrooms, etc. (e.g. tourism sector).

2.4.3.2 Non-financial measures

Some of the non-financial measures identified included by stakeholders were:

- Institute a risk transfer scheme for small farmers (i.e. a special fund or multi-peril crop insurance scheme)
- Establish specialized training to enhance technical capacity and personnel at the CRDU.
- Training for small farmers conducted on a regular basis for the installation, maintenance, and agronomic operation of protective cover structures in all districts of Belize.
- Refurbishment and maintenance programmed by CRDU in coordination with farmers results in moderating temperature in Greenhouses/PCSs to near ambient temperature.
- Educate more small farmers on the economic, social and environmental benefits of cultivating under cool PCSs.
- Expand farmer's exchange programs in neighbouring countries that are profitably utilizing improved ventilated and cooler tropical greenhouse technology (e.g. Yucatan/Quintana Roo, Mexico, Guatemala and Honduras.).

Table 25 is a summary of barriers and corresponding measures to facilitate the diffusion of improved cooling systems for protective cover structures and PCS technology and use in general.

Table 26: Summary of barriers and corresponding measures for diffusion of PCS redesigned cooling system

Categories	Identified Barriers	Measures to overcome barriers	Intervention		Funding Sources	
			Legal	Other	National	External
Economic and financial	−High initial/capital investment	− Expand access to finance		√	√	√
	− Limited subsidies and high import duties/taxes for technology components	− Lobby for reduced import Tax on equipment and seeds	√		√	
	− High cost of installation of integrated cooling systems for PCS	− Provide technology companies & suppliers with concession to service specific areas or groups of clients at reduced service costs (Public-private partnership)		√		√
	− Gaps in technology value chain	− Conduct feasibility study for setting-up local assembling industry		√	√	
Market conditions	− Local hardware stores often low in stocks of spares & components	− Expand access to products and services Grow the market for new technologies related to PCS (solar water pumps, water harvesting, drip irrigation, inputs, etc.)		√	√	√
	− Unstable and small, monopoly, special interest groups control	− Implement policies & regulations for favourable market climate	√		√	
Legal and regulatory	− Inadequate policy and regulatory framework	− Improve policy and enabling environment (e.g. seed policy, market liberalisation, protectionism, monopoly of incumbent technology)	√		√	
	− No office of testing and certification	− Establish regulatory agency for standards, testing and certification (equipment, seeds, etc.)	√		√	√
	− Import of cheaper,	− Strengthen regulatory	√		√	

	inferior-quality equipment/products	framework (e.g. implementation & penalty)				
	− Networking among professionals and agencies weak and ineffective	− Enhance networking for PCS technology/ improved drip irrigation − Strengthen research, development and demonstration for improved PCS technology		√	√	√
Network structures	− Farmers cooperatives generally work in insolation (crop specific)	− Strengthen Cooperative Dep. and association of farmer's cooperatives. Use modern ICT for networking	√	√	√	
	− Limited farmer to farmer visits	− Increase local and regional farmer's networking		√	√	√
	− Limited awareness and knowledge of new technology	− Establish management programme and education/awareness campaign among key stakeholders for new technology		√		√
Others	− Low technical capacity	− Establish training component in technology diffusion programme		√		√
	− Farming communities and farmers suspicious and afraid of change	− Through technology diffusion programme address social, cultural and behavioural issues; improve KAP* among users		√		√

2.5 Barrier analysis and possible enabling measures for in-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties.

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 Laboratory could serve as the institution to test, validate, and reproduce seedlings for experimental plots. Through the MOA, these will be disseminated to farmers.

2.5.1 General description of in-country Irish potato clean-stock production unit

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 trailed 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.

Medium-term Strategic Action Plan for Horticulture (Potato) Cultivation, MOA

Program: Horticulture

This strategic plan is derived from the workplans submitted by the different units of the Horticulture Section.

Objective: To increase production, productivity and competitiveness of horticulture crops in a sustainable manner through the promotion of climate smart agriculture.

Timeframe: 2017 -2020

Table 27: Short term strategy for expanding Potato cultivation

Target Commodity	Objective	Components (how? Strategy)	Deliverables 2017 - 2018	Location	Lead Person	Partner
Potato	To extend the locally produced supply of potatoes from 2 to 4 months.	1. Conduct preliminary varietal trials to determine extension of planting season. 2. Reduce post-harvest losses 3. Increase storability 4. Manage pest and diseases in a sustainable manner. 5. Promote the production of potatoes that meet consumer preferences and national standards.	1. Best varieties for storage identified. 2. Farmer training guide for post-harvest and storage of potatoes. 3. Report on varietal performance during off-season planting. 4. Report on varietal performance under storage conditions 5. X trainings of producers in the national standards of potatoes.	Cayo	C. Teck	DAC Cayo, BAHA. PCB, CARDI Farmer Group

(Source: Strategic Action Plan 2017 - 2020, Ministry of Agriculture, July 2017)

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.

Figure 12 shows a flow diagram of the steps to the produce certified tuber-seed for quality potato harvest. Field trials for micro propagated seedling and dissemination of certified potato seeds will proceed as follow:

1) Initial field trial evaluation of (10) certified varieties by Ministry of Agriculture Research and 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.

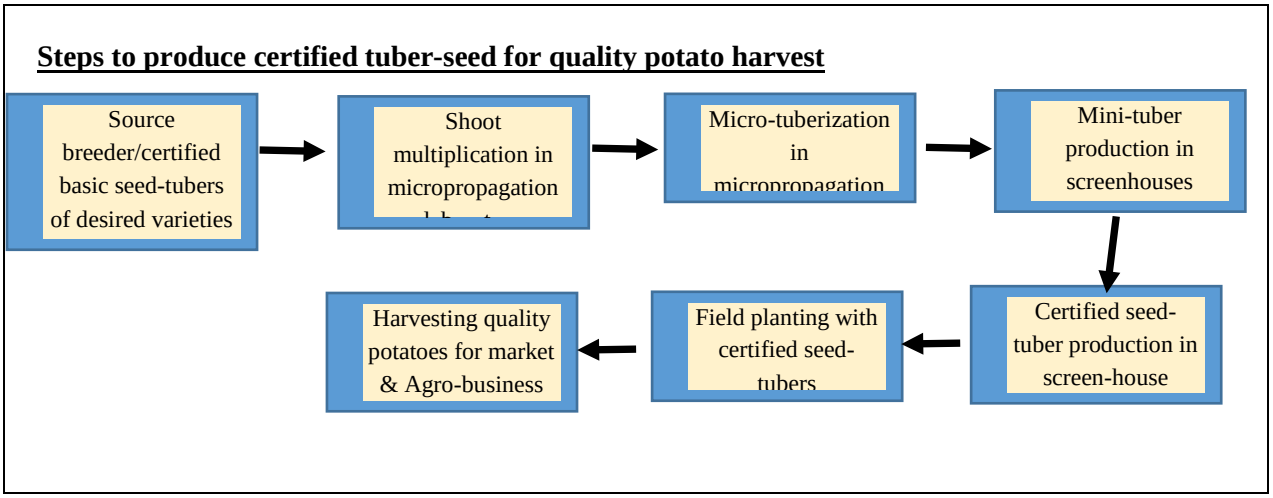


Figure 12: Process for the production of certified tuber-seed for quality potato harvest

International Potato Centre

The International Potato Centre (CIP) is a non-profit international agricultural research-for-development organization with a focus on potato, sweet potato, and Andean roots and tuber crops. CIP's vision is "roots and tubers improving the lives of the poor". Its mission is to contribute towards food security and improved well-being in the developing world through research and partnerships guided by science, state-of-the-art technology, and training. The headquarters of CIP is in Lima, Peru, with branches in over 30 locations in Asia, Africa, and Latin America. CIP is a member of the Consultative Group of International Agricultural Research (CGIAR), consisting of 15 research centres mostly in the developing world, and supported by more than 50 major public and private donors.

2.5.2 Identification of barriers for in-country Irish potato clean and certified seed-tuber production

A list of the general barriers identified by stakeholders to ease the transfer of 'in-country Irish Potato clean stock production' were:

- Legislative framework/strategic plan does not effectively address the potential of potato cultivation for the country.
- Very narrow or limited policy for improving the potato varieties cultivated in Belize.
- High cost to farmers to purchase the annual imported Red la Roche Irish potato variety seeds.
- Potato cultivated in only selected locations by few farmers during cool transition period (i.e. December – February).
- High initial cost for small farmers to cultivate potato.
- Training and capacity-building for small farmers is limited.

- Limited institutional capacity (i.e. Extension Service inadequately manned and financed.
- Low priority given to potato cultivation.
- Institutional capacity at the UB Plant Propagation Laboratory to micro-propagate climate resilient Irish potato breeder seedlings limited.
- An effective business plan to expand the Plant Micro-Propagation Laboratory does not exist.
- Seedings of cool season Irish Potato varieties imported annually by private interest to make a profit.
- Moderate to high interest rates to make a loan to establish a potato crop for a season.
- Lack of loan guarantee for small producers.
- High risk to crop failure due to extreme conditions at the end of the hurricane season and unusually warm cool seasons.
- In-country Research and Development in potato variety trials/cultivation very limited or none-existent due to adequate funding and market demand for climate resilient, micro-propagated seed-tubers.
- The perception that is cheaper to import potato. This stifles agriculture production and only selected importers benefits.
- Inability of farmers to produce for the market at a profitable rate due to instability of local market for potato, and non-international market opportunities.
- High Initial costs for refurbishing Micro-propagation laboratory for production of certified potato seed-tubers.
- Incumbent monopoly, and resistant by 'interest parties' for an alternative option to access certified Irish potato seed-tubers planting material.

Selection and decomposition of critical barriers for diffusion of improved drip irrigation

Table 28: Criteria and Importance of Barriers for improved drip irrigation and fertigation

No.	Barriers	Criteria and Importance of Barriers for Technology 2					
	Economic & Financial	**1. Critical (killer, non-starter)**	**2. Crucial**	**3. Important**	**4. Less important**	**5. Insignificant (easy starter)**	**Rank**
1	- High Initial costs for refurbishing Micro-propagation laboratory for production of certified potato seed-tubers	x					1
2	- Access to limited low-interest financing limited		x				1

3	- High import taxes and limited subsidies		x				2
4	- Unfavourable market status at harvest discourage farmers to invest	x					3
5	- Elevated financial risks due to crop failure		x				2
6	- Lack of risks transfer mechanism			x			3
7	- Foreign exchange and corresponding banking				x		4
	Non-financial						
7	- Frustrating land tenure issues			x			3
8	- Limited use of drip irrigation by farmers	x					1
9	- Limited subsidies and incentives		x				2
10	- Constraints on drip irrigation market due to local economies of scale.		x				2
11	- Extension Service limited in technical capacity		x				2
12	- Limited technical capacity among small farmers			x			3
13	- Rising fuel costs		x				2
14	- Rising costs of transportation			x			3
15	- Incumbent monopoly, and resistant by 'interest parties' for an alternative to access certified Irish potato seed-tubers planting material		x				2

Table 29: Selection of killer or non-starter barriers to the diffusion of micro-propagation of climate resilient Potato certified seed-tubers

Category of Barriers	1. Critical (killer, non-starter)	3. Crucial	Elements of killer or non-starters	Dimension of barrier elements
Economic & Financial	- High Initial costs for irrigation systems	- Credits and limited low-interest financing facilities not too attractive for small farmers - High import taxes and limited subsidies for irrigation components/spares - Elevated financial risks due to crop failure - Rising fuel prices	- High interest rates - High import duties of components - Elevated cost of specialized services -	- 12 – 15 % on certain components - Service cost could be as high as 15 % of capital cost - Interest rebates could be 6 to 12 % per annum
Market failures	- Unfavourable market status at harvest discourage farmers to invest	- Constraints on drip irrigation market due to local economies of scale.	- Unstable markets - Incumbent and monopoly have greater slice of market - Supply greater than demands	- Market policy and strategy not clear ad focus - Middleman strongly influence prices, returns for producers often not equitable - Imports, contraband and monopoly skew market against local producers
Non-financial	- Limited use of drip irrigation by farmers	- Limited subsidies and incentives - Extension Service limited in technical capacity - Imported equipment not of the best quality	- Limited knowledge and technical capacity among farmers - Cannot afford installation cost - Bad experience with mal-functioning system	- Farmer's income not sufficient and stable to make investment - Training selective and does not reach most farmers - Inadequate design and poor material

Figure 13 shows a Problem tree analysis conducted with some key stakeholders to identify the main causes and effects to the focal problem: “Irish Potato imported seeds are cool season varieties only and not climate resilient”.

Some of the main causes and effects contributing to this dilemma are outlined in the Problem tree and were derived from the general list of current barriers listed by the stakeholders.

Some of the glaring effects of this problem include

1) Potato cultivation in Belize confined only to the cool season and in few localities.
2) Only few farmers benefit from this potential industry.
3) Limited capacity and opportunities of other farmers interested in potato cultivation.
4) When local production is consumed, Government imports potato. Only the selected few importers benefits.
5) Cash crop diversification limited. Economic opportunities frequently missed!
6) Very limited storage facility, hence farmers must sell at lower prices after harvest.
7) Middleman set prices, income for growers low, and indirectly impacts community.
8) The *status quo* persists: crop vulnerable to climate change; adding to elevated risk to food security;
9) Lower income opportunities for farmers
10) UB Plant Micro-Propagation Laboratory under utilized.
11) Elevated risks arising due to crop failure may result in loss of assists and investment.
12) Policy short-sighted with respect to the potential of expanding in potato cultivation.

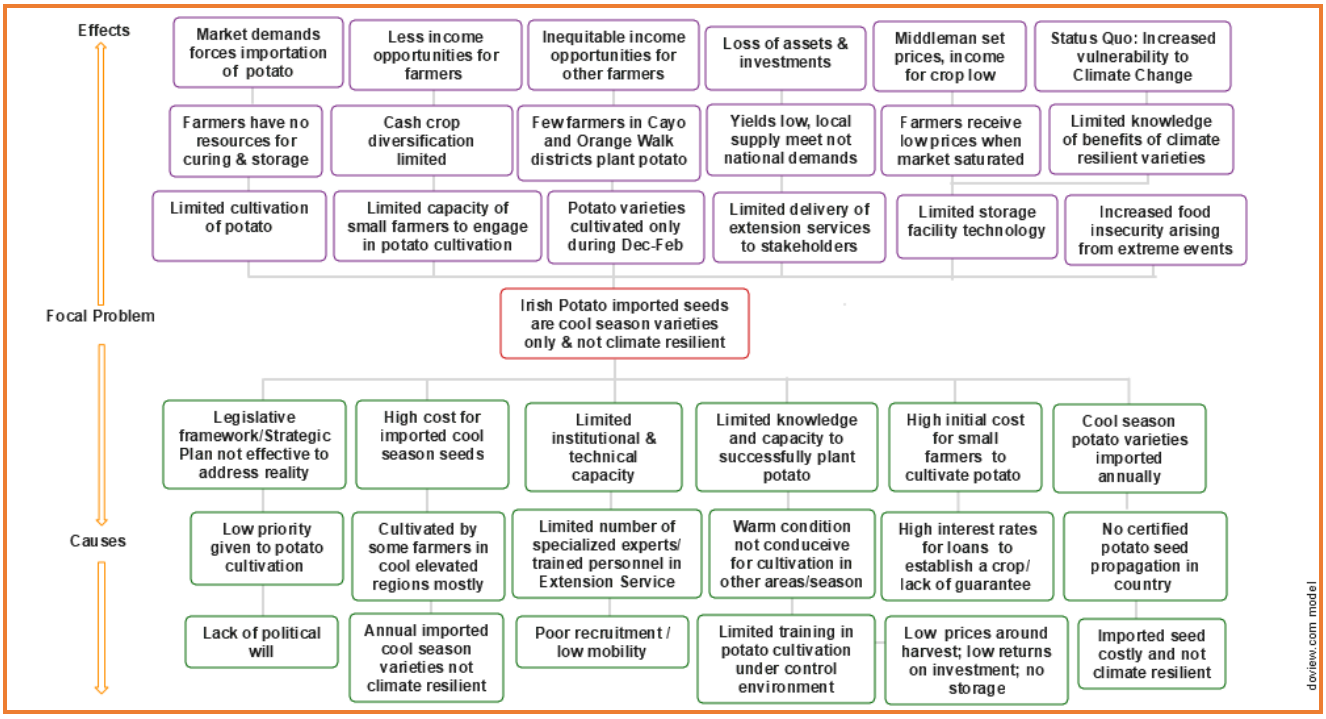


Figure 13 : Problem Tree for imported none-climate resilient potato seeds

2.5.2.1 Economic and financial barriers

Market Mapping for transfer and diffusion of clean, certified seed tuber Potato varieties

Summary, barriers and gaps

Reference Market mapping schematic for micro-propagation of clean, climate resilient, certified Irish potato seed-tubers in Annex II H2.

i. *Source Basic Seeds (Clean parent material):* Procured from potato breeding centres in the United States and/or the International Potato Centre in Peru (CIP). Private sector importers, GOB through MOA/UB, CARDI, others.
ii. *Import duties/taxes and subsidies:* Taxes may apply, but subsidies may be granted to importers which can be passed down to the farmers at the other end of the market chain.
iii. *UB micro-propagation laboratory:* Equipment and material will have to be procured in the capital cost for up-grading laboratory facilities, and fund must be available for first 2.5 years of operation and maintenance. Funds for expert consultant for developing production strategic workplan and guidelines for micro-propagation of 'Source Basic Seeds" to certified potato seed tubers for farmers, must be part of the capital costs. Training of micro-propagation laboratory technicians and field workers, and farmer's outreach programme and technology awareness/education campaign, should be funded from capital cost.
iv. *Importers and Retailers:* Equipment and spares for irrigation, fertigation, cover structures, nursery, and water pumping/harvesting and storage, shall be imported, and

stocks available. Import taxes are mostly zero rated for irrigation and solar PV systems, but taxes are applied for certain components such as inverters, batteries, and miscellaneous spares.

v. *Input and Service Providers:* Generally available. Gaps exist in provision of information on technology and the changing market, and also networking among producers and service providers and importers.

vi. *Enabling Business Environment:* MOA and partners (CARDI, BELTRAIDE, IICA, DFC and others) are available to provide guidance and advise to farmers on issues related to affordable loans, other finance opportunities, the market, and policy changes. The gap here seems to be limited networking among main actors, the leadership role here is the MOA, whose extension service and policy office is closest to farmers. The Extension Service plays a crucial role and must be empowered (through training, increased capacity and public relations) to continue the good work of improving production among the small and medium scale farmers.

The micro-propagation of climate resilient, Source Basic Seeds of Irish Potato is envisioned to become sustainable and profitable in the medium term as potato production increases, and market opportunities are secured.

The key economic and financial barriers short-listed by the stakeholders were:

- High initial cost for small farmers to cultivate potato.
- Moderate to high interest rates to make a loan to establish a potato crop for a season.
- High cost to farmers to purchase the annual imported Red la Roche Irish potato variety seeds
- In-country Research and Development in potato variety trials/cultivation very limited or none-existent due to adequate funding or a recurrent budget.
- Lost of investment due to elevated risks related to crop failure.
- In In-country Research and Development in potato variety trials/cultivation very limited or none-existent due to adequate funding or a recurrent budget.
- Inability of farmers to market produce at a profitable rate due to instability of local market or non-international market opportunities.

2.5.2.2 Non-financial barriers

Some of the most critical non-financial barriers included:

- Legislative framework/strategic plan does not effectively address the potential of potato cultivation.
- Very narrow or limited policy for improving the potato varieties cultivated in Belize.

- Potato cultivated in only selected locations by few farmers during cool transition period (i.e. December – February).
- Training and capacity for small farmers limited.
- Limited institutional capacity (i.e. Extension Service inadequately manned and financed.
- Low priority given to potato cultivation.
- Institutional capacity at the UB Plant Propagation Laboratory to micro-propagate climate resilient Irish potato breeder seedlings limited.
- Farmers afraid to diversify to non-traditional crops.
- High risk to crop failure due to extreme conditions.
- Institutional capacity in the MOA/private sector very limited to take advantage of the economic opportunities that a vibrant potato industry could offer.

Summary of key barriers for micro-propagation and successful diffusion of clean, certified Irish Potato seed-tubers

Clean, certified Irish potato seed-tubers replicated locally through micro-propagation of imported climate resilient, 'source basic seed' would probably be twice the cost of a unit of incumbent seeds, but GOB subsidy would make it affordable for farmers. Certified seeds-tubers will be climate resilient and tested to be more adaptable to warmer and drier conditions and yields per acre or hectare can be higher with the appropriate input. Initial cost for drip irrigation (if used) is not included, but the benefits to potato growers would be profitable in the short and medium term. If storage is available, farmers will very likely be able to fetch higher prices per unit weight of their potato as market demands increase.

The killer barriers for this technology transfer is the capital costs and time constraints for upgrading the UB Micro-Propagation Laboratory facilities and building necessary technical capacity. Also, another barrier is the need to accelerate the actual micro-propagation of imported 'Source Basic Seeds (i.e. clean parent material) to micro-tuberization stage, reproduction of mini-tubers in screen houses (protective covered structures), and then mini-tuber germination to produce certified seed-tubers for farmers. However, the propagation of new batches of clean, planting material will be staggered and ongoing, once the process commences; so, there will always be mini-tubers in storage and at the stage of germination, to produce additional quantities of certified seed-tubers for growers. Trials on different varieties of Irish potato could be encourage at random, specifically for varieties that meet certain market demand, both locally and regionally, and in this way, Belize may be able to develop a profitable, potato production industry.

2.5.3 Identified measures

The ‘measures’ and ‘results’ to achieve the proposed Objective: “Climate resilient varieties of Potato seed micro-propagated in country”, were analysed in the Objective tree depicted in Figure 14 and presented in a matrix in Table 9. The green-shaded boxes in the Objective tree provide one option for a strategic pathway to effectively realize the general Objective stated.

The measures and results in Table 9 are not necessarily in an order of importance but can later be arrange in perspective in a formal strategic plan. However, first and foremost would be policy framework: “A policy and strategic plan to effectively address the reality of potato cultivation”, followed by addressing the “institutional and technical capacity” to implement actions to expand potato cultivation in Belize. Next would come the “Political will and budget allocation for programs in climate resilient Irish Potato cultivation”. Local funds and Donor Agencies resources will have to be procured to successfully impellent the programme of actions. Beneficiaries will include: existing and new potato-growing farmers, MOA, consumers, University of Belize Faculty of Agriculture, Partners in R&D in Agriculture, and other stakeholders.

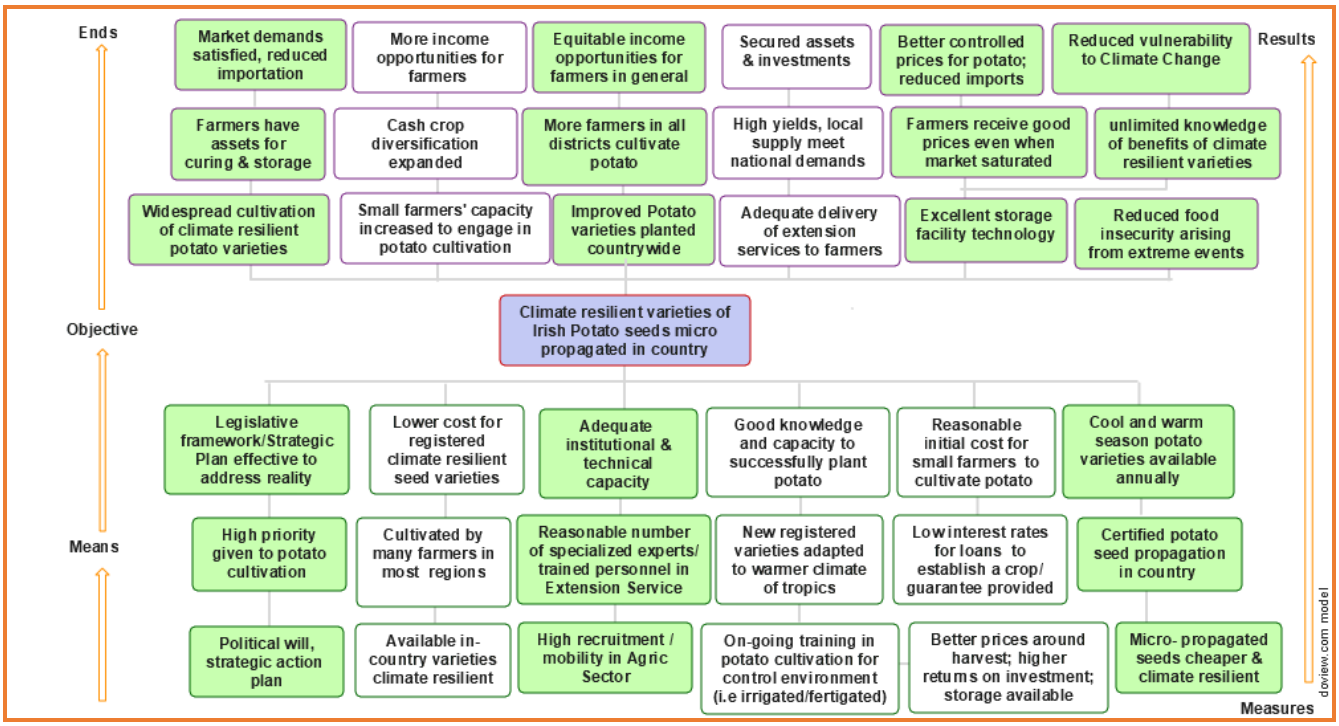


Figure 14: Objective Tree for in-country micro-propagated climate resilient potato seeds

Table 30: Proposed strategic pathway for objective, 'Climate resilient varieties of Irish Potato seed micro-propagated in country'

Objective	Measures	Results	Timeframe
Climate resilient varieties of Irish Potato seeds micro-propagated in country	Adequate institutional and technical capacity	Climate resilient Irish potato varieties planted in most localities	Medium to long term
	Reasonable number of specialized experts/trained personnel in Extension Service	-Increased knowledge of the benefits of climate resilient potato varieties; -More farmers cultivate potato; -equitable income opportunities for more farming communities.	Short/medium term
	High recruitment / mobility in Agriculture Sector & agro-industry	Adequate delivery of Extension Service to farmers.	Short/Medium term
	Policies & strategic plan of action effective to address reality	Market demands satisfied; increased agro-processing and added value industries; reduced importation of potato	Medium/long term
	Political will and budget allocation for programs in climate resilient Irish Potato cultivation	-farmers have resources for curing/storage -Increased income for farmers; stimulates local economy	Medium term
	Low importation duties and taxes for Breeder seed material benefiting importers/seed propagation laboratory	Micro propagation Laboratory facilities expanded. Specialized training; increased R&D programme	Medium term
	Micro-propagated seeds cheaper & climate resilient	Higher yields; fair control prices and reduced food insecurity arising from extreme weather	Medium/long term

	Funds available for more farmers to acquire certified seeds (sources: DFC/Banks/Credit Unions)	Stemmed foreign exchange of dollars & reduce food insecurity	Medium/long term

2.5.3.1 Economic and financial measures

The short list of economic measures includes:

- Procure funds for pilot project to conduct a feasibility study/guidelines and procedures to conduct successful climate resilient potato seed micro propagation and protected cover nurseries for certified seedling trials
- Develop and marketing strategy for sale of in country, micro-propagated Irish potato 'certified' seeds.
- Funds available in the form of soft loans for more farmers to acquire certified seeds and expand potato cultivation (e.g. from DFC/The National Bank/Credit Unions etc.).
- Low importation duties and taxes for Breeder seed material benefiting importers/seed propagation laboratory
- Government facilitate market opportunities for potato producers, including "value added";
- Increased job opportunities that stimulate local economy.

2.5.3.2 Non-financial measures

Critical none-financial measures identified were:

- Cool and warm season, climate resilient potato varieties available;
- Micro-propagated seeds cheaper and climate resilient;
- A more trained and energized Extension Service providing technical advice to potato growers in Belize;
- Benefits of 'added value' encourages more farmers to purchase and cultivate micro-propagated, climate resilient varieties
- Potato crop treatment and cool storage facilities increased at key locations.

Table 31: Summary of barriers and corresponding measures for micro-propagated production of clean, climate resilient Irish potato seed-tubers

Categories	Identified Barriers	Measures to overcome barriers	Intervention		Funding Sources	
			Legal	Other	National	External
Economic and financial	−High initial investment	− Expand access to finance		√	√	√
	− Limited subsidies for technology components	− Lobby for reduced import Tax on equipment and seeds	√		√	
	− High cost of installation	− Provide technology companies & suppliers with concession to service specific areas or groups of clients at reduced service costs (Public-private partnership)		√		√
Market conditions	− Gaps in technology value chain	− Set up local assembling industry		√	√	
	− Local hardware stores often low in stocks of spares & components	− Improve access to products and services. Grow the market for new technology		√	√	√
	− Unstable, monopoly, special interest groups	− Implement policies & regulations for favourable market climate	√		√	
	− Inadequate policy and regulatory framework	− Improve policy and enabling environment (e.g. seed policy, market liberalisation, protectionism, monopoly of incumbent technology)	√		√	
Legal and regulatory	− No office of testing and certification	− Establish regulatory agency for standards, testing and certification (equipment, seeds, etc.)	√		√	√
	− Import of cheaper, inferior-quality equipment/products	− Strengthen regulatory framework (e.g. implementation & penalty)	√		√	
Network structures	− Networking among professionals and agencies weak and ineffective	− Enhance networking for certified seed production/ improved drip irrigation / potato cultivation chain		√	√	√

		actors. −Strengthen research, development and demonstration of new technology				
	− Farmers cooperatives generally work in insolation (crop specific)	− Strengthen Cooperative Dep. and form an association of farmer's cooperatives	√		√	
	− Limited farmer to farmer visits	− Increase local and regional farmer's networking		√	√	√
	− Limited awareness and knowledge of new technology	− Establish management programme and education/awareness campaign among key stakeholders for new technology		√		√
Others	− Low technical capacity	− Establish training component in technology diffusion programme		√		√
	− Farming communities and farmers suspicious − afraid of change	− Through technology diffusion programme address social, cultural and behavioural issues; improve KAP* among users		√		√

2.6 Linkages of the barriers identified

Table 10 is summary of the linkages of critical barriers per prioritized technology in the Agriculture Sector. These critical barriers were discussed in small, stakeholder's group meetings, and a couple were drawn directly from proceedings of several policy meetings in the Ministry of Agriculture in 2017. The tick marks indicate the barrier linkages among the proposed technologies in the TNA process.

Table 32: Linkages of Barriers by Technologies in the Agricultural Sector

Barriers	***Improved Drip Irrigation / Fertigation / Water Catchment***	***Grain production of climate resilient varieties of Corn & Beans seeds***	***Cooling System for Crop Cover Structure/Belhouses / Tropical Greenhouses***	***In-country micro-propagation of climate resilient Potato seeds***
1) Inadequate and incoherent policy incentive frameworks (e.g. absence of a seed policy)	√	√		√
2) Weak governance systems and mechanisms - monitoring and evaluation systems are still in infancy stages		√	√	√
3) Regulations that support contract farming or provide a fair operating field for producers and buyers not available		√		√
4) Local market opportunities are limited; *centros de acopio y servicio* - buying agricultural centres) not well developed, still in infancy		√		√
5) Value Added (additions) still in its infancy among small producers and agro-processors		√		√
6) Poor infrastructure, including SPS, standards, food safety monitoring	√	√	√	√
7) Affordable credit and financing not easily accessible to small producers	√	√	√	√
8) Low levels of productivity and high production costs especially fuel, agro-inputs		√		√
9) Limited research and deficient	√	√	√	√

extension services to support rural producers				
10) Limited technologies and usage	√	√	√	√
11) Limited resilience capacity to risks (including economic downturn or market volatility) and natural disasters (related to climate variability and change)	√	√	√	√
12) High initial costs		√		√
13) Weak political will and limited subsidies/incentives	√	√	√	√
14) Networking among professionals and agencies weak and ineffective	√	√	√	√
15) Gaps in technology value chain	√	√		√
16) No office of testing and certification for agriculture	√	√	√	√

2.7 Enabling framework for overcoming the barriers in the Agriculture Sector

The enabling framework that exists or will exist at the Ministry of Agriculture level to facilitate technology transfer in the Agriculture sector as outlined by stakeholders during the small group meetings were:

1. Technical cooperation and cooperation with regional institutions such as: CARDI, IICA, INFAP, Mexican Scientific and Technical Cooperation (AMEXCID).

2. Present initiatives of MOA to strengthen its Research and Extension Service including greater emphasis in the use of information and communication technology (ICT) in agriculture.

3. The Ministry's initiative, with the collaboration of IDB, to improve and systematize its agriculture data and information in a way that is readily accessible for decision making.

4. Technical cooperation projects being pursued or will be pursued with FAO, CDB, IFAD, etc.

5. Adoption of a National Agriculture and Food Policy 2015-2030, and the drafting and adoption of an updated Agriculture Development, Management and Operational Strategy (ADMOS), that will both help to steer sustainable agricultural development in Belize for the short and medium term.

6. Climate Smart Agriculture initiative.

Measures at the technical level to attain the stated objectives were analysed with Problem and Solution trees that help to identify a strategic pathway to solve the focal problem and facilitate the transfer of the said technologies.

Table 32 is a matrix of the enabling framework to facilitate the transfer of the prioritized technologies in the Agriculture sector. It considers solutions to the key barriers identified during the consultative process that are current with the short/medium term.

Table 33: Enabling framework for overcoming barriers for technology transfer in the Agriculture Sector

Barriers	Measures	Results	Timeframe	Estimated Cost
1) Inadequate and incoherent policy incentive frameworks (e.g. absence of a seed policy)	- MOA will review and update policies & strategic plan of action to address gaps and needs for sustainable agriculture production - MOA in coordination with local & regional partners will conduct regular and systematic training to upgrade institutional and technical capacity	- Facilitates the implementation and success of TNA prioritized technologies for Agriculture. - Common goal improves cooperation and trust among partners	Medium to long term	Initial Cost: GOB in kind contribution Operational cost: GOB in kind contribution to facilitate technology transfer. Project capital financing covers greater cost of training
2) Weak governance systems and mechanisms 3) Monitoring and evaluation systems are still in infancy stages	- MOA & partners including UB will implement technology transfer programme by which Extension Services/Lab facilities will be strengthened with specialized experts and personnel. - Intervention is underway and will continue to improve and systematize agriculture database and information with support from IDB.	- Professional services offered to farmers and farming cooperatives; - Scientifically compiled and verified agriculture data to inform policies, decisions makers and stakeholders. - Reasonable and measurable indicators developed to measure impacts of TNA project implementation and success. .	Medium/Long term	Cost of this intervention is attributed to the nature of the IDB grant or loan to GOB/

4) Regulations that support contract farming or provide a fair operating field for producers and buyers not available	- Draft and adopt supporting contract farming policies, which will provide a fair operating field for producers and buyers. -	- Minimizes miss-trust, conflicts and animosity; - Establishes a just and more equitable market environment for producers/small farmers and buyers. - Stimulates the economy, keep dollars at home, and benefits the small farmers	Short/Medium term	Initial cost: GOB in-kind contribution and is part of its social contract with producers and consumers
5) Local market opportunities are limited; (buying agricultural centres) not well developed, still in infancy.	- Review and adopt policies and regulations to facilitate local Market opportunities for producers and buyers. -	- Market demands satisfied; increased agro-processing and added value industries; reduced importation of potato, for example. - Farmers get a better price for their produce. - GOB heightens its protection of small producers	Medium/Long term	GOB driven initiative. GOB in kind contribution to facilitate technologies that are increasing agricultural yields.
6) Value Added (additions) still in its infancy among small producers and agro-processors.	- Lobby and advance political will and budget allocation for programs to build climate resilient agro-industries based on 'Value Added' of local produce including: grains, potato, and equipment for tropical greenhouses/Belhouses, and	- Farmers have resources for curing/storage of grains and potato; - Increased income for farmers; stimulates local economy; - increase technical skills	Medium term	Cost will depend on Objective and actions and extent of intervention. Funding will be from both local and international sources.

	components for water harvesting; fertigation, drip irrigation and Solar PV. -	and job opportunities. - increase food security; - Increase adaptation to Climate Change		
7) Poor infrastructure, including Supply, Packaging and Storage (SPS); issues with sanitary and phytosanitary standards; inadequate food safety monitoring, etc.	- Funding will be identified and procured for upgrading/ enhancing infrastructure including SPS, sanitary and phytosanitary standards, and increased food safety monitoring -	- Belize easily meets the requirements for export of its agriculture products - Increased R&D programme under controlled facilities - Facilities at BAHA upgraded to test imported grain and potato 'breeder' seeds.	Medium term	Costs: GOB allocation for improved Agriculture infrastructure
8) Affordable credit and financing not easily accessible to medium and small-scale producers.	- Affordable low-interest credits and financing will be made accessible for small producers interested to invest in improved drip irrigation/fertigation systems; redesigned and cooler protective covered structures; and climate resilient, 'certified' grain and potato seeds.	- Farmers invest in improved technologies and benefit from increased yields and economic returns. - Increased in technical capacity of Extension Service personnel, R&D staff and technicians. - Improved livelihood security for farmers	Medium/Long term	Cost: TNA prioritized technologies cumulative costs (See factsheets for an estimate). GOB in kind contribution through services and training of Extension Service personnel and technicians

9) Low levels of productivity and high input/ production costs especially fuel, agro-inputs, imported equipment/spares	- Request for a reduction in the import duties for equipment components related to agriculture technology transfer - Request tax exception or reduction for spares/components of agriculture equipment and improved technology hardware	- Increased in vestments on improved agriculture technology. - Increased productivity in climate resilient crops (grains, potato, horticulture, etc.). - Reduced input cost for small farmers, increased yields and profits.	Short/Medium term	GOB intervention to facilitate technology transfer and increased production for local, regional and international markets.
10) Limited research and development, and deficient extension services to support rural producers	- Strengthen R&D and Extension Services, putting greater emphasis in the use of Information Communication and Technology (ICT) - Develop a revolving fund for R&D, with seed money procured from Local/Regional/International sources.	- Increased use of ICT in agriculture to provide farmers with: i) timely and relevant information; ii) access to credit; and changing/better market prices - Improved farming systems, increased yields, and reduce environmental impacts	Short /Medium term	Initial cost: US$ 80,000.00
11) Limited technologies and usage	- Procure finance for prioritized TNA project technologies in climate change adaptation from local, regional and international sources as opportunities are identified and acted upon. -	- Increased capacity and institutional strengthening in the Agriculture Sector; - Increased job opportunities; - Improved yields; - Increased economic	Short to Medium term	The costs are multiple and depend on the specific interventions being considered and/or implemented.

		benefits for farmers; - Reduced food insecurity; - Will contribute to achieving MDG # 8.		
12) Limited resilience capacity to risks (including economic downturn or market volatility) and natural disasters (related to climate variability and change)	- Increase knowledge, capacity and resources of stakeholders and farmers to build resilience and enhance their livelihood. - Establish a risk transfer mechanism/multi-peril crop insurance scheme to cover losses due to extreme events and market volatility. - Increased crop diversification among farmers that are engaged in cultivation of only staples or traditional crops	- Increased resilience to climate change impacts among small farmers; - Disaster risk reduction enhanced among farmers, who can easily recover from the impacts of extreme climatic events, poor yields, and market volatility.	Short/Medium term	Costs to increased multi-peril resilience must be borne by GOB through multi-interventions, procuring seed money for a revolving risk transfer programme, and in-kind contribution for DRR in the Agriculture Sector.
13) High initial costs for new and improved technology	- Reduced import duties and taxes on hardware and spares/components for Agriculture technology transfer. - Procure finance from multiple sources to offset high initial costs	- New and improved agriculture adaptation technologies pilots implemented. -	Short/Medium term	Cost are multiple and technology specific. See factsheets for a preliminary estimate per technology
14) Weak political will and limited subsidies / incentives for small farmers	- Partners and stakeholder adocate for increased action from area representative - Lobby for reduced import duties; - increase market opportunities for farmers	- Policymakers and Area Representatives on the side of small farmers - Increased investments in new and improved technology	Short/Medium term	Cost of advocacy borne by local farmers groups, partners in Agriculture, the private sector, NGOs, and others. GOB absorbs cost for

	-	- Farmers get a better price for their products		financial incentive/subsidy.
15) Institutional conflicts and overlapping roles, (turf protection)	- Upgrade MOA human resources programme for efficient and effective cooperation and resources utilization. - Strengthen partnerships and identify common goals among key Agencies in the Sector. -	- Enhanced professional partnerships between MOA and key national, regional and international agencies. - Increased trust among farmers and MOA, and other private sector entities.	Short/Medium Term	Initial cost: Minimal. MOA can coordinate this effort among key stakeholders in the public and private sectors, and at the Regional and International levels
16) Non-enforcement of the Land Use Policy creating an inbalance in the ecosystem and impacting on biodiversity	- Ensure the implementation of the Agriculture and Food Policy 2015-2030 which addresses climate change impacts and integrated water resources management in agriculture, and biodiversity conservation. - Strenghten the Water Resources and Climate Change Unit in the MOA.	- Increased training of farmers biodiversity conservation and water management in watersheds - Improved drip irrigation / fertigation system technology help reduce the impact on biodiversity and increased, unsustainable land use - Improved water resources management and increased yields	Short to Medium term	Initial cost for proposed six improved drip irrigation / fertigation systems with RE component for pilot demonstration and training is: US $ 126,800 Operating cost per annum: US$ 45,000

17) Knowledge, Attitude, Perception (KAP) on the impacts of Climate Change among farmers is generally below average	- Synergize the Water Resources and Climate Change Unit with the Extension Services to conduct education and outreach to farmers.	- Climate Smart Agriculture Country Profile is being conducted for Belize under a World Bank funded project (2018). - Expanded knowledge and positive attitude and perceptions of the impacts of Climate Change among farming communities.	Medium term	Initial Cost: US$ 80,000.00

CHAPTER 3. Coastal and marine ecosystem sector

3.1 Preliminary targets for technology transfer and diffusion

One of Belize's natural and greatest assets 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.

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.

Increasing the capacity of the Fisheries Department to monitor and evaluate the physical and anthropogenic-related changes and impacts in the coastal and marine ecosystem, is important in improving the management of coastal and marine resources. The proposed technology transfer of an upgraded coastal zone monitoring network and Early Warning System is an essential component to this end.

Table 33 below is a summary of technology targets for the coastal and marine sector and the benefits versus costs.

Table 34: summary of technology targets for the coastal and marine sector

Sector: Technologies	Targets / beneficiaries	Too Ambitious or not	Conservative
Coastal & Marine			
1. Marine Environmental Monitoring Network & Early Warning System	-Fishers and fishing communities; -Tourism sector and coastal developers; -Other communities; -light industries and infra-structure integrity -partners in CZM	-Not necessarily so. The benefits can be directly or indirectly far reaching. The coastal zone is a vital economic zone and home to just over 40% of the country's population. Also, about 30% or more of GDP is directly linked to commercial activities in the coastal zone,	Yes. The benefits of establishing a modern and reliable environmental monitoring network and marine early warning system for the coastal and marine environment far out weighs the costs. The preliminary costs for establishing and operating the monitoring network and early warning system with proper communication system and other components is: US$ 177,965.33. Operational cost for five years US$ 84,491.34.

3.2 Barrier analysis and possible enabling measures for Belize's Coastal Zone monitoring network and Early Warning System

Some critical barriers identified by stakeholders during the working sessions held at the Fisheries Department conference facility, that can restrict the implementation of an effective, environmental coastal and marine monitoring network and early warning system include:

- The lack of an integrated, strategic environmental monitoring and evaluation plan and early warning system for the coastal and marine zone.
- High cost of marine monitoring platforms and deployment.
- High operational and maintenance costs.
- Lack of cost-benefit analysis to highlight the advantages for establishment an effective marine environmental monitoring network, and early warning for stakeholders.
- None-existing national policies to monitor impacts of current agricultural and tourist-centric development practices to ensure viable Zone of Influence (ZOI) to the coastal zone.
- Increasing threat to marine and coastal zone resources and use.
- Failure in many instances to follow the coastal zone management plan (GOB/GEO, 2010).
- Limited long-term research in coastal communities.
- Limited enforcement of national regulations to protect coastal resources.
- Variable or limited knowledge of the impacts of climate change on marine ecosystems.
- Lack of historic and current oceanographic/marine resources database.
- Inadequate, high-capacity human resources.
- Lack of effective synergy and coordinated work programme with other key agencies/departments/ministries/NGO/communities in coastal zone management.
- Lack of adequate finance for effective regulatory and enforcement mandate and R&D.
- Institutional capacity for the sector have room for improvement.
- Weak coordination and cooperation with developers and key stakeholders in implementation and compliance of fisheries regulations, and coastal zone management programmes.
- Limited resilience capacity to risks (including economic downturn or market volatility) and natural disasters (related to climate variability and change).
- Illegal fishing and resource extraction common.
- Failure to establish and maintain credibility with public evident at times.
- Implementing same old strategies and expecting different results.
- The impacts of climate change coupled with anthropogenic stressors not fully understood by majority of stakeholders.
- Restrictive/weak coordination among regulating agencies/departments/ministries / NGOs / communities in the coastal zone

Selection and decomposition of critical barriers for transfer of technology for a Marine environmental monitoring network and early warning system

Table 34 is a summary of the selection of critical and crucial barriers to the transfer and diffusion of the technology to develop an effective, environmental marine monitoring systems and early warning system, based upon criteria on a Likert scale, and their importance. Table 35 shows a simple decomposition of the killer and crucial barriers identified during the selection process.

Table 35: Criteria and Importance of barriers impeding the transfer of technology for a marine environmental monitoring network and early warning system

No.	Barriers	Criteria and Importance of Barriers for Technology 2					
	Economic & Financial	**1. Critical (killer, non-starter)**	**2. Crucial**	**3. Important**	**4. Less important**	**5. Insignificant (easy starter)**	**Rank**
1	- High Initial costs for procuring and establishing a fully operational marine monitoring platforms and deployment	x					1
2	- Lack of an integrated, strategic environmental monitoring and evaluation plan and early warning system	x					1
3	- Credits and limited low-interest financing, and non-favourable payment plans			x			3
4	- High import taxes and limited subsidies		x				2
5	- High operational and maintenance costs	x					1
6	- Elevated financial risks to programme due to vandalism		x				2

	and praedial larceny						
7	- Elevated financial risks to programme due to extreme climatic event			x			3
8	- Foreign exchange and corresponding banking				x		4
9	- Lack of cost-benefit analysis to highlight the advantages for establishment of an effective marine environmental monitoring network, and early warning						
	- Lack of adequate finance for effective regulatory and enforcement mandate and R&D			x			3
	Non-financial						
	- Limited environmental monitoring and enforcement in the face of increasing threat to marine and coastal zone resources and use	x					1
	- None-existing national policies to monitor impacts of current agricultural and tourist-centric		x				2

	development						
7	- Illegal fishing and resource extraction common			x			3
8	- Weak co-ordination and cooperation with developers/key stakeholders in implementation and compliance of fisheries regulations				x		4
9	- Limited subsidies and incentives		x				2
10	- Institutional capacity of regulating agencies need strengthening		x				2
11	- Restrictive/weak coordination among regulating agencies/departments/ministries / NGOs / communities in the coastal zone		x				2
12	- Limited technical capacity		x				2
13	- Rising fuel costs			x			2
14	- Failure in many instances to follow the coastal zone management plan			x			3
	- Imported equipment not of the best quality		x				2

Table 36: Selection of killer or non-starter barriers for technology transfer of a marine environmental monitoring network and early warning system

Category of Barriers	1. Critical (killer, non-starter)	2. Crucial	Elements of killer or non-starters	Dimension of barrier elements
Economic & Financial	- High Initial costs for procuring and establishing a fully operational marine monitoring platforms and deployment. - High operational & maintenance costs.	- High import taxes and limited subsidies - Elevated financial risks to programme due to vandalism and praedial larceny - Rising fuel prices	- High interest rates - High import duties of components - Elevated cost of specialized technical services - - High cost for technical services - Funds for spares and components may be in accessible - Risk costs arising from vandalism, praedial larcerny and natural hazards may be high	- 12 – 15 % on certain components - Service cost could be as high as 15 % of capital cost - Interest rates could be 6 to 12 % per annum - Specialized technical service providers/personnel not available locally - Elevated costs to upgrade sensors and commnunication system - No insurance or a lack of a risk transfer nechanism.
Market failures	-	- Imported equipment not of the best quality. -	- Unsatisfactory procurement practices - Bad experience with mal-functioning system - Supply greater than demands - Inaccessibility to spares	- Field trials in the tropical marine environment not rigorous - Costly equipment not necessarily the best in the market - Poor maintenance - Indequate designed sensors
Non-financial	- Limited environmental monitoring and enforcement in	- Institutional capacity of regulating agencies need strengthening	- Limited enforcement - Increase encroughment and	- Resource depletion - Less income for stakeholders -

	the face of increasing threat to marine and coastal zone resources and use. - Incoherent environmental monitoring and evaluation plan & early warning system. -	- Limited subsidies and incentives - Restrictive/weak coordination among regulating agencies / departments/ministries/ NOGs / communities in the coastal zone. - None-existing national policies to monitor impacts of current agricultural and tourist-centric development -	illegal fishing - Illegal dredging and indiscriminate development - Decreasing catch - - Increased pollution - Coral reef bleaching - Limited monitoring and interaction	- Undersize catch - - - - - - Poor water quality - Die back and negative impacts on marine ecosystems - Early warning and advisories not coordinated and disseminated on a timely basis

Enabling environment elements were listed by the working groups in order of importance as follow:

- The Fisheries Department, CZMAI, and local NGOs have extensive experience working in the Belize Coastal Zone.
- Some institutional capacity exists.
- Increase in national and regional scientific research and access to research results.
- Both Fisheries Department and CZMAI are executing sustainable fisheries and climate change projects, such as the MCCAP and the Estuarine Water Quality Monitoring.
- The recently adopted National Integrated Coastal Zone Management Plan for Belize: Creating a Blueprint for Sustainable Coastal Resources Use" (CZMAI, 2016), provides a framework and guidance for sustainable use of marine resources.
- The Tourism Sector and other related productive sub sectors in the Coastal Zone are vitally important to the economic development of the country. Industries in the Coastal Zone contributed about 60% to GDP in 2016.
- Belize's Barrier Reef (the largest proportion of the Meso-American Barrier Reef System) is a critical national assess, and a habitat for numerous marine species.
- Fishery is the livelihood of thousands of Belizeans and must continue to be managed sustainably.
- Legal framework empowers Fisheries Department and the CZMAI to regulate and manage resource uptake and sustainable development enterprise in the Coastal Zone.
- Marine Protected Areas (MPAs) and No-Take-Zone are now being respected and observed by stakeholders.

- Fairly good communication exists in the Coastal Zone.
- Fisheries and co-management NGOs/University of Belize already have some establish monitoring sites…Calabash Caye, South Water Caye, Hol Chan Marine Reserve, Half Moon Caye, Gladdens Spit, to name a few.
- Belize Coast Guard has a foreword base near Belize City, and operational centres in several localities in the coastal zone.
- Tax exemption in place for importation of Government-commission, scientific, marine monitoring equipment.
- Environmental advocacy has played an important in campaigning for policies and management strategies that focus on balancing the needs of various industries and sustaining the health of the costal zone (State of the Belize Coastal Zone: 2003-2013, CZMAI, 2014).

3.2.1 General description of Belize's Coastal Zone monitoring network and Early Warning System

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.

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*. Reliable environmental early warning systems improve climate risk planning, management and action, and are necessary to address the impacts of Climate Change, especially coral bleaching and fish stock migration and influx/control of invasive species.

The threats to the coastal zone arise from a number of activities connected with tourism and recreational facilities, increase in population and urban expansion, utility supply, dredging and minerals extraction, land clearance and mangrove deforestation, pollution, waste disposal, fisheries/illegal fishing and aquaculture, and agriculture runoff (CZMAI, 2014).

Some pollution and ecosystem health indicators in the marine environment are: Water Clarity, Total Dissolved Oxygen, Coastal Wetland Loss, Eutrophic Condition, Sediment Contamination, Benthic Index, Fish Tissue Contaminants, Manatee and Fish Kill, and Multiple Marine Ecological Disturbances (e.g. coastline erosion rates, coastline retreat, sea level rise, etc.) (Guefact, 2007).

Earlier in 2016 the Government of Belize adopted the "National Integrated Coastal Zone Management Plan (ICZMP) 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 has installed 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 was partner with the Caribbean Community Climate Change Centre (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 less than two years; thereafter the onboard sensors began mal-functioning, and data recording and acquisition stopped. Maintenance of these monitoring platforms was not conducted as scheduled and the marine environmental network fell into disrepair and CREWS monitoring programme in Belize ended.

The Fisheries Department proposes to upgrade their 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.

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 (tidal fluctuation), 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, Faecal Coliform, E-coli, Total Bacteria, etc. during the proposed five years of the project cycle.

5. Develop protocol to retrieve, quality check, archive, and process/analyse data and information for Early Warning Bulletins for stakeholders, including policymakers.

6. Maintain updated and accessible environmental and marine database for research and marine study, policy recommendation, management strategy and the annual State of the Belize Coastal Zone reports.

The GOB through the Fisheries Department will spearhead this intervention and the dissemination of information and regular 'early warning' bulletins among key stakeholders.

Supporting Department and Agencies in the Coastal and Marine Ecosystems Sector

The key stakeholders for the TNA adaptation intervention in the Coastal and Marine Ecosystem sector include: Fisheries Department, the Coastal Zone Management Authority and Institute (CZMAI), Fishing Cooperatives and members, the National Meteorological Service, Forest Department, 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.

Fisheries Department

The Belize Fisheries Department in the Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development (MAFFESD) is responsible for conservation and sustainable use of fishery resources, registration and licenses, fisheries research, education, liaise with fishing cooperatives, management of marine reserves, enforcement of fishing laws and regulations, export and research permits.

The Fisheries Unit Laboratory became a Department in 1987. The establishment and management of the Fisheries Department is legally facilitated through the Fisheries Act of 1977 and its subsidiary regulations.

Ongoing intervention is the five-year Belize Marine Conservation and Climate Adaptation Project (MCCAP), implemented by the World Bank and funded by an Adaptation Fund grant is the sum of US$ 5.53 million, and US$ 1.78 million in-kind contribution by the Government of Belize. The objective of the MCCAP is to implement priority ecosystem-based marine conservation and climate adaptation measures to strengthen the climate resilience of the Belize Barrier Reef System. The timeframe of the MCCAP is 2015-2020. The vision for the Fisheries Sector of Belize is captured in Figure xxx, as illustrated in the 2012 draft of the Economic Alternatives and Fisheries Diversification Plan commissioned by the Fisheries Department in collaboration with the Nature Conservancy.

Vision of the Fisheries Sector of Belize

By 2023, fishing communities have a high standard of living with diversified income sources based on multiple economic activities including the sustainable harvesting of a healthy fishery with effective collaboration among all stakeholders.
(Source: Shal, V., O. Salas, N. Requena, 2012)

More information on the Fisheries Department can be accessed from: www.fisheries.gov.bz/.

*Coastal Zone Management Authority and Institu***te** (CZMAI)
The CZMAI was established as a statutory body within the public service through the 1999 Coastal Zone Management Act and is envisioned as the Agency to carry out relevant research and monitoring of coastal ecosystems, in order to inform effective coastal zone management of the Authority. The CZMAI has the mandate to manage the coastal zone of the country by drawing from technical expertise and findings from the Institute as well as from an advisory board comprising of various private and public-sector stakeholder agencies (CZMAI, 2004).

Key Supporting Departments and Agencies for the Coastal Zone and Marine Sector

Other key supporting departments and agencies include the:

- *Ministry of Economic Development, Petroleum, Investment, Trade & Commerce;*

- *Belize Customs and Excise Department;*
- *Belize Trade and Investment Development Service (BELTRAIDE);*
- *Protective Area Conservation Trust;*
- *National Meteorological Service (Meteorology Department);*
- *Forest Department;*
- *Department of the Environment;*
- *Belize Coast Guard;*
- *Pan American Development Foundation;*
- *Fishing and Marine Products Co-operatives; and*
- *Several UN Agencies and NGOs.*

The existing co-operatives in the Fishing and Marine sub-sector are: National Fishermen, Northern Fishermen, Placencia Producers, and the Rio Grande Fishermen Co-operative.

Further information on these supporting agencies for the Marine and Coastal Zone sector can be reviewed in Annex X of this report.

3.2.2 Identification of barriers for Belize's Coastal Zone monitoring network and Early Warning System

Barriers to consider in the technology transfer of equipment for marine environmental monitoring net work

Barriers were identified in key components for this technology in the Coastal and Marine Ecosystem Sector:

- **Financial Barriers**

High upfront costs for marine environmental monitoring equipment and spares is a barrier that may easily discourage potential investors.

Organizational/regulatory Barriers

- Many organizations operate in the Coastal Zone but some work in isolation. Coordination and synergy among some key stakeholders is lacking. Fisheries regulations are in place and are arduously being implemented, but there are those stakeholders that have maintain that measures are too restrictive and affect their livelihood.

- **Weak Enabling policy environments for establishment of adequate Marine Environmental Monitoring Network.**
  Currently, marine environmental monitoring is being done for water quality and other physical impacts along coastline and the barrier reef. However, the data collection covers only small sections of the marine environment and historical data is fragmented or periodic, and key indicators/parameters are missing. The Coastal Zone Development and Management Plan makes provision for comprehensive marine

environmental monitoring, but capacity, professional human resources and financing are major barriers for an improved and extended marine environmental monitoring network.

- **Incumbent Technology**
  Investments in marine environmental monitoring platforms and network have been carried out in the past through many projects and scientific research programme. However, sustainability has proven to be a major problem as funding dry-up and plans to maintain the monitoring network fall apart for lack of finance, decreased I institutional capacity and phasing out of old technology by new, improved and faster systems. This can be a major hurdle in the establishment of a modern, high technology marine monitoring network for the long haul, and workable measures must be implemented for sustainability and safeguarding the capital investment.

- **Information Barriers**
  Information on the most reliable, high precision, durable and affordable marine monitoring platforms or sensors is available. In formation on environmental monitoring systems is not a barrier per se; however, the use and its interpretation can be a barrier by the inexperience technicians, clients or environmental officers.

- **Technical Barriers**
  Operation and maintenance of an efficient marine environmental monitoring network requires technically skilled technicians. Most of these skill persons are in the Private sector, but many are available in the Public sector. Capacity in the Fisheries and CZMAI is limited, but personnel can be trained to operate the marine monitoring network.

Figure 15 is a problem tree analysis on the "Increasing threats to coastal zone resources and use". The problem tree analysis was conducted with the marine STWG, during which participants identified some of the key barriers to the transfer of marine monitoring platform technology, to provide timely, scientific information to help address the threats to marine ecosystems and the sustainable use of resources. The legal framework for coastal zone management and resource use exist, but the implementation of the same is weak in many instances. Political will is becoming more evident, but sufficient budget for conservation programme and monitoring compliance with the law/regulations is often insufficient. Environmental monitoring by the Fisheries Department is currently none existent, while the database for historic marine elements is disjointed and of short duration (J. Azueta, Project Coordinator, personal comm. October, 2016). The lack of funding for R&D and also for environmental monitoring and evaluation (M&E) constraint the delivery of technical/professional services to stakeholders.

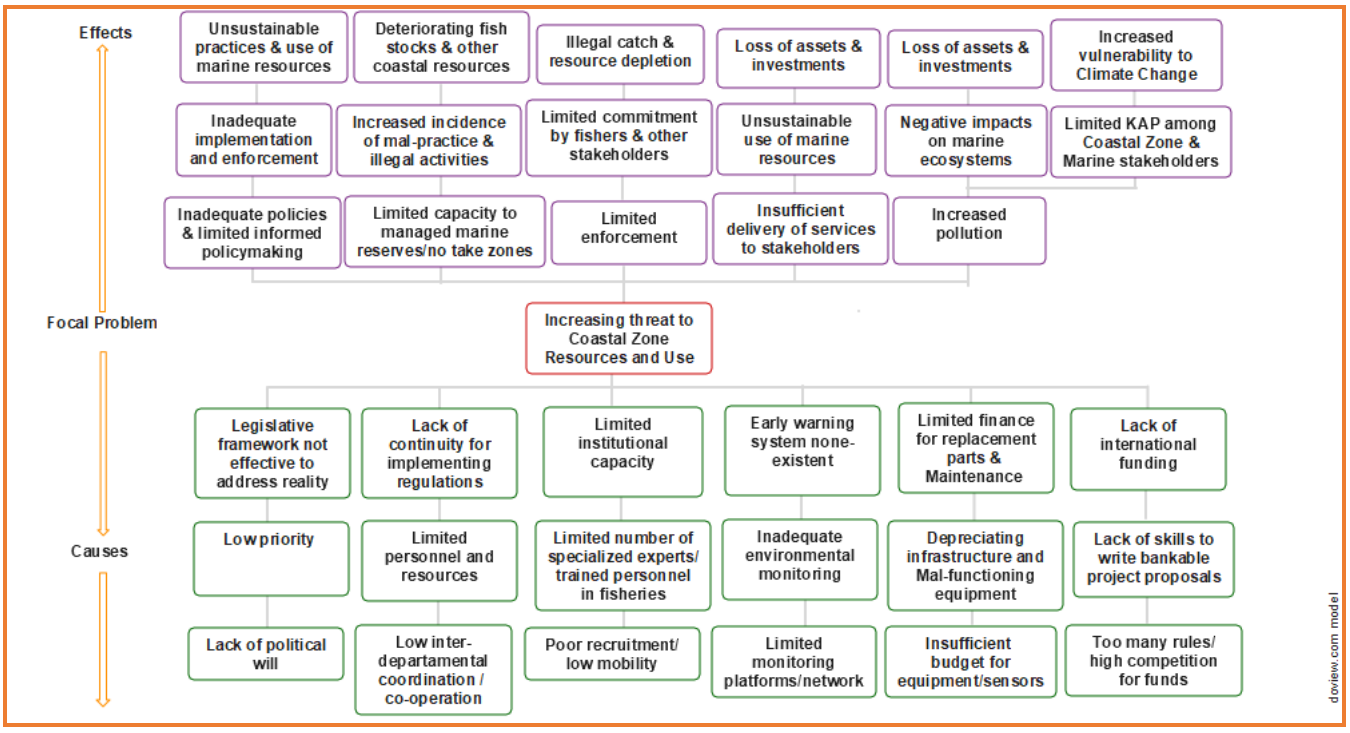


Figure 15: Problem tree for increasing threat to coastal and marine resources and use

3.2.2.1 Economic and financial barriers

Stakeholders indicated that the main economic and financial barriers that may hamper the transferal of technology for the establishment of a marine environmnetal monitoring network and Early Warning system is capital funds of equipment purchase, deployment and spares, as can be obsered in the problem tree analysis and in the summary of critical barriers in Table 35. Annual bugetary allocation for effective regulatory duties by the Fisheries Department covers the basic costs of enforcement, but finance for R&D is available only through projects and in-kind contributions from partners (CZMAI, 2014). Local finance for R&D is often unavailable for institutional scientific research. The Government of Belize in kind contribution will assist to meet maintenance costs once the equipment is deployed and the monitoring network is functioning. Another economic barrier is the inability of local institutions to access financial assistant from international donors because of the complicated requirements involved, and the lack of local experts who can prepare good proposals that can attract funding.

Preliminary Economic Evaluation for Establishment of a Coastal Zone Environmental Monitoring Network and Early Warning System

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 and plans to coordinate the climate change adaptation technology for the Coastal and Marine sector, namely: *Improved Marine Monitoring Network and Early Warning System for Belize's Coastal Zone to Increase Resilience to Climate Change*.

Preliminary estimates for the capital investment and operational cost are shown below.
Capital Investment: 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).

3.2.2.2 Non-financial barriers

The main none-financial barriers to the successful establishment of the marine environmental monitoring network as envisage by the Fisheries Department include:

- Elevated risks to the project resulting from extreme climatic events in the western Caribbean.
- Vandalism resulting in loss of expensive equipment.
- Change in political administration resulting in a change of priority and strategy.
- Change in management, personnel and governance that may impact the Fisheries sector.
- Weak advocacy that does not inform better policies/regulations for integrated and sustainable management of marine resources and build stronger partnership among stakeholders.
- Distrust/lack of communication among stakeholders and coastal communities on critical issues.
- Weak implementation of regulations and adherence to conservation protocols
- Failure to follow the Integrated Coastal Zone Management Plan.

- Lack of synergy among partners on critical issues like pollution, effluence discharge, offshore oil exploration, no-take-zones, mangrove forest degradation, dredging in sensitive areas, coral reef bleaching, fish stock depletion, etc.

3.2.3 Identified measures

Figure 16 is the objective or solution tree analysis of measures to reduce the barriers to the transferal of technology for establishing a modern, marine environmental network of monitoring stations to provide daily needed information for a timely and reliable coastal zone Early Warning System. The general objective is: "Early Warning contributes to decrease threats to Coastal Zone resources and use". One strategic pathway to achieve this objective is to integrate the 'boxes' shaded in green in the 'means' and 'end' portion of the Problem tree diagram.

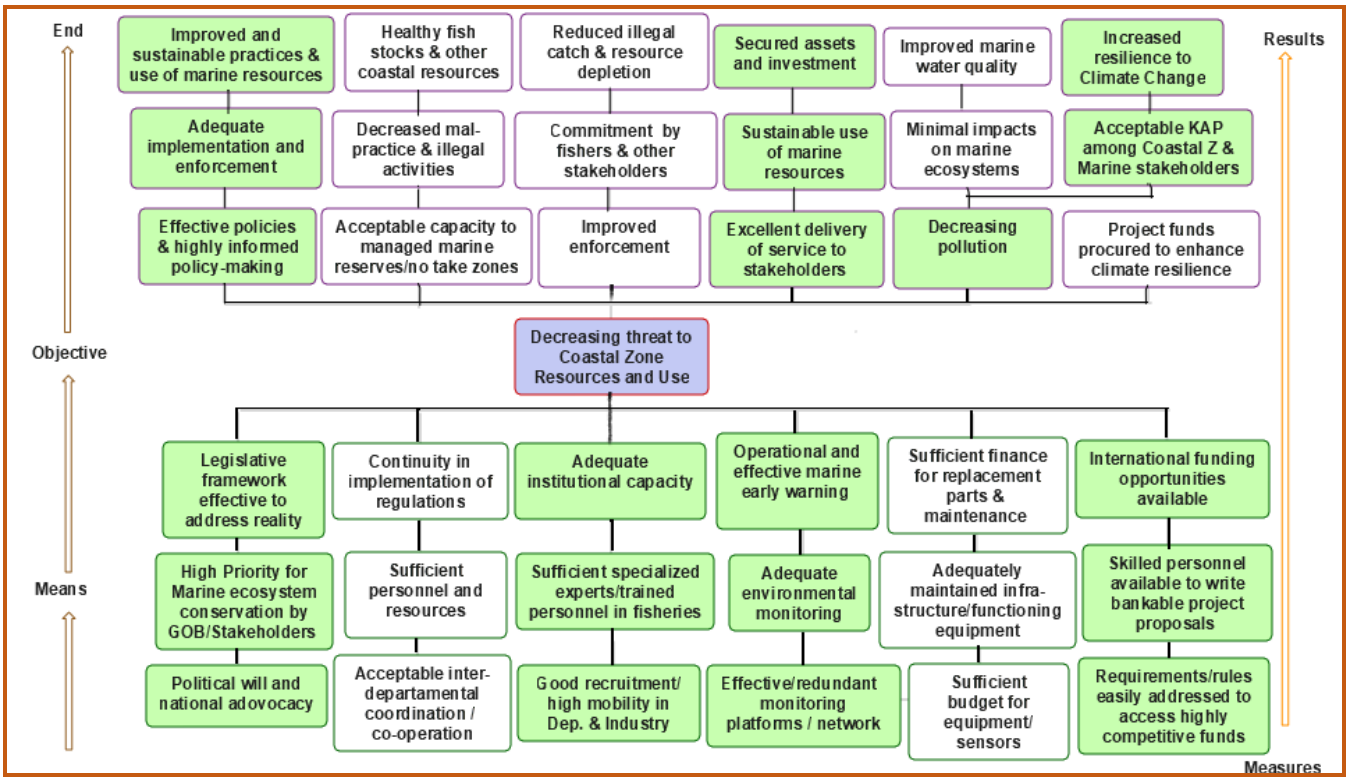


Figure 16: Solution tree for, 'Early Warning contributes to decreased threat to coastal and marine resources and use'

The proposed strategic pathway is illustrated in Figure 17. Central to the means or measures are: a) Enhance the institutional capacity of the relevant Government agencies and their partner. This is a difficult task, but with the political will and strategic management plan, short and medium-term funding can be identified at the local and international levels. This will facilitate an increase in professional staffing and experts to conduct research and development, and provide scientifically sound data to inform policies and provide an

effective and timely Early Warning for coastal and marine stakeholders and policymakers. The other measures and results all support the objective.

Table 37: Proposed strategic pathway for objective: 'Early Warning Contributes to decreased threat to Coastal Zone Resources and Use'

Objective	Measures	Results	Timeframe
Decreased threat to Coastal and Marine resources and unsustainable use through improved marine environmental monitoring and Early Warning System	Upgrade institutional capacity and effectiveness of key agencies (Fisheries Dep, CZMAI, etc.)	- Improved the enforcement of regulations and provided professional services to stakeholders	medium to long term
	Increase the number of specialized experts/trained personnel in fisheries	- Effective policies and highly informed sector - Improved services and research	medium term
	Upgrade the implementation of legislative framework / regulations	- Effective implementation and enforcement of regulations	Short/Medium term
	Foster at all levels, high priority for marine ecosystem conservation (Public & private stakeholders)	Sustainable practices & use of marine resources among fishers and other stakeholders. Acceptable KAP among coastal zone & marine stakeholders	Short/Medium term
	Increase advocacy among partners/stakeholders for the ICZMP implementation	Healthy fish stock & other marine resources	Short/Medium term
	Establish an operational and effective marine Early Warning system and delivery	Excellent delivery of services (including data access and an effective Marine Early Warning) to stakeholders	Medium/Long term
	Procure and deploy an effective & redundant monitoring marine environmental network	Reliable and timely data to enhance marine data base	Medium/long term
	Train key personnel to develop skills to write bankable project	Reduced illegal catch and resource depletion	Short term

	proposals and management projects		
	Identify and access International funding opportunities	Secured finance and investment	Short/medium term
	Implement measures to keep operational and maintenance costs at an affordable level	Sustainability of marine environmental monitoring programme	Medium/.long term

*KAP: Knowledge, Attitude and Perception

3.2.3.1 Economic and financial measures

Capital investment for procuring sensors and marine environmental platforms (stations) are available and can be accessed following the proper protocols and meet strict requirements from international donors such as the Green Fund, GEF, the Climate funds and others. Timely and critical local lobbying can often result in the Government of Belize and local partners contributing in-kind assistant to compliment capital financial assistance from international sources.

3.2.3.2 Non-financial measures

Some non-financial measures identified by stakeholders, that may facilitate the smooth transferral of technology for the establishment of a high-techniology, marine environmental monitoring network of observation stations or platforms include:

- Stimulate interest for the marine environment monitoring network and Early Warning System among officials (policymakers) and technical personnel of the Fisheries Department and CZMAI.
- Improve facilities and upgrade technical expertise in the Fisheries Department and among partners (i.e. NGOs, CZMAI, and others) to establish and deploy wireless, monitoring stations at strategic locations across the Belize coastal zone.
- Continue the implementation of Guidelines for effective management of Coastal and Marine resources/reserves as directed in the revise Integrate Coastal Zone Management Plan (CZMAI, 2014).
- Strengthen cooperation and interest among coastal and marine stakeholders and the authorities.

Table 37 summarizes the economic and non-economic barriers and corresponding measures for the transfer and diffusion of the proposed marine monitoring network and early warning system.

Table 38: Market and non-market barriers and corresponding measures related to the transfer of the marine monitoring network and Early Warning

Categories	Identified Barriers	Measures to overcome barriers	Intervention		Funding Sources	
			Legal	Other	National	External
Economic and financial	− High up-front cost of monitoring equipment/platforms	− Expand access to finance		√	√	√
	− High import tax and limited subsidies for technology components	− Lobby for reduced import tax on equipment. Some tax/duties may not be applicable for public goods.	√		√	
	− High cost of installation - High operational and maintenance cost - Elevated financial risks to programme due to vandalism and praedial larceny - Rising fuel prices	− Provide technology companies & suppliers with concession to service specific areas or groups of clients at reduced service costs (Public-private partnership) -		√	√	√
	−			√	√	
Market conditions	− Low stocks of spares & components	− Improve access to products and services.		√	√	√
	− Special interest groups control market share and incumbent technology	− Implement policies & regulations for favourable market climate	√		√	
	− Inadequate policy and regulatory framework	− Improve policy and enabling environment	√		√	
Legal and regulatory	− No office for testing and certification	− Establish regulatory agency for standards, testing and certification (equipment, componenets, etc.)	√		√	√
	− Import of cheaper, inferior-quality equipment/products	− Strengthen regulatory framework (e.g. implementation & penalty)	√		√	
Network structures	− Networking among professionals and agencies weak and	− Enhance networking among key actors and fisherfolks		√	√	√

	ineffective	− Strengthen research, development and demonstration of new technology				
	− Limited environmental monitoring and enforcement in the face of increasing threat to marine and coastal zone resources and use.	− Increase advocacy among partners / stakeholders for the ICZMP implementation	√		√	
	− Incoherent environmental monitoring and evaluation plan & early warning system.	− Establish an operational and effective marine Early Warning system and delivery protocol		√	√	√
	− Limited awareness and knowledge of new technology	− Establish education / public awareness campaign among key stakeholders		√		√
	− Low technical capacity	− Upgrade institutional capacity and effectiveness of key agencies (Fisheries Dep, CZMAI, etc.)				
		- Include training component in technology diffusion programme;		√		√
Others		− Increase the number of specialized experts/trained personnel in fisheries & CZMAI				
	− Low KAP among fishers and other key stakeholders operating in the coastal zone	− Through technology diffusion programme address social, cultural, educational and behavioural issues; improve KAP* among actors on the effects of climate change and		√		√

	technology transfer components (Marine environmental monitoring and Early Warning system)				
- Institutional capacity of regulating agencies need strengthening	- Recruit and increase training locally and abroad - Build capacity among key stakeholders and partners to partition the workload		√	√	
- Restrictive/weak coordination among regulating agencies / departments/ministries/ NOGs / communities in the coastal zone.	- Increase advocacy and strengthen coordination among partners		√	√	
- Ineffective policies to monitor impacts on the coastal zone of current agricultural and tourist-centric development	- Recommend policy statements/alternatives for improving monitoring programme for marine ecosystems.	√		√	√

3.3 Linkages of the barriers identified

Table 38 is a color-coded illustration that attempts to follow the linkage between the economic and non-economic barriers that can suppress the easy transfer of technology for establishing an effective marine environmental monitoring network that will help to inform research, decision makers and an Early Warning bulletin for all stakeholders operating in the Coastal Zone of the country.

Table 39: Linkages of economic and non-economic barriers identified for the proposed marine environmental monitoring network and early warning system

Focal Problem	Identified Barriers	
	Economic/Financial	**Non-financial**
Increased threats to Coastal Zone Resources and Use	• High cost of marine environmental monitoring stations/equipment	• Absence of an effective marine monitoring network and Early Warning System • Inaccessibility to spares
	• Limited finance for deployment, spares, and high costs for maintenance	• Weak advocacy that does not inform better policies/regulations for integrated and sustainable management of marine resources • Distrust/lack of communication among stakeholders and coastal communities on critical issues.
	• Inability of local institutions to access financial assistant from international donors because of the complicated requirements involved	• Few monitoring / conservation and R&D projects being implemented in the coastal zone
	• Lack of local experts who can prepare bankable project proposals that can attract funding	• Failure to follow the Integrated Coastal Zone Management Plan • Weak implementation of regulations and adherence to conservation protocols
	• High import duties and taxes; all taxes may not apply to public goods	• High risks to the project resulting from extreme climatic events • Vandalism resulting in loss of expensive equipment • Change in political administration resulting in a change of priority and strategy • Change in management, personnel and governance that may impact the

		Fisheries sector.
	• Marine environmental monitoring network and Early Warning technology is a Public Good and will not enjoy 'direct' returns on investment	• Limited monitoring of the marine environment and oceanographic changes
	• Ability to source finance locally is legally problematic; hence only GOB can provide such allocation	• Weak coordination and advocacy among partners
	• Elevated risks to investment arising from extreme events impacting the Coastal Zone	• Missed opportunities for sustainable development project (GEF, Climate Fund, etc.)

Table 39 is another approach to illustrate the linkages to the barriers that may impede the smooth technology transfer to establish a marine environmental monitoring network. It basically highlights the linkages of the barriers with respect to components of the prioritized technology.

Table 40: Linkages of identified barriers with components of proposed marine environmental monitoring network and early warning system

Barriers/Technology Transfer	*Early Warning Contributes to decreased threat to Coastal and Marine Resources and Sustainable Use*	*Establishment of a modern marine environmental monitoring Network*	*Institutional strengthening improved and sustained*
i. Incoherent environmental monitoring and evaluation plan and early warning system	√	√	√
ii. None existence of national policies to monitor current agricultural and tourist-centric development practices	√	√	
iii. Gaps/short-coming to follow a coastal zone management plan		√	√
iv. Limited long-term research in the marine ecosystem and coastal communities	√		√
v. Lack of historic and current oceanographic /marine resources database		√	√

vi. Inadequate infrastructure & lack of a marine monitoring network	√	√	
vii. Constraint of high-capacity human resources	√		√
viii. Lack of synergy and coordinated work programme with other key partners	√	√	
ix. Limited, scientifically informed policies	√	√	√
x. High initial costs	√		
xi. Weak political will and limited subsidies and incentives		√	√
xii. Lack of adequate finance for effective regulatory and enforcement mandate and R&D	√	√	√
xiii. Illegal fishing and unsustainable resource extraction/use common.	√		√
xiv. The impacts of climate change coupled with anthropogenic stressors not fully understood by majority of stakeholders		√	
xv. Weak coordination and cooperation with developers and key stakeholders in implementation and compliance of fisheries regulations		√	√
xvi. Failure to establish and maintain credibility with public	√	√	√
xvii. Implementing same old strategies and expecting different results	√		√

3.4 Enabling framework for overcoming the barriers in the Coastal and Marine Ecosystem Sector

The strategic measures selected from the earlier enabling framework list and the synthesis from the Objective Tree (Table 36 and Table 37) are listed below. Adopting the measures (actions) can help to facilitate the smooth transferal of technology for the establishment of a modern, marine environmental monitoring network to provide timely and crucial data for the proposed Marine Early Warning System, and inform policy makers and other stakeholders of changes, alterations and impacts observed/measured in the coastal zone, and marine habitats. Some pesent and future actions contributing the an enabling environment in the coastal and Marine sectors are:

- Upgarding the institutional capacity of the Fisheries Department.
- Recommend legislative framework to address reality on the ground.
- Support national and regional scientific research, and access to research results.
- Advocate for high priority given to marine ecosystem conservation by GOB & partners
- Maintain support for recently adopted National Integrated Coastal Zone Management Plan for Belize: Creating a Blueprint for Sustainable Coastal Resources Use" (CZMAI, 2016), provides a framework and guidance for sustainable use and protection of marine resources.
- Procure/hire or train personnel with skills to write bankable project proposals.
- Strengthen co-management programme with NGOs/University of Belize at established sites/marine reserves, such as: Calabash Caye, South Water Caye, Hol Chan Marine Reserve, Half Moon Caye, Gladdens Spit, Bacalar Chico, Swallow Caye Marine Reserves to name a few.
- Request tax exemption for importation of Government-commissioned, scientific, marine monitoring and communication equipment.
- Identify international funding opportunities for capital finance for technology transfer.
- Maintain close working relationship with the Tourism Sector and other related productive sub sectors in the Coastal Zone.
- Promulgate the Belize's Barrier Reef (the largest proportion of the Meso-American Barrier Reef System and a sensitive and critical habitat for numerous marine species) as rallying cry for increased support and coordination among local and international partners
- Fisheries Department and CZMAI are strengthened to continue to carry out their mandate to help regulate sustainable development in the Coastal Zone.
- Marine Protected Areas (MPAs) and No-Take-Zone are closely managed and utilized.
- Belize Coast Guard has a foreward base near Belize City, and operational centres in several localities in the coastal zone, and provide assistance to safeguard life and property.

Table 40 is a matrix of the Enabling Framework for the diffusion of the prioritized technology: "Marine Environmental Monitoring Network and Early Warning System". Measures and results are listed, along with preliminary timeframe, estimated cost, and responsible entity.

Table 41: Enabling framework for proposed marine early warning system

Barriers	Measures	Results	Timeframe & Costs	Responsible Entity
Political/Legal *-Political will lukewarm;* *-Laws & Environmental advocacy not fully implemented;* *- Change in political administration resulting in change of priority/strategy;* *-Political appointment*	- Keep policymakers informed - strengthen legislation to address reality - empower stakeholders - Improve synergy and coordination with key partners - Advocate for continuity & mobility in Fisheries Sector - Minimized political appointment, ensure hiring of qualified technicians	- Political will & environmental advocacy heightened; - High priority to marine ecosystem conservation - Institutional capacity enhanced and maintained - Improved services	Short/medium term Estimated Initial Cost: US $ 177,965.33 Operational cost: US $ 84,491.34	FD, CZMAI, NGOs
Economic and Financial *-High cost of procuring and deploying marine monitoring stations;* *High cost for spares, equipment & maintenance;* *-lack of tangible economic benefits of marine early warning;* *- Elevated training costs*	- Funds procured for marine monitoring network and accessories - Revolving funds available for spares, deployment, and maintenance - Benefits of Marine Early Warning assessed/measured through indicators and economic performance - Funds for on-going training, institutional strengthening and advocacy available	- Data base of marine information and environmental monitoring parameters - An effective Coastal and Marine Early Warning system - Technical and scientific information and data to inform policy	Short/medium term	FD, CZMAI, NGOs

and security of equipment .				
Non-financial *-Fragmented and weak water quality/marine ecosystem monitoring programme/ protocol;*	- Establishment of a robust and dependable Marine environmental monitoring network in the coastal zone of Belize; - Establish an improved Marine database in the Fisheries Department.	- Technical and scientific information and data to inform policy; - - Reliable data for future research - Realizable data to help evaluate changes in marine resources	Short/Medium term	FD, CZMAI, NGOs
Culture / Tradition *-Negative attitude & perception of marine ecosystem conservation;* *-General lack of interest;* *- corruption and kickbacks*	- Expanded public awareness and education programme - - Increased advocacy among coastal and marine stakeholders	- Increased sensitivity to protect and conserve marine resources - Less incidents of illegal fishing, especially in No Take Zones and protected areas - Less report of out-of-season fishing - Stakeholders respect and abide by the laws and regulations.	Short/Medium term	FD, CZMAI, NGOs
Sustainability *-Lack of reliable information and data to inform long-term decision;* - *Weak institutional /technical capacity* - *Negative impacts of extreme climatic events*	- Procure and deploy fully equipped network of marine environmental monitoring stations - Qualified personnel always available - Fund available for spares and maintenance	- Timely and reliable marine environmental Early Warning System - Revolving fund for spares, maintenance and replacement - Reduced staff turnover, fully qualified personnel maintained - Safety and insurance for equipment/sensors	Short/Medium term	FD, CZMAI, NGOs

CHAPTER 4. Water sector

4.1 Preliminary targets for technology transfer and diffusion

The preliminary target for the WSP technology transfer is summarized in Table xxx. On the question that the intervention is too ambitious: the answer is 'no'. The benefits of ensuring that rural communities of over 200 families have a reliable and secured supply of potable water, far outweighs the costs. The aim of establishing an integrated management strategy for water safety and potable water system to rural communities is to ensure an efficient water delivery service that meets all the health safety and engineering standards to improve the livelihood security of clients. For those unable pay the minimal fee for the service, GOB will provide a mechanism to defray the cost, so that the RWS remains viable.

Table 42: Summary of the WSP technology targets for the water sector and benefits versus costs

Sector: Technologies	Targets	Too Ambitious?	Conservative
Water			
1. Integrated Management Strategy for Water Safety for Rural Water Supply Systems	-Establishing Water Safety Management Plan for threatened RWS in eight rural communities of approximately 200 families per village. The technology transfer will ensure secured potable water and sustainable use of water resources.	No. The benefits including: Human health and safety; reduced costs to the national health service; more time for productive activities, improved nutritional intakes and decreased food insecurity, etc., far out weigh the costs. The intervention will engender increased cooperation among key actors in RWS operations and village water boards. The management strategy for water safety for RWS can be replicated in	Yes. Properly implemented water safety plans ensure good water quality, and efficient and reliable distribution to clients. It will safeguard the resource and contribute towards the country's commitment to the SDGs. The preliminary cost for this technology transfer is estimated as: US$ 342,000.00. Three-year operational cost is US$ 71,000.00

		other communities experiencing similar problems, thus strengthening the national network of RWS water services.	

4.2 Barrier analysis and possible enabling measures for integrated management strategy for water safety in eight Rural Water Supply Systems

4.2.1 General description of for integrated management strategy for water safety in eight Rural Water Supply Systems

The technology intervention through the TNA initiative: *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 service. In these communities, Village Water Boards are on record for poor water delivery services, and inadequate management of water service systems is 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, Principal Public Health Officer, pers. Comm. Oct. 2016).

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 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 Figure 17 shows a schematic of the framework for safe drinking adapted from Davidson et al. (2005). The main programmes of the safe drinking water framework are: System assessment, monitoring, and management and communication.

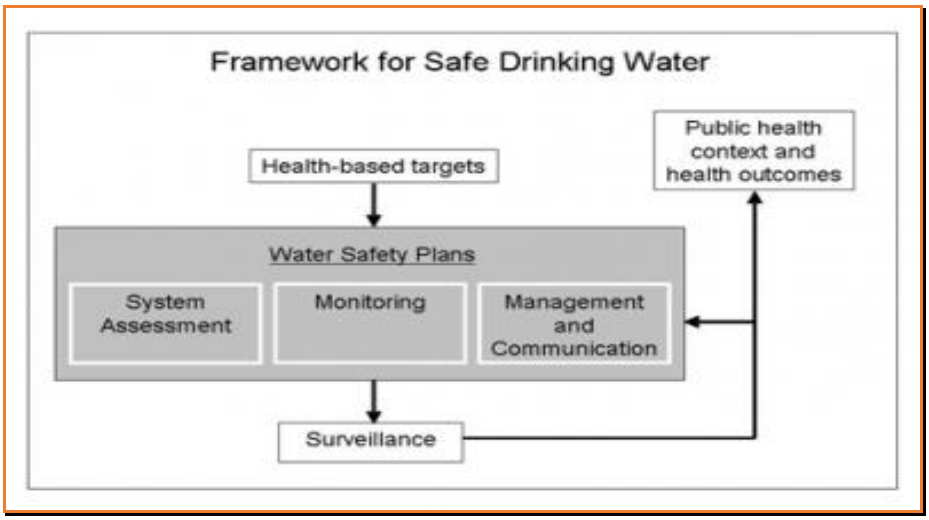


Figure 17: Steps in the development of a WSP (Adapted from Davison et al., 2005)

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 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 hired for three months to coordinate and develop the WSP. Adoption by Cabinet and operationalization by the MOH and partners will take at least eight.
3) Following adoption of the WSP, the Public Health Bureau, along with key stakeholders such as Rural Water Unit (Ministry of Labour, Local Government and Human 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 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 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 four Rudimentary Water System Technicians, Two Water Quality Analyst, and one National WSP

Coordinator. WSP Coordinator will be nominated from among Public Health personnel.

5) Cost for hiring one Water Consultant for three months to develop and coordinate the public consultation and adoption of the WSP.

Supporting Department and Agencies in the Water Sector

- *Rural Development Department, Ministry of Labour, Local Government and Rural Development (MLLGRD).*
- *Public Health Bureau in the Ministry of Health.*
- *Ministry of Finance.*
- *Ministry of Natural Resources and Agriculture.*
- *The Belize Social Investment Fund.*
- *Statistical Institute of Belize.*
- *The National Hydrological Service, Ministry of Natural Resources*

4.2.2 Identification of barriers for integrated management strategy for water safety in eight Rural Water Supply Systems

The list of barriers identified by stakeholders in connection with the proposed, integrated management strategy for water safety in eight rural water supply systems were the following:

- Political will to support improved rural water services.
- Animosity and weak water governance at the local level.
- Insufficient funds to improve infrastructure in water distribution system.
- Limited technical and managerial capacity.
- Initial/capital costs for drafting, reviewing and implementing management strategy and technical training programme for RWS will be comparatively high.
- High cost of spares and equipment.
- 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 cost can be high.
- Weak ccoordination among key actors /Departments and agencies associated with RWS.
- 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
- Water Board members appointed, and not totally committed.
- Inadequate training from technical personnel and village Water Board members

Barriers to consider in the technology transfer for the Management and Operation for Water Safety of eight Rural Water Supply Systems in Belize.

The characteristics of barriers identified by key components for this technology transfer in the Water Sector are the following:

- **Financial Barriers**

Financial management in the operation of Rudimentary Water Systems (RWS) is key for a successful water delivery service and its sustainability. Poor financial management of RWS is attributed to weak institutional capacity. The high cost of spares, such as water pumps and chemicals, is also a barrier for the successful operation of RWS.

- **Organizational/regulatory Barriers**

Members of Village Water Boards are politically assigned or nominated. Many of the political appointees do not have the capacity or commitment to do the job. The Village Council Act that governs the Village Water Boards must be reviewed, and amendments made to address this issue. Weak coordination among key actors/Departments and agencies associated with RWS

- **Weak Enabling policy environments for management and operation of Rural Water systems**

The policy regarding Village Water Board needs to be revised so that qualified personnel committed to the work can be hired or contracted.

- **Incumbent Technology**

RWS have worked in many parts of the world including Belize. Investments in this technology for delivery of safe water supply to rural communities will continue. The improved technology has become automated, including the water purification component. Solar PV technology is also being introduced to run the water pumps. However, the problem is governance of these systems, and the main barrier to address this problem is self interest and control.

- **Market failures**

As a water service provider, RWS that are run by Village Water Boards should embrace the service as a business and as such, each should have a business plan, taking into considetation that some villagers or the poor, may have to be subidies, until thay can afford to pay for the service. Otherwise, the RWS may not be sustainable.

- **Information Barriers**

Relevant information on components of RWS is lodged in the offices of the Rural Development Department in the Ministry of Labour, Local Government and Rural

Development, in the Public Health Bureau, and at the Social Investment Fund (SIF). Technical and managerial capacity to run the daily operations of an RWS successfully is the critical barrier identified by stakeholders. Information and audits of RWS are inaccessible or do not exists.

- **Technical Barriers**

Committed and skilled persons are required to operate, manage and maintain RWS in accordance with an adopted Water Safety Plan. The technology transfer for the *Management and Operation for Water Safety of eight Rural Water Supply Systems* will include measures to overcome the technical deficiency associated with the following:

- The need for sustainable and safe water delivery systems for the target communities.
- Efficient and transparent village Rudimentary Water System services.

Selection and decomposition of critical barriers for diffusion of improved drip irrigation

Table 43 shows the outcome of categorization of barriers as per Financial and None-Financial barriers in accordance to a criteria and their importance for the transfer and diffusion of water safety technology. Barriers scoring a 1 or 2 on a Likert scale (1 to 5) were selected for further analysis.

Table 43: Criteria and Importance of Barriers for the diffusion of an Integrated Management Strategy for threatened Rudimentary Water Systems

No.	Barriers	Criteria and Importance of Barriers for Technology 2					
	Economic & Financial	**1. Critical (killer, non-starter)**	**2. Crucial**	**3. Important**	**4. Less important**	**5. Insignificant (easy starter)**	**Rank**
1	- High cost of spares and equipment	x					1
2	- Lack of funds to improve infrastructure in water distribution system		x				2
	- Initial/capital costs for drafting, reviewing and implementing	x					1

	management strategy and technical training programme for RWS will be comparatively high						
3	- Poor financial management of RWS		x				2
4	- Foreign exchange and corresponding banking				x		4
	Non-financial						
	Organization / Regulatory			x			3
5	- Water Board members lack managerial skills - Water Board members politically appointed and not totally committed	x					1
6	- Weak coordination among key actors/Dep/ agencies associated with RWS	x					1
	Enabling policy environments						
7	- Policy regarding Village Water Board needs to be revised		x				2
	Incumbent RWS technology						
8	- Un-metered		x				2

	village water supply systems.						
9	- Monopoly and personal interest groups politically connected		x				2
10	- Fragmented & weak water quality monitoring protocol			x			3
	Information barrier						
11	- Lack of reliable information and data on rural water quality and supply.			x			3
	Technical barrier						
12	- Limited or weak technical capacity in RWS services	x					1
13	- Weak management capacity in the RWS serices	x					1
	Others						
14	- Rising fuel costs		x				2
15	- Rising costs of transportation			x			3
16	- Very little R & D done on groundwater capacity, characteristics and sources pollution			x			3

Table 44 is a summary of the decomposition of critical (none-starter) and crucial barriers for the smooth transfer and diffusion of the technology to implement an integrated management strategy for threatened RWS.

Table 44: Selection of killer or non-starter barriers to the diffusion of an Integrated Management Strategy for threatened Rudimentary Water Systems (RWS)

Category of Barriers	**1. Critical (killer, non-starter)**	**2. Crucial**	**Elements of killer or non-starters**	**Dimension of barrier elements**
Economic & Financial	- Initial/capital costs for drafting, reviewing and implementing management strategy and technical training programme for 8 RWS will be comparatively high	- Poor financial management of RWS - High import taxes and limited subsidies - None metered connections resulting in revenue loss - Financial records not transparent - Rising fuel prices	- High interest rates - Elevated cost of specialized services -	- 12 – 15 % on certain components - Interest rates could be 6 to 12 % per annum
	- High cost of spares and equipment (e,g, electrical energy, water pumps, etc.)		- High import duties & taxes on components	- Service cost could be as high as 15 % of capital cost
	- High O & M costs	-	- Scarcity of certified technical personnel locally	- Technical capacity in key Dep./Units etc. low or does not exist. - Staff/personnel stretch thin
Market failures	-	-	-	-
Policy/Regulations	-	- Policy regarding Village Water Board needs to be revised	- Village Council Act make provision for Water Board membership	- Water Board members (i.e. Chairperson) appointed by Minister

Non-financial	- Water Board members lack managerial skills - Water Board politically appointed and not totally committed - Poor/limited institutional capacity of Village Water Boards - Weak coordination among key actors/Dep/ agencies associated with RWS -	- Public Service limited in specialized personnel - Imported equipment and reagents not of the best quality - Monopoly and personal interest groups politically connected	- Limited knowledge and technical & managerial capacity among Water Board members - Bad experience with mal-functioning system and chemicals - Cannot afford installation cost - Reassess and develop new working strategy among key actors related to RWS	- Lack of coordinated training - Water Borad personnel engage in other occupation - Inadequate design and poor material - Extended subsidies for the poor, or totally un-metered RWS service. - Actors/agencies / Departments institutionally weak

Figure 18 is a Problem Tree centered on the focal problem: "Limited Institutional Capacity of Village Water Boards". The main causes and effects highlighted were identified by stakeholders in the Sector-based Technology Working Group (STWG).

Some of the main causes attributed to the problem are:

- limited knowledge and technical skills of water systems;
- Few training programme for technical personnel and Water Board members;
- Inadequate appointment policy for Water Board members;
- Irregular or extended time interval between laboratory water test;
- Limited finance for replacement parts and maintenance;
- Unreliable water supply service;
- Responsibility for operation and maintenance not taken seriously.

Some effects include:

- Limited commitment
- Poorly managed system;
- Inefficient Watter Boards and RWS service
- Inadequate water supply systems;

- Poor water quality.

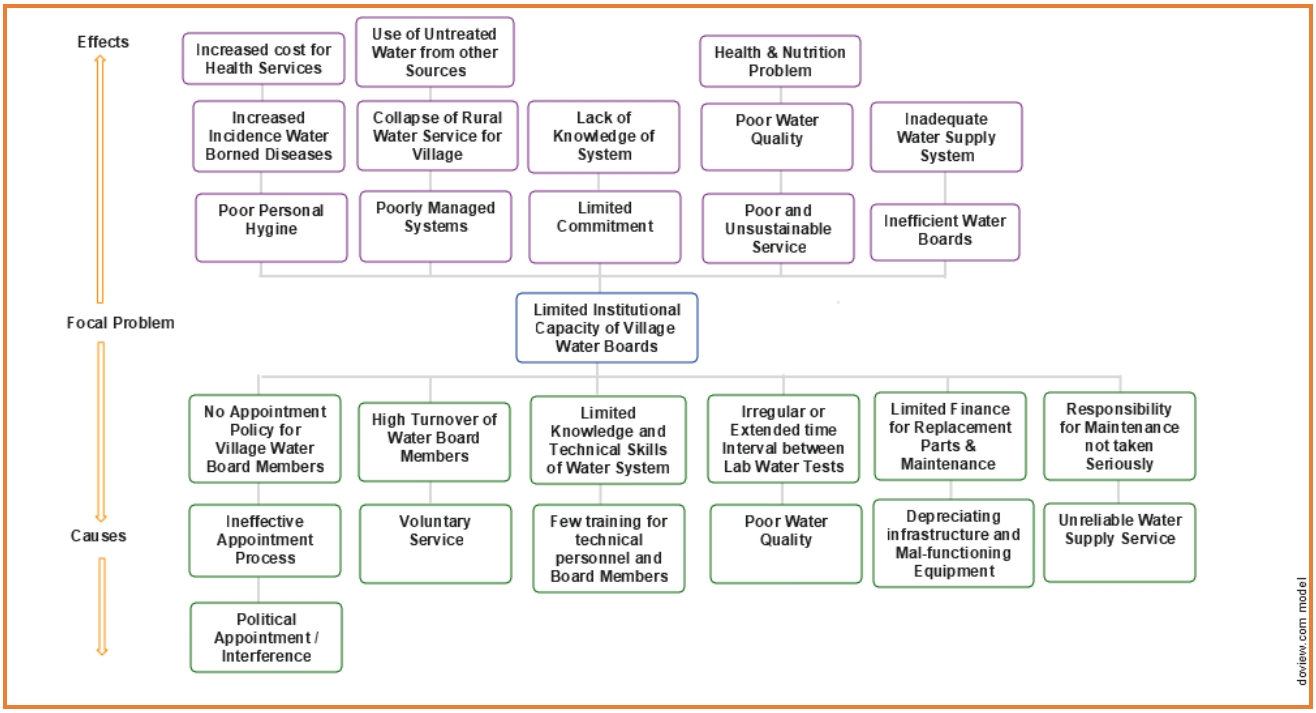


Figure 18: Problem Tree for limited institutional capacity/management of Rural Water Boards

4.2.2.1 Economic and financial barriers

The main economic barriers to the transfer of the technology identified by stakeholders are:

- High cost of spare parts and equipment.
- Limited finance for replacement costs and maintenance.
- Poor financial management of RWS.
- Board members not paid, mostly voluntary service.
- Little investment in basic financial management and improving technical skills.
- Some RWS not metered, hence minimum returns for water services and inadequate budget for operation.
- Water Boards should be “business oriented”, have a business approach to their operation, while seeking a balance for the social needs of communities.

Preliminary Economic Evaluation for ‘Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize’

In rural communities, Village Water Boards manage the Rudimentary Water Systems and piped water to residence. Here, the coverage nationwide is about 95 % and the water source

is mostly groundwater. There are some 150 Village Water Boards and about a third of them have experienced and continue to experience water quality, 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 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 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 hired for three months to coordinate and develop the WSP. Adoption by Cabinet and operationalization by the MOH and partners will take at least eight.

3) Following adoption of the WSP, the Public Health Bureau, along with key stakeholders such as Rural Water Unit (Ministry of Labour, Local Government and Human 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 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 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 four Rudimentary Water System Technicians, Two Water Quality Analyst, and one National WSP

Coordinator. WSP Coordinator will be nominated from among Public Health personnel.

5) Cost for hiring one Water Consultant for three months to develop and coordinate the public consultation and adoption of the WSP.

Capital Investment: US $ 342,000.00 will cover costs for hiring one Public Health and Water expert for three months, hiring two water quality analysts and four Rudimentary Water System technicians (3 years), purchasing eight spare water pumps, one vehicle for field work, information and database equipment, and training costs.

Operating cost: US $71,000.00

(Source: Factsheet for Water Sector Technology: *Integrated Management Strategy for Water Safety in Eight Rural Water Supply Systems in Belize*, TNA project, Belize)

4.2.2.2 Non-financial barriers

- Political appointments;
- Little commitment and interest;
- Poor management tradition of Village Water Boards;
- Fragmented and weak water quality monitoring protocol;
- Lack of reliable information and data on rural water quality and supply;
- Very limited knowledge and data of groundwater;
- Very little study and research done on groundwater capacity, characteristics and sources pollution;
- Water authorities and public health reactive and not proactive on issues related to water supply and water quality.

4.2.3 Identified measures

A Solution Tree based on the objective: “Improved Institutional Capacity of Village Water Boards”, is shown in Figure 19. A preliminary strategic option for this objective are summarised in Table 45 and are based on the ‘Measures’ and ‘Results’ boxes shaded in green.

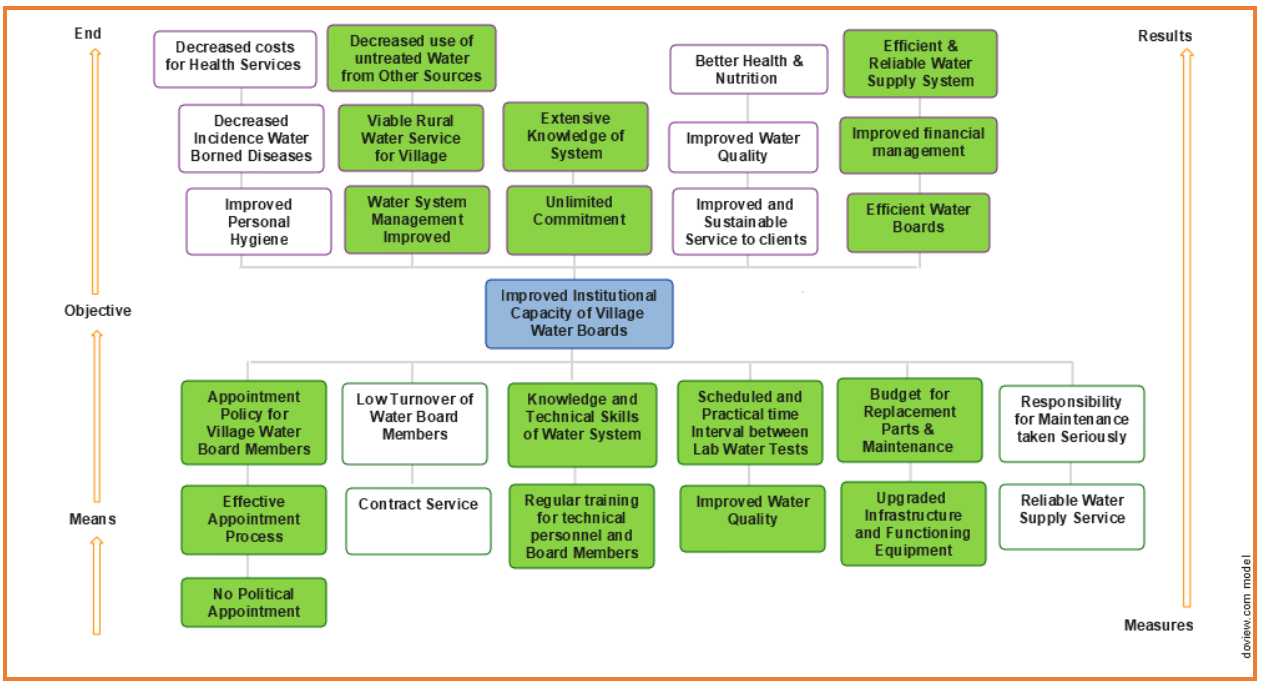


Figure 19: Solution/Objective Tree for improved management of Rural Water Boards

Table 45: Proposed strategic pathway for objective, 'Improved Institutional Capacity of Village Water Boards'

Objective	Measures	Results	Timeframe
Improved Institutional Capacity of Village Water Boards	Implement training programme to increase knowledge & technical skills of Rural Water Systems	Unlimited commitment; Extensive knowledge of system	Short/medium term
	Hire or contract skilled operators	Improved operation and maintenance	Short/medium term
	Redress appointment policy for Village Water Board members	Water system management improved	Short/Medium term
	Improve financial and operational management of RWS	Efficient and reliable water supply system	Medium/long term
	Budget for replacement parts and maintenance	Efficient Water Boards	Medium/long term
	Revise and implement protocol for an efficient water quality analysis programme	Decreased use of untreated water from other sources. Potable water through distribution line	Short/Medium term
	Upgraded infra-structure and equipment	Improved health and nutrition	Medium/long term

4.2.3.1 Economic and financial measures

Some identified economic and financial measures to achieve the objective: *Improved Institutional Capacity of Village Water Boards* include:

- Establish contract service for all Water Boards in the country.
- Establish an effective and non-political appointment process for non-contract members. Will require policy change for Water Board member appointments
- Conduct annual financial estimates of receivables and expenditures (Audit), if it is not being carried. This is critical for transparency and good management. Cost covered by recurrent budget of Village Water Boards.
- Designate a recurrent and feasible budget for O&M in RWS services.
- Install metering to all RWS system.
- Ensure subsidies for poorer clients are provided.
- Village Water Boards in coordination with Rural Water Dep, Public Health and partners, will identified and use capital financing for development of Water Safety Plans and effective training of Trainers and target Water Board members and others.

4.2.3.2 Non-financial measures

The following is the list of non-financial measures:

- Lobby for policy change for appointment of Water Board members.
- Establish an open and transparent RWS management system.
- Expand knowledge & technical skills of Rural Water Systems technicians
- Conduct regular training targeting Water Boards members.
- Public Health Bureau develops and implements a timely water quality monitoring protocol for target Rudimentary Water Systems.
- Institute and implement timely actions on the part of Public Health Bureau, Rural Development Department, and Village Water Boards to deal with water safety, related issues connected with target RWS.
- NAVCO helps coordinate ‘best practice’ programme for RWS services.

Table 46 is a summary of financial and none-financial barriers and corresponding measures to facilitate ‘an integrated water safety mananement strategy and plan for threatened RWS’.

Table 46: Summary of barriers and corresponding measures for instituting an Integrated water safety management strategy and plan for threatened RWS

Categories	Identified Barriers	Measures to overcome barriers	Intervention		Funding Sources	
			Legal	Other	National	External
Economic and financial	− High initial investment	− Expand access to finance - Utilize capital financing for development of Water Safety Plans and effective training of Trainers and target Water Board members.		√	√	√
	− Limited subsidies for technology components	− Lobby for reduced import taxes on equipment	√		√	
	− High cost of installation and operation of RWS	− Provide technology companies & suppliers with concession to service specific areas or groups of clients at reduced service costs (Public-private partnership)		√		√
	- Poor financial management of RWS	- Improve financial and operational management of RWS		√	√	√
	− Appointment and voluntary service	− Establish contract service for all Water Boards in the country		√	√	
Market conditions	− Local hardware stores often low in stocks of spares & components	− Improve access to products and services. Grow the market for new technology		√	√	√
	− Unstable, monopoly, special interest groups	− Implement policies & regulations for favourable market climate	√		√	
Legal and regulatory	− Inadequate policy and regulatory framework	− Lobby for Policy revision regarding Village Water Board contracts and appointment	√		√	
Network structures & others	− Networking among Village Water Boards, professionals in water resources and related	− Enhance networking of RWS Village Water Boards through NAVCO. − Strengthen research and development in water resource management &		√	√	√

	agencies weak and ineffective	services			
	- Poor/limited institutional capacity of Village Water Boards	Develop an on-going training programme for Water Board members		√	√
	- Weak coordination among key actors/Dep/ agencies associated with RWS	Strenghten coordination and work programme among key actors, departments and agencies associated with RWS		√	√
	− Water authorities and Public Health reactive to issues related to RWS services, not pro-active.	− Update protocol to address water safety issues related to RWS. - Build institutional capacity -	√		√
	− Low technical capacity − Afraid of change	− Establish training component in technology diffusion programme − Through technology diffusion programme address social, cultural and behavioural issues; improve KAP* among users		√ √	√ √

4.3 Linkages of the barriers identified

Table 47 illustrates the linkages of identified financial and non-financial barriers in a color-coded format. An example of this linkage is that of the “Fragmented and weak water quality monitoring protocol” under non-financial barrier, and the “High cost of spares and equipment” and “Limited finance for replacement costs and maintenance”. The measures to these barriers then form the strategic pathway for facilitating the technology transfer and improved management of the threatened RWS in Belize.

Table 47: Linkages of Barriers identified for Limited Institutional Capacity of Village Water Boards

Focal Problem	Identified Barriers	
	Economic/Financial	**Non-financial**
Limited Institutional Capacity of Village Water Boards	• High cost of spares and equipment	• Political appointments
	• Limited finance for replacement costs and maintenance	• Little commitment and interest
	• Poor financial management of RWS	• Poor management tradition of Village Water Boards
	• Board members not paid, mostly voluntary service	• Fragmented and weak water quality monitoring protocol
	• Little investment in basic financial management and improving technical skills (training)	• Lack of reliable information and data on rural water quality and supply
	• Some RWS not metered, hence minimum returns for water services and inadequate budget for operation.	• Very limited knowledge of groundwater resources
	• Water Boards should be "business oriented", have a business approach to their operation, while seeking a balance for the social needs of communities	• Very little study and research done on groundwater capacity, characteristics and sources pollution
		• Water authorities and Public Health reactive and not proactive on water supply and water quality issues

4.4 Enabling framework for overcoming the barriers in the Water Sector

The enabling framework for overcoming barriers to the technology transfer for improved management of the threatened Rudimentary Water Systems (RWS) in Belize are summarized in Table 19 below.

Table 48: Enabling framework for facilitating technology transfer for improved management of threatened RWS

Barriers	Measures	Results	Timeframe & Cost UD $	Responsible Entity
Political/Legal *-Political appointment of Water Board members;* *-Low commitment & interest;* *-Lack of knowledge/skills*	- Village Council Act reviewed for possible amendment - Lobby for change in policy for appointment/hiring Village Water Board members - Establish training and management programme for technicians and Village Water Board members	- Unlimited commitment. - Extensive knowledge of system. - Contract members of Village Water Board. - Abolished political appointment of Board members - Improved water service.	Short/medium term Estimated Initial Cost: US$ In-kind GOB Operational cost: US$ 20,000	Rural Deelopment Dep. (RDD), Public Health, PUC
Economic and Financial *-High cost of spare, equipment & chemicals;* *-Funds unavailable to conduct coordinated WSP training and develop Guidelines (High initial costs);* *Poor financial management of RWS by some Water Boards.*	- Fund procured for SWP training - Conduct annual Audit - Implement business-oriented RWS operation & management - Initial cost for solar powered water pumps and water treatment chemical procured	- Contract members with salary - Efficient and reliable RWS service - Spares available (e.g. electric water pump run on RE) and weekly maintenance	Short/medium term	Public Health, RDD
Non-financial *Poor management tradition by Water Boards;* *Fragmented and weak water quality monitoring protocol;*	- Public Health Bureau develops and implements a timely water quality monitoring protocol for target Rudimentary Water Systems.	- Decreased use of untreated water from other sources - Improved health and nutrition -	Short term	Public Health

Water authorities and Public Health reactive w/r to water supply and water quality issues				
Culture / Tradition *Attitude & perception that water is free; General lack of interest*	• Improved management practice of Village Water Boards • Changed "water free' perception of clients/villagers • Adjudicate subsidies for poor	• Improved water service delivery • Regular Training of personnel/Village Water Board members • Rights to safe potable water for all.	Short term	Public Health, RDD,
Sustainability *Lack of reliable information and data on rural water quality and supply; Weak institutional /technical capacity*	- Metered water service - Set requirement for qualified personnel to be available always - Ensure that service payment funds available for spares and maintenance	- Revolving fund and profits - Extensive local knowledge and skill of RWS - Less breakdown, reduced waste of water, and reliable deliver service	Short/Medium term	RDD, Water Boards,

CHAPTER 5. Conclusions

Successful technology transfer requires participation and building on indigenous knowledge. Social, economic and environmental indicators, clearly selected and measurable, should reveal if goals and objectives are being achieved or were achieved. While hardware has taken centre stage in activities and interventions to reduce greenhouse gas emissions, processes and institutions are central to building capacity and resilience to the impacts of climate change.

The Barrier Analysis and Enabling Framework Report, together with the National Reports form the basis for the third and final phase of the TNA Process in Belize. Processing six adaptation technologies in this report was a challenge that could not have been realized without the assistance of personnel of the National Climate Change Office and UNEP-DTU. Also, the participation and input of sectoral stakeholders in the small group consultative meetings were clearly the catalyst that facilitated the evaluation of barriers and identifications of feasible measures for the smooth diffusion of the prioritized technologies considered in this Report.

The challenge now is to integrate the relevant information into a Technology Action Plan endorsed and owned by the People and Government of Belize, which actually will be prepared and presented as a bankable portfolio of project concepts, that if realized, will increased, in some way, the country's resilience to climate change and contribute to the livelihood security of many Belizeans in the short and medium term.

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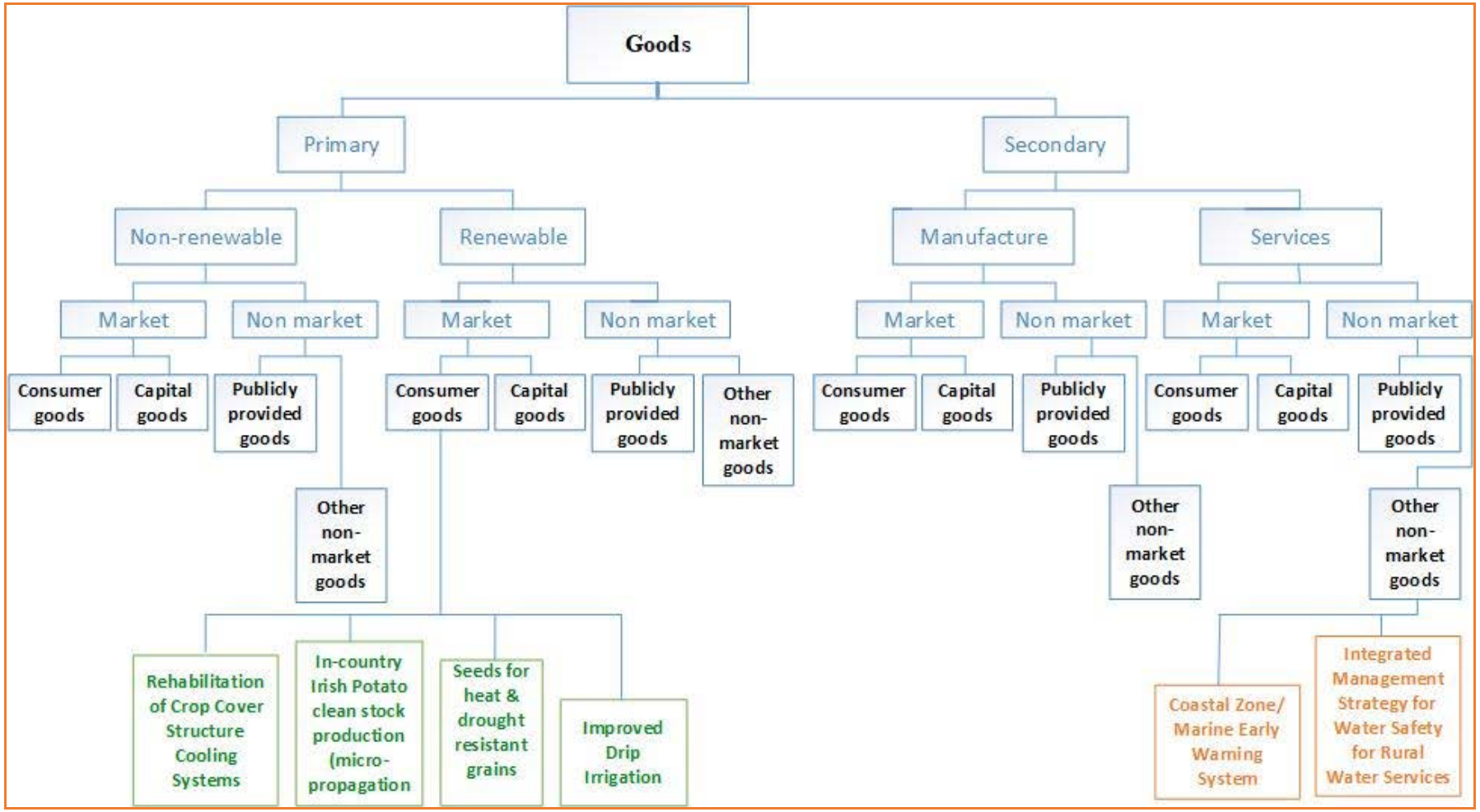
ANNEX A1-1: Categorization of prioritized adaptation technologies for the TNA process in Belize

Table I-A. 1: Schematic of Goods and Category of TNA Prioritized Technologies



(Source: adopted from Nygaard and Hansen, 2015 and Schumacher 1973; flowchart developed by R. Frutos 2017)

Table A1-2: Categorization of Prioritized Adaptation Technologies

Goods	Category	Description	Market characteristics	Prioritized Technology
Market Goods	**Consumer goods**	-Goods targeting the mass market; households, businesses and institutions.	– a high number of potential consumers – interaction with existing markets and requiring distribution, maintenance and installer networks in the supply chain – extended and complicated supply chains with many actors, including producers, assemblers, importers, wholesalers, retailers and end consumers – barriers may exist in all steps of supply chain – demand depends on consumer awareness and preferences and on commercial marketing and promotional efforts	– *Heat and drought resistant variety of open-pollinating corn and bean seeds for reproduction and marketing.* – *Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement.* – *In-country Irish potato clean-stock production unit to produce quality seed-tuber planting material varieties.* – *Rehabilitation of crop cover structure cooling systems*
	Capital goods	Machinery and equipment used in the production of goods, e.g. consumer goods or electricity or agro-processing products	– a limited number of potential sites/consumers – relatively large capital investment – simpler market chain, i.e. few or no existing technology providers – demand is profit-driven and depends on demand for the products the capital goods are used to make	
Non-market Goods	**Publicly provided goods**	Technologies in this category are often (although not always) publicly owned, and production of goods and services are available (free or paid) to the public or large group	– very few sites – large investment, government/donor funding – public ownership or own by large companies – simple market chain; technology procured through national or international tenders. – investments in large-scale technologies tend to be decided at the government level and heavily dependent on existing infrastructure and policies.	
	Other non-market goods	Non-tradable technologies transferred and diffused under non-market conditions: governments, public or non-profit institutions, foreign donors or NGOs	– technologies are not transferred as part of a market but within a public non-commercial domain. – serves overall political objectives, such as energy saving and poverty alleviation – donor or government funding	- *Improved environmental monitoring network and early warning system for Belize's coastal zone to increase resilience to climate change.* - *An integrated management strategy for water safety for rural water supply systems in Belize*

(Source: adopted from Nygaard and Hansen, 2015)

Table A1- 3: Sample of technologies and related barriers for Non-Market Goods

Non-Market Goods				
		Other Non-Market Goods		
	Publicly Provided Goods	**I. Technologies Provided by Public Institutions**	**II. Institutional Change: Improved Rural Livelihood**	**III. Behavioural Change at the Individual Level (Change of Practice)**
Examples	-Large infrastructure projects; -Large capital investment; -May depend on donor funding; -Political decision at government level - large hydro dams; - New highway infrastructure; - Modern airport etc.	- Early warning system for drought; - Environmental Monitoring Network & Early Warning System for Coastal and Marine Resources & Ecosystems Management/Use; - Seasonal Weather Forecasts, etc.	- Forest management groups and village councils - Micro finance institutions - Water Safety Plans (WSP) for rural water systems (set of actors along with Village Water Boards)	- Energy-saving/efficiency measures, e.g. new types of electric bulbs (LCD over incandescent) - Individual cars to public transport and bicycles - Changing farm practices - Changing attitude and perception of the benefits of climate change adaptation technologies
Requirements & impacts	-Investment preceded by socio economic CBA -EIA - Impacts a large group of actors/stakeholders; -Positive/negative impacts not equally shared by affected actors; e.g. -Large hydro dams, resettlement of rural poor, loss of tourist sites and farmland, lower electricity prices for urban dwellers, employment during construction, job opportunities	- Feasibility studies and CBA lacking; - Institutional capacity - Trained personnel/technicians - Difficulty to access funds; - Political will.	- Socio-economic CBA - Infrastructure and/or incumbent technology in place - Impacts community (health, livelihood and security)	- Conduct a KAP survey among key stakeholders - -
Barriers to procurement	- Few feasibility studies and CBA - Difficulty accessing finance - Resistance by locals and	- Bankable project proposals lacking - Donors/funding sources inaccessible	- Difficulty accessing finance - -	- Difficulty accessing finance - Weak capacity to write bankable project proposals - Lack of knowledge of sources of

	international NGOs	- High capital/initial cost		finance
Barriers to long-term sustainability	- Management costs - Inadequate management -	- Availability of budget-line to carry on after external funding exhausted - Misuse of funds - Lack of advocacy to strengthen cooperation among key actors - Poor management	- Misappropriation of funds - Dependency syndrome - Availability of budget-line to carry on after external funding exhausted - Poor management tradition	- Weak institutional capacity - Ineffective implementation of strategic plan - External funding stopped, programmes and related activities disrupted or reduced
Barriers to Implementation	- Resistance by locals and international NGOs - Difficulty approving ESIA -	- Experience with similar technology intervention not totally successful or mixed - Procurement of funding lie with donors & development agencies - Enabling agencies / actors /policies may not be in place	- Not too good experience with similar interventions - Inaccessible funding - Political will - Inadequate institutional capacity	- - -
Barriers to Achieving Change	- Resettlement costs - Benefits not equitable -	- Strategies of dependence on continued donor finance - Negative response to new technology by some stakeholders - Tangible benefits not evident for some actors…	- Political appointment is common - Inadequate technical capacity among actors - Low commitment	- -
Measures	-	-	- Contract regulations (hire actors instead of appointment) - Improve training - Better project preparation among key actors - Improve project management - Better understanding donor/recipient relations	-

(Source: adopted from Nygaard and Hansen, 2015)

ANNEX I-B: Grain and Potato Production Statistics, 2010 – 1016

BELIZE		lbs	ton	Acre	Hectare				
Grain and Potato Production		2204.6	1	1	0.4047				
PRODUCTS	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016 (P)**	**Average Yields**	
GRAINS, BEANS								**(lbs)/acre**	**tons/ha**
BLACK BEANS									
Mechanized									
Production (lbs)	925,900	680,600	**1,719,400**	**243,600**	422,900	1,089,100	1,255,000	905,214	410.60
Acres	994	700	**1,607**	**398**	795	1,202	1,993	1,098.4	444.53
Yield (lb)	931	972	**1,070**	**612**	532	906	630	**824.10**	**0.92**
Milpa									
Production (lbs)	2,964,380	3,339,100	**5,251,800**	**4,262,420**	4,807,965	5,547,000	430,200	3,800,409.29	1,723.85
Acres	3,135	3,317	**4,724**	**3,855**	4,147	7,021	448	3,806.71	1,540.58
Yield	946	1,007	**1,112**	**1,106**	1,159	790	960	**998.34**	**1.12**
Total Production	**3,890,280**	**4,019,700**	**6,971,200**	**4,506,020**	**5,230,865**	**6,636,100**	**1,685,200**		
Total Acres	**4,129**	**4,017**	**6,331**	**4,253**	**4,942**	**8,223**	**2,441**		
R.K. BEANS									
Milpa:									
Production (lbs)	682,860	1,175,875	**1,312,050**	**943,760**	854,075	459,375	439,870	838,266.4	380.2
Acres	796	1,300	**1,513**	**1,176**	875	385	498	934.7	378.3
Yield (lb)	858	905	**867**	**803**	976	1,193	883	**896.82**	**1.01**
Mechanized:									
Production (lbs)	13,890,300	6,991,400	**12,006,200**	**11,535,400**	9,486,275	20,779,500	9,240,500	11,989,939.3	5,438.6
Acres	16,650	11,400	**12,869**	**19,594**	16,010	23,759	16,207	16,641.3	6,734.7
Yield (lbs)	834	613	**933**	**589**	593	875	570	**720.49**	**0.81**
Total production	14,573,160	8,167,275	13,318,250	12,479,160	10,340,350	21,238,875	9,680,370		
total acres	17,446	12,700	14,382	20,770	16,885	24,144	16,705		
CORN Yellow									
Milpa:									
Production (lbs)	10,236,800	9,524,450	**5,604,019**	**7,806,093**	5,106,706	4,938,585	1,333,450	6,364,300.43	2,886.83
Acres	7,163	6,206	**4,146**	**6,065**	5,463	5,101	1,306	5,064.29	2,049.52
Yield (lb)	1,429	1,535	1,352	**1,287**	935	968	1,021	**1,256.70**	**1.41**
Mechanized:									
Production (lbs)	89,017,500	99,868,500	**114,871,970**	**139,136,880**	140,265,342	106,117,200	135,694,765	117,853,165.29	53,457.85
Acres	26,513	27,924	**29,021**	**38,199**	35,492	32,984	49,408	34,220.14	13,848.89
Yield (lb)	3,358	3,576	3,958	**3,642**	3,952	3,217	2,746	**3,443.97**	**3.86**
Mech.Irrig						3,850,000			
Acres harvested						700			
Total production	**99,254,300**	**109,392,950**	**120,475,989**	**146,942,973**	**145,372,048**	**114,905,785**	**137,028,215**		
Total acres	**33,676**	**34,130**	**33,167**	**44,264**	**40,955**	**38,785**	**50,714**		
CORN White									
Milpa:									
Production (lbs)	15,565,631	15,314,025	**8,816,478**	**8,893,550**	4,031,587	5,110,628	712,180	8,349,154.14	3,787.15
Acres	11,130	9,354	**6,237**	**6,123**	4,109	5,212	714	6,125.57	2,479.02
Yield (lb)	1,399	1,637	**1,414**	**1,452**	981	981		**1,363.00**	**1.53**
Mechanized:									
Production (lbs)	13,155,400	13,534,200	**10,637,510**	**2,730,920**	3,087,000	7,193,000	7,237,600	8,225,090.00	3,730.88
Acres	4,189	4,563	**3,416**	**1,249**	1,683	5,782	3,138	3,431.43	1,388.70
Yield (lb)	3,140	2,966	3,114	**2,186**	1,834	1,244	2,306	**2,396.99**	**2.69**
Total production	28,721,031	28,848,225	19,453,988	11,624,470	7,118,587	12,303,628	7,949,780		
Total acres	15,319	13,917	9,653	7,372	5,792	10,994	3,852		
PRODUCTS	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016 (P)**	**Average Yields**	
Irish Potato								**(lbs)/acre**	**tons/ha**
Production (lbs)	1,809,500	2,473,000	3,014,000	2,231,000	2,379,737	2,240,300	2,173,000	2,331,505.3	1,057.6
Acres	222	251	277	108	224	214	245	220.1	89.1
Yields	8,151	9,853	10,881	20,658	10,624	10,469	8,869	**10,590.9**	**11.9**

(Source: M. Truijillo, Agronomist, MOA, Jan. 2018)

ANNEX I-C: Cost-Benefit Review for Agriculture Sector Technologies

Cost-Benefit Analysis for Cultivation of One and 15 Acres of Incumbent Yellow Corn

ESTIMATED COST OF PRODUCTION FOR ONE ACRE OF YELLOW CORN FOR SEED PRODUCTION					
Planting System:	Mechanized/Commercial Production				
Av. Yield - lbs/acre:	2000				
Date:	Feb-18				
Updated By:	Manuel Trujillo				
Activity	**Unit**	**Quantity**	**Unit**	**Cost**	
			Cost $	**1 acre**	
Ploughing	acre	1	$ 50.00	$ 50.00	Heavy disk ploughing
Harrowing	acre	1	$ 75.00	$ 75.00	
Planting & Fertilizing	acre	1	$ 25.00	$ 25.00	
Herbicide application	acre	1	$ 12.00	$ 12.00	1 application
Insecticide application	acre	2	$ 12.00	$ 24.00	2 applications
Inter-row cultivation	acre	1	$ 20.00	$ 20.00	1 pass
Inputs					
Seeds - CARDI YC -001		30	$ 3.00	$ 90.00	
Fertilizer - 14-36-12	110-lb bag	1	$ 52.00	$ 52.00	Fertilizer is applied at planting
Urea	110-lb bag	1	$ 40.00	$ 40.00	Fertilizer is applied 5 weeks after planting
Primero (herbicide)	acre	1	$ 41.00	$ 41.00	Selective, post-emergent herbicide
Cypermethrin 25EC	liter	0.4	$ 35.00	$ 14.00	Control of armyworms
Round-up	Gallon	0.5	$ 53.00	$ 26.50	
Rimone (insecticide)	liter	0.4	$ 185.00	$ 74.00	Systemic conrol of armyworm
Bull grass	liter	0.5	19.00	9.50	
Harvesting/Post-Harvest					
Harvesting (Combine)	acre	1	$ 50.00	$ 50.00	Mositure content 25%
Transportation	100 lb-bag	30	$ 1.50	$ 45.00	
Drying	100-lb bag	30	$ 3.00	$ 90.00	Dried at Moisture content from 25% to 14%
Cleaning	100 lbs-bag	20	$ 3.00	$ 60.00	
Bags for pacckaging	100 lbs-bag	20	$ 0.75	$ 15.00	
Storage	bags	20	$ 1.50	$ 30.00	
Total				**$ 843.00**	
Cost Benefit Analysis					
		Wholesale			
Dry Weight Corn (14%)	**Av. Yield lbs/Ac**	**Price/lb**	**Total Sales**		
	2000	$ 1.50	$ 3,000.00		
Cost of production from planting to storage			$ 843.00		
Net Profit			**$ 2,157.00**		
Cost of Producing 15 acres of corn	**Yield of 15 acres of Corn**	**Price/lb of corn seed**		**Projected Sales in 15 acres**	
	30000	$ 1.50		$ 45,000.00	
				$ 8,430.00	
Net Profit				**$ 36,570.00**	

(Source: M. Truijillo, Agronomist, MOA, Jan. 2018)

Cost-Benefit Analysis for Cultivation of One and 15 Acres of Incumbent beans

ESTIMATED COST OF PRODUCTION FOR ONE ACRE OF BLACK AND SMALL RED BEANS SEED PRODUCTION					
Planting System:	Semi Mechanized/Commercial Production				
Av. Yield - lbs/acre:	1000				
Date:	Feb. 2018				
Updated By:	Manuel Trujillo	Agronomist, Ministry of Agriculture			
	Belize				
Activity	**Unit**	**Quantity**	**Unit**	**Cost BZD**	
			Cost $	**1 acre**	
Ploughing	acre	1	$ 50.00	$ 50.00	Heavy disk ploughing
Harrowing	acre	1	$ 75.00	$ 75.00	
Planting & Fertilizing	acre	1	$ 25.00	$ 25.00	
Herbicide application	acre	1	$ 12.00	$ 12.00	2 applications
Insecticide application	acre	2	$ 12.00	$ 24.00	2 applications
Inter-row cultivation	acre	1	$ 20.00	$ 20.00	1 pass
Inputs				$ -	
Seeds	lbs	25	$ 5.00	$ 125.00	
Fertilizer - 14:36:12	110-lb bag	1	$ 52.00	$ 52.00	Fertilizer is applied at planting
Flex	liter	0.3	$ 80.00	$ 24.00	Selective herbicide for broadleaves
Round up	gal	0.5	$ 54.00	$ 27.00	
Antracol	pk	1	$ 25.00	$ 25.00	Fungicide
Deltametrina	liter	0.25	$ 35.00	$ 8.75	Insecticide
Spreader sticker	liter	0.5	$ 9.00	$ 4.50	
				$ -	
Harvesting/Post-Harvest				$ -	
Manual Harvesting (uprooting and winrowing)	acre	1	BZ$85.00	$ 85.00	
Winrowng	acre	1	BZ$20.00	$ 20.00	
Harvesting (Combine)	acre	1	$ 40.00	$ 40.00	
Transportation	100 lb-bags	10	$ 1.50	$ 15.00	
Drying	100 lb-bags	10	$ 2.50	$ 25.00	
Cleaning	100lb-bags	10	$ 3.00	$ 30.00	
Storage	100-lb-bags	10	$ 1.25	$ 12.50	
Baging	bags	10	$ 0.75	$ 7.50	
Total Input Cost				**$ 707.25**	

Cost Benefit Analysis					
	Av. Yield lbs/Ac	**Price/lb**	**Total**		
	1000	$ 2.00	$ 2,000.00		
Cost of production			$ 707.25		
Net Profit/acre			**$ 1,292.75**		
	Yield lbs for 15 acres	**Price/lb**	**Project Sales**		
	15000	$ 2.00	$ 30,000.00		
	Cost per acre	**Acres Planted**	**Total Cost of Production**		
Cost of Production/acre	$ 707.25	15	$ 10,608.75		
Net Profit			**$ 19,391.25**		

(Source: M. Truijillo, Agronomist, MOA, Jan. 2018)

Irish Potato Cultivation

Estimated cost for cultivation of 'one' acre of incumbent Potato variety in 2012 without irrigation

Activity	Unit	Amount	Unit Cost BZ$	Total BZ$
Land preparation	acre	1	120.00	120.00
Seeds	lb	800	1.05	840.00
Bags	bag	100	1.00	100.00

Fertilizers				681.00
Pesticides			285.00	285.00
Labour				1,348.00
Transportation				250.00
Storage	days	90	4.00	360.00
Total				**3,984.00**

(Source: M. Trujillo, A. Pulido, and D. Nabet, 2012. Irish Potato Planting Guide. MOA, Dec. 4, 2012)

Yields (lbs/acre)		10,000
Price/lb (Wholesale)	$	0.60
Total Return	$	6,000.00
Total Return	$	6,000.00
Estimated Cost of Production (without Storage)	$	3,624.00
Net Profit (Benefit)	$	2,376.00

All cost and returns are 2012 values. Prices fluctuate as economic conditions changes.

Note: Clean, certified Irish potato seed-tubers replicated locally through micro-propagation of imported climate resilient, 'source basic seed' would probably be twice the cost of a unit of incumbent seeds, but GOB subsidy would make it affordable for farmers. Certified seeds-tubers will be climate resilient and tested to be more adaptable to warmer and drier conditions and yields per acre or hectare can be higher with the appropriate input. Initial cost for drip irrigation (if used) is not included, but the benefits to potato growers would be profitable in the short and medium term. If storage is available, farmers will very likely be able to fetch higher prices per unit weight of their potato as market demands increase.

The killer barrier for this technology transfer is the capital costs and time constraints for improving the UB Micro-Propagation Laboratory facilities and technical capacity; and accelerating the actual micro-propagation of imported 'Source Basic Seeds (i.e. clean parent material), to micro-tuberization, reproduction of mini-tubers in screen houses (protective covered structures), and then mini-tuber germination to produce certified seed tubers for farmers. However, the propagation of new batches of clean, planting material will be staggered and ongoing, once the process commences; so, there will always be mini-tubers in storage and germinating, to produce more certified seed tubers for growers. Trials on different varieties of potato could be encourage at random, specifically for varieties that meet certain market demand, both locally and regionally, and in this way, Belize may be able to develop a profitable, potato production industry.

Cost of Production for 1 acre of irrigated potato in the Orange Walk District for the 2014 cropping season

Variety: *Red La Rouge, Pontiac*

Total Revenue:

Yield (lbs/acre):	25,000	
Market Price:	BZ$ 0.85/lb.	$ 21,250.00
Estimated Net:		$ 13,267.95

Input & Activity	Unit	Cost/Unit	Quantity	Cost BZ$	Sub-total
Total Land Preparation					332.50
Total Labour					1,560.00
Seeds		1.05	1,000	1,050.00	1,050.00
Newgibs	1 pk. (100 grams)	17.00	1	17.00	17.00
Inputs (Seeds & New Gib)					1,067.00
Total Herbicide					174.80
Total Insecticide					392.00
Total Fungicide					850.50
Total Fertilizer					786.70
Post Harvest Costs					325.00
Total Input (BZ$)					**5,488.50**

(Source of data: M. Trujillo, Fruit Trees and Crop Production Unit, MOA, Central Farm, 2014)

With Irrigation System

Equipment	Unit	Cost per Unit BZ$	Total BZ$
5 Hp Gasoline pump	1	1,400.00	1,400.00
2 " Main pipe rolls	1	575.00	575.00
Rolls T-tape	1	675.00	675.00
Take Off	117	3.50	409.50
Gallons fuel	40	10.73	429.20
Lubricants 10% of fuel	0.1	429.20	42.92
Accessories fittings	1	300.00	300.00
TOTAL			**3,831.62**

Fixed and variable costs

Fixed costs	Cost	Depreciation Years	1	2	3	4	5
Equipment & Material							
5 Hp Gasoline pump	1,400.00	5	280.00	280.00	280.00	280.00	280.00
2 "Main pipe	575.00	2	288.00	288.00			
Bi-wall	675.00	1	675.00				
Take Off	409.50	2	205.00	205.00			
Accessories and fittings	300.00	1	300.00				

Total			**1,747.00**	**772.00**	**280.00**	**280.00**	**280.00**
Variable Costs							
Fuel			429.20				
Lubricants			42.92				
Total Inputs			5,488.50				
5% Inputs Contingency			274.43				
TOTAL COSTS/ACRE POTATO			**7,982.05**				

Summary of Potato Production–One Acre, Irrigated

Yield per acre in pounds (lbs)		25,000
Market Price per lb BZ$	$	0.85
Gross Income BZ$	$	21,250.00
Total Expenditure/acre	$	7,982.05
Net Income	**$**	**13,267.95**
Unit cost of product	$	0.32

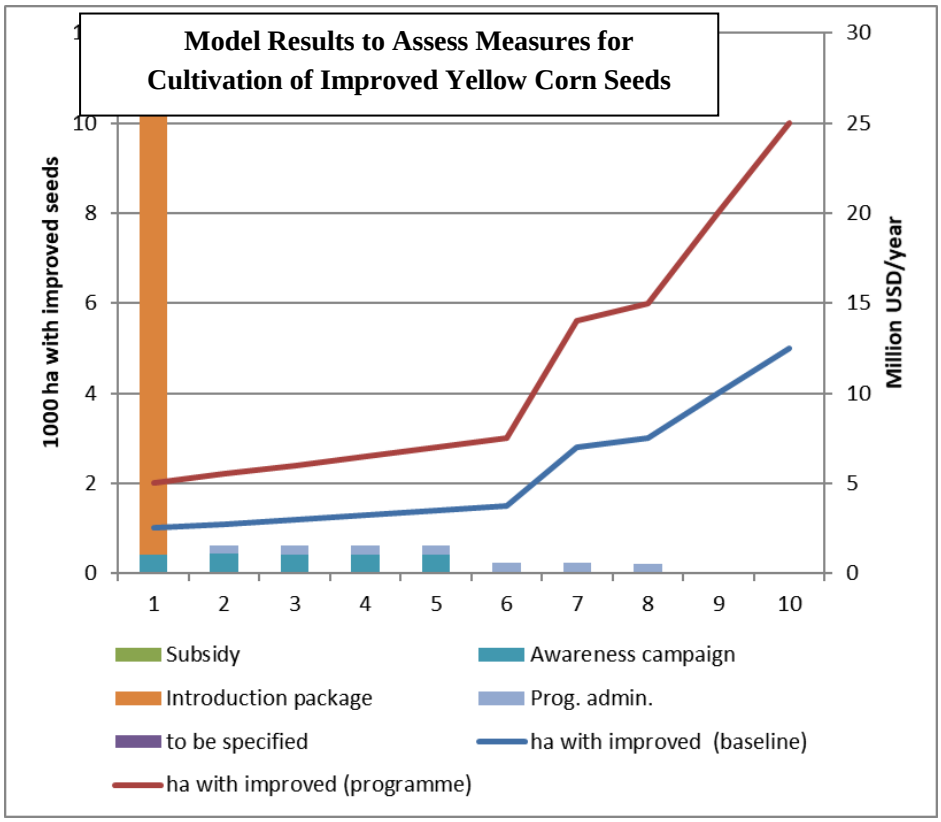
Chemical Species

CO	Carbon monoxide
CO_2	Carbon dioxide
CH_4	Methane
H_2	Hydrogen gas
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide

ANNEX I-D: Model Output to Assess Impacts of some Measures for Diffusion of Technologies

Impacts of measures for diffusion of improved Yellow Corn seeds

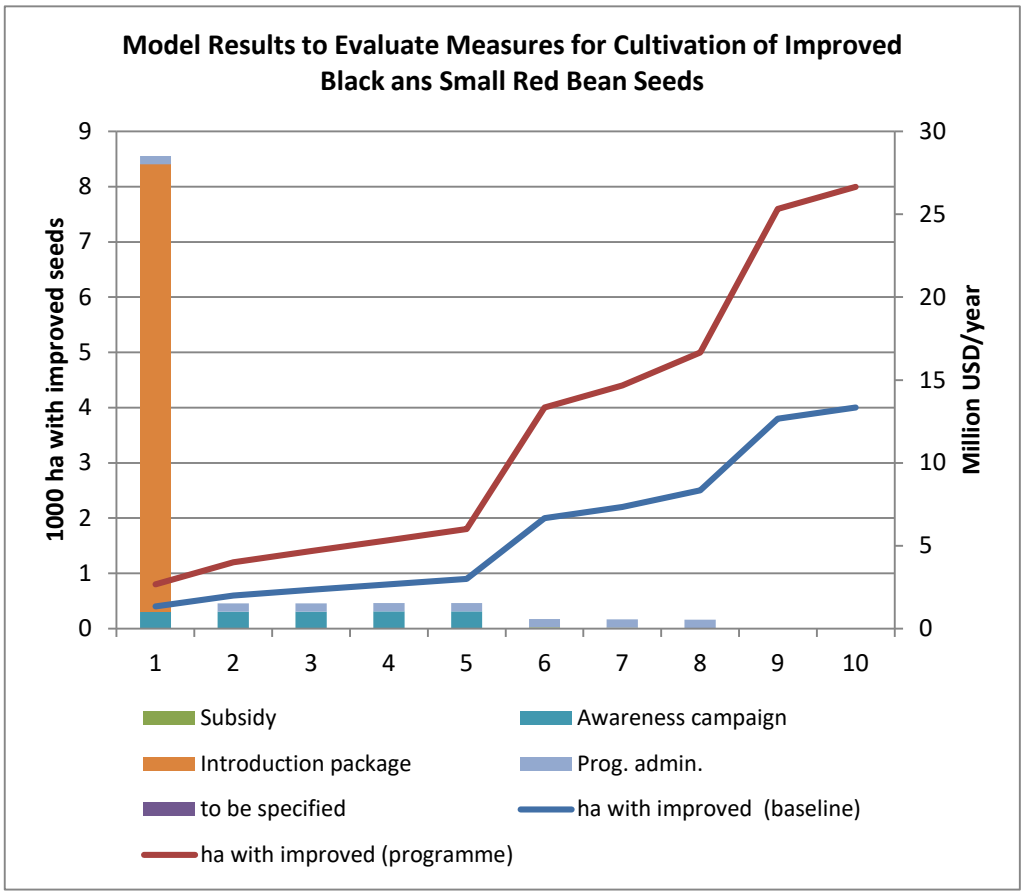
Assessing sets of measures for improved maize seeds						INPUT CELLS IN YELLOW						
Assumptions	Increased yield		3.86	tonne/ha		Disc. rate		0.1				
Text	Unit	Total 10 years	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
Impact												
ha with improved (baseline)	1000	22.3	1	1.1	1.2	1.3	1.4	1.5	2.8	3	4	5
ha with improved (programme)	1000	44.6	2	2.2	2.4	2.6	2.8	3	5.6	6	8	10
Effect (ha with improved seeds)	1000	22.3	1	1.1	1.2	1.3	1.4	1.5	2.8	3	4	5
Programme costs		NPV										
Subsidty on seeds per ha	USD		30	30	25	20	20	20	10	5	0	0
Subsidy on seeds	M USD	0.3	0.06	0.066	0.06	0.052	0.056	0.06	0.056	0.03	0	0
Introduction package	M USD	24.5	27	0	0	0	0	0	0	0	0	0
Awareness campaign	M USD	3.8	1	1	1	1	1	0	0	0	0	0
to be specified												
Program administration	M USD	2.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0
Total programme cost (NPV)	M USD	31.3	28.56	1.566	1.56	1.552	1.556	0.56	0.556	0.53	0	0
Benefits	1000											
Increased production	tonnes	86.1	3.86	4.246	4.632	5.018	5.404	5.79	10.808	11.58	15.44	19.3
Cost vs. benefits												
Programme costs/tonne of extra yield		363.7	USD/tonne maíze			Market price for maize				110	USD/tonne	



(Source: After Nygaard and Hansen, 2015)

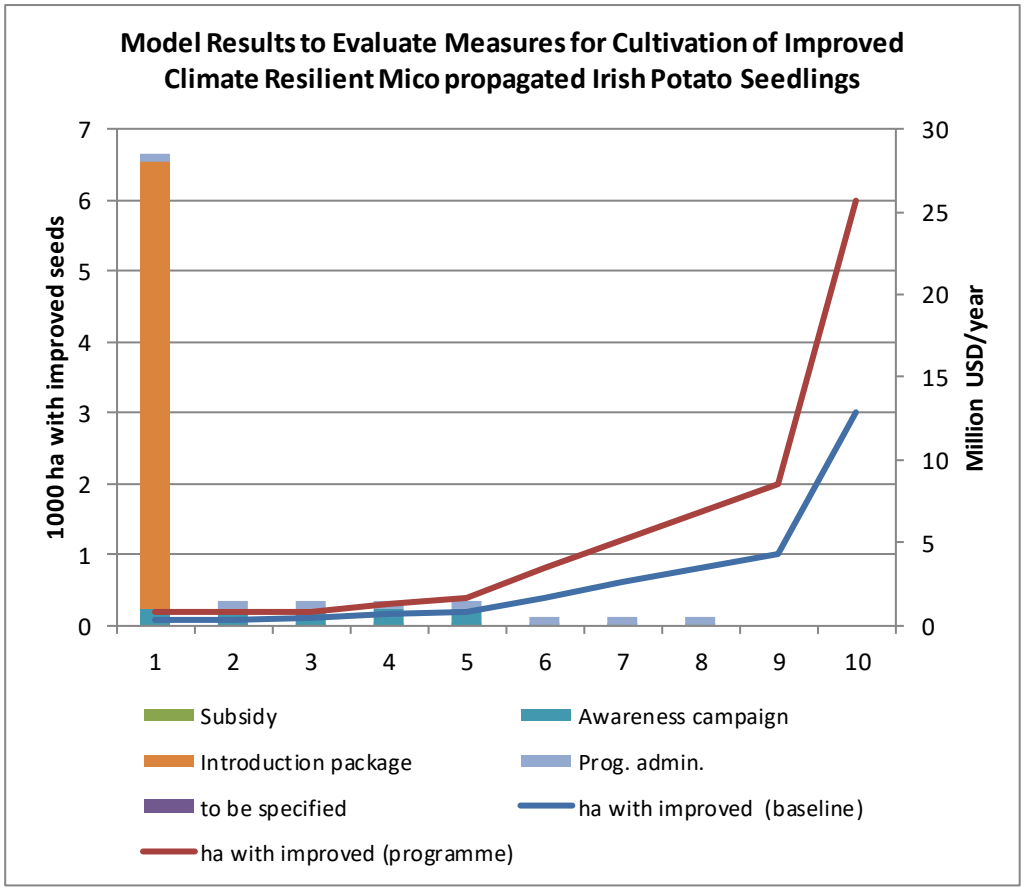
Impacts of measures for diffusion of improved Black / Small Red Beans seeds

Assessing sets of measures for improved seeds						INPUT CELLS IN YELLOW									
Black and Small Red Beans															
Assumptions	Increased yield		0.81	tonne/ha		Disc. rate		10%							
Text	Unit	Total 10 years	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10			
Impact															
ha with improved (baseline)	1000	17.9	0.4	0.6	0.7	0.8	0.9	2	2.2	2.5	3.8	4			
ha with improved (programme)	1000	35.8	0.8	1.2	1.4	1.6	1.8	4	4.4	5	7.6	8			
Effect (ha with improved seeds)	1000	17.9	0.4	0.6	0.7	0.8	0.9	2	2.2	2.5	3.8	4			
Programme costs		NPV													
Subsidty on seeds per ha	USD		20.0	20.0	15.0	20.0	20.0	20.0	10.0	5.0	-	-			
Subsidy on seeds	M USD	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	-			
Introduction package	M USD	24.5	27.0	-	-	-	-	-	-	-	-	-			
Awareness campaign	M USD	3.8	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-			
to be specified															
Program administration	M USD	2.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-	-			
Total programme cost (NPV)	M USD	31.2	28.5	1.5	1.5	1.5	1.5	0.6	0.5	0.5	-	-			
Benefits	1000														
Increased production	tonnes	14	0	0	1	1	1	2	2	2	3	3			
Cost vs. benefits															
Programme costs/tonne of extra yield		2,150	USD/tonne beans			Market price for RK Beans				400	USD/tonne				



Impacts of measures for diffusion of certified Irish potato seed tubers

Assessing sets of measures for improved seeds						INPUT CELLS IN YELLOW					
Climate Resilient Irish Potato Production											
Assumptions	Increased yield		11.87	tonne/ha		Disc. rate		10%			
Text	Unit	Total 10 years	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
Impact												
ha with improved (baseline)	1000	6.429	0.089	0.09	0.1	0.15	0.2	0.4	0.6	0.8	1	3
ha with improved (programme)	1000	12.86	0.18	0.18	0.2	0.3	0.4	0.8	1.2	1.6	2	6
Effect (ha with improved seeds)	1000	6.431	0.091	0.09	0.1	0.15	0.2	0.4	0.6	0.8	1	3
Programme costs		NPV										
Subsidty on seeds per ha	USD		20.0	20.0	15.0	20.0	20.0	20.0	10.0	5.0	-	-
Subsidy on seeds	M USD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Introduction package	M USD	24.5	27.0	-	-	-	-	-	-	-	-	-
Awareness campaign	M USD	3.8	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-
to be specified												
Program administration	M USD	2.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-	-
Total programme cost (NPV)	M USD	31.0	28.5	1.5	1.5	1.5	1.5	0.5	0.5	0.5	-	-
Benefits	1000											
Increased production	tonnes	76	1	1	1	2	2	5	7	9	12	36
Cost vs. benefits												
Programme costs/tonne of extra yield		407	USD/tonne Potat			Market price for Irish Potato				300	USD/tonne	



(Source: adopted from Nygaard and Hansen, 2015)

ANNEX II: Economic Evaluation and Renewable Energy Input for Different Agriculture Adaptation Technologies

A) 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*

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 systems 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 1,800 acres of rice in the Toledo District of Belize. The average yield from such production ranges from 1,500 – 2,500 lbs./acre, while the mechanized, irrigated, low land produces upward of 5,000 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 expansion and 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, five district agriculture training/demonstration sub-stations, and the Ministry of Agriculture training centre at Central Farm. 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. Seven improved drip irrigation/water harvesting & fertigation systems are being considered for this adaptation technology transfer, and coordinated, managed and maintained by the CRDU and the Extension Service of the Ministry of Agriculture.

B) Crop Diversification and New Varieties

Technology Application: *Refurbishment of Seven Protective Structure 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 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).

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

- Natural Passive Ventilation (Air exchange) and shading systems;
- Mechanical Active Ventilation powered with a small diesel generator;
- 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 favourable 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.

C) 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.*

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 contributes 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.

D) 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

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.)* belongs 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, is 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 are reproduced vegetative (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 Progresso 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 lb./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 were 25,869 lb./ha. In a January 2018 Press Release by the MOA, it was announced that total estimated potato production for the 2017-18 cropping season was 3.7 million pounds, with potato cultivation spreading to the northern Corozal District and southern Stann Creek District.

Economic Evaluation

E1) Drip Irrigation Systems

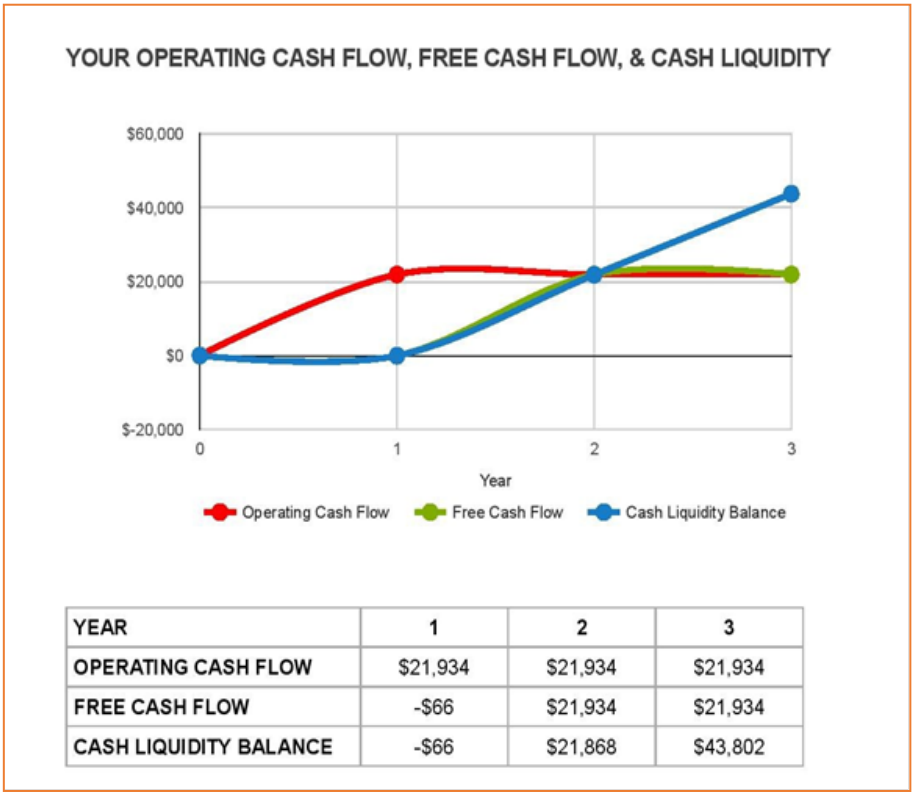
Technology Application: *Improved drip irrigation systems using rainwater harvesting and fertigation for crop nutrient requirement for five farmers groups plus a training centre at Central Farm*

All prices are in USD

Capital Investment Cost	Six only improved drip irrigation system with irrigation and water abstraction facility to irrigate 6 acres:

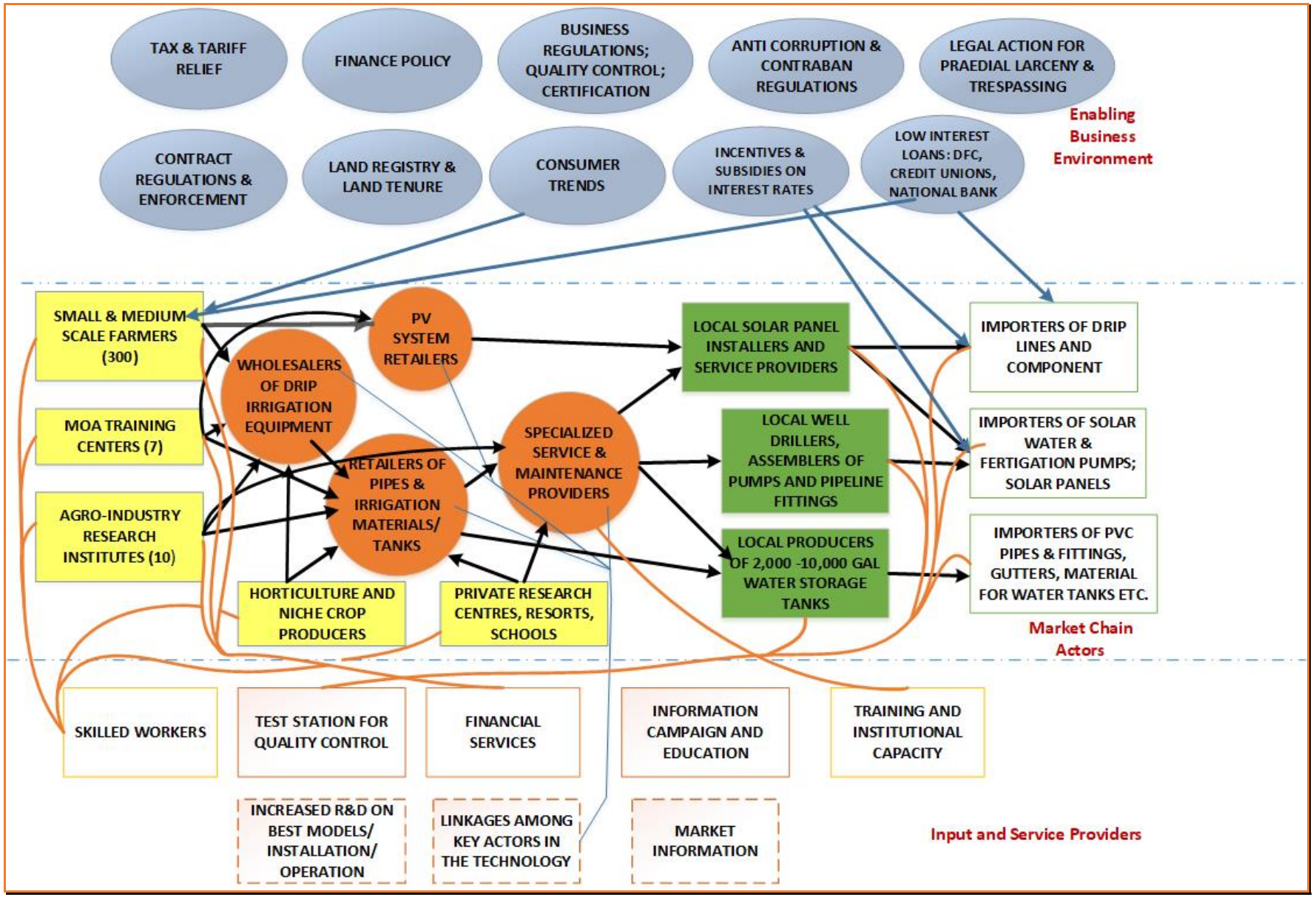
	@ US$ 7,000.00 each **Cost** **US$ 42,000.00** Six pumps @ US$ 1,200.00 3,000.00 solar) **Cost** **US $7,200.00 (18,000.00)** Six wells @ US$ 7,000.00 **Cost** **US$ 42,000.00** **Six 2,000 gallons Water Tanks** @ US$ 800.00 **Cost** **US$ 4,800.00** Training extension personnel and four farmers groups @ US$ 5,000.00 **Cost** **US$ 20,000.00** **Total Cost** **US$ 116,000.00 (126,800)**
Operating Cost	Spares and maintenance per year US$15,000.00 **Total Cost** **US$ 45,000.00**

NPV: 213,300.00 US$. IRR: 200.4%



YEAR	1	2	3
OPERATING CASH FLOW	$21,934	$21,934	$21,934
FREE CASH FLOW	-$66	$21,934	$21,934
CASH LIQUIDITY BALANCE	-$66	$21,868	$43,802

Annex-II E2: Market Mapping for improved drip irrigation and fertigation



(Source: After Nygaard and Hansen, 2015)

Market Mapping for transfer and diffusion of improved drip irrigation and fertigation system

Summary, barriers and gaps

Reference Market mapping schematic for improved drip irrigation

i. *Exporters/manufacturers of drip irrigation system & components/spares:* Procured from foreign manufacturers/outlets etc. by local importers & retailers of agro-technology equipment. Funds for procurement of irrigation equipment and components from importers/retailers will come from capital costs. Farmers may purchase from importers. Retailers, or if they preferred, directly from the manufacturer/franchise.

ii. *Import duties/taxes and subsidies:* Taxes may apply, but subsidies may be granted to importers which can be passed down to the farmers and institutions at the other end of the market chain.

iii. *Importers and Retailers:* Equipment and spares for irrigation, fertigation, cover structures, nurseries, harvesting, cool storage facilities, solar-powered water pumps, and water tanks shall be imported from manufacturers or their outlets, and stocks will be made available for retailers and clients. Import taxes are mostly zero rated for irrigation and solar PV systems, but taxes may apply for certain components such as inverters, batteries, pvc pipes/fittings, and material to manufacture water tanks, etc.

iv. *Input and Service Providers:* Inputs for crop protection, fertilizers, etc., and Service Providers for RE system installation (i.e. Solar PV, dryers, and cold storage facilities for grains) are available. The Research and Development Unit provides service and training for installing drip irrigation systems. Technology information and demonstration are made available to famers, but there is more to be done for expanded dissemination of relevant information and training of new technologies. Also, information and training in market principles and basic economics is limited, as is the need to utilize social media as a form for networking among producers, service providers/assemblers and importers. Another limitation or barrier is the limited level of education of many small and medium-scale farmers. Language barriers also exist in some instances.

v. *Enabling Business Environment:* MOA and partners (CARDI, BELTRAIDE, IICA, DFC and others) are available to provide guidance and advise to farmers on issues related to affordable loans, other financing opportunities, market fluctuations and opportunities, and policy changes. The gap here seems to be limited networking among main actors. The leadership role here is the MOA, whose Extension Service and Policy Unit are closest to farmer's interests. The Extension Service plays a crucial role and must be empowered (through training, increased capacity and public relations guidance) to continue the good work of improving production and climate smart agriculture among the small and medium scale farmers. On their own, most small famers, and to a lesser extent, medium-scale farmers, do not have the capital to invest on a medium-size (5 – 10 acres) irrigation system. Large farmers impact the environment to a greater extent, A gap exist here that requires the joint cooperation of key actors in the Sector to address with sustainable development programmes and outreach.

vi. Policies and medium-term strategies must be updated and adopted to respond to the advances in technologies and changing market conditions, that if properly managed and use, can significantly improve yields of high quality, competitive products, with minimal impacts on the environment.

vii. Training at specific links of the drip irrigation market change (e.g. Service Providers, MOA CRDU, Extension Service and at the Farm level) is paramount for successful operation. Farmer's outreach programme and MOA's Public Relations activities have room for improvement and expansion.. Funds for capacity building and networking should be allocated from the operational budget.

viii. Another gap identified is an Agriculture Testing/Certification Centre that can certify the quality of equipment, spares, inputs, seeds etc. The status of testing or certification is mainly for Phyto-sanitary, biosafety and risk analysis for import/export of organisms/products through BAHA, while the Pesticides Control Board is responsible for the safe use and control of pesticides.

ix. The economic and technical capacity of many small farmers to procure and operate an improved drip/fertigation irrigation system is generally limited. Medium-scale farmers would be the favoured target group in the market chain for this technology diffusion (L. Gladden, Chief, NCO, personal comm. Mar. 2018).

x. The Policy and Strategy for drainage and irrigation should be reviewed and implemented. The issue of integrated water resource management and irrigation becomes crucial, as the stress on this vital resource increases as a result of anthropogenic impacts in the watersheds, coupled with the increasing negative impacts of climate change on the rainfall regime. Spearheading this initiative should be the Water Management and Climate Change Unit of the Ministry of Agriculture.

F) Crop Diversification and New Varieties

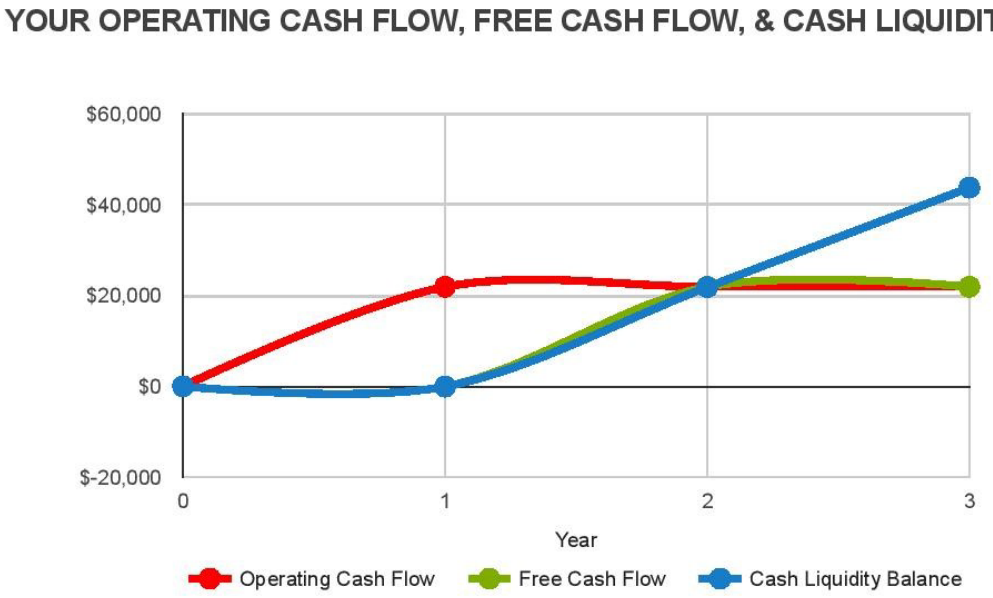
Technology Application: *Refurbishment of Seven Protective Structure Cooling Systems*

Capital Investment Cost	**Refurbishment of 1-unit Tropical Greenhouse with dimensions: 54′ x 82′ x 23′; Volume: 101,844 ft³** 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 1 Unit US$ 20,000.00 **Sub Total: US$ 25,000.00** **Refurbishment of 7 typical unit Bel Tunnel with dimensions: 14′ x 60′ x 12′; Volume: 10,080 ft³** 2) Redesigning natural ventilations: US$ 1,000.00 3) Ceiling Shading US$ 1,500.00 4) 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** 5) Training of 6 Technicians 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.

Tropical Greenhouse with dimensions: 54' x 82' x 23'; Volume: 101,844 ft^3

NPV: 43,604.00 US$
IRR: 51.7 %

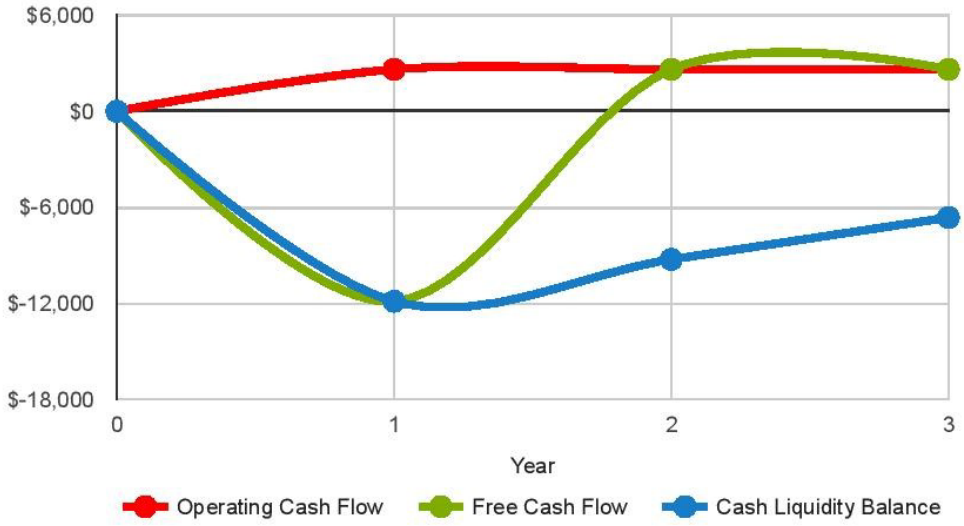


YEAR	1	2	3
OPERATING CASH FLOW	$21,934	$21,934	$21,934
FREE CASH FLOW	-$66	$21,934	$21,934
CASH LIQUIDITY BALANCE	-$66	$21,868	$43,802

Bel Tunnel with dimensions: 14' x 60' x 12'; Volume: 10,080 ft^3

NPV:-42,280.900
IRR: -176.6 %

YOUR OPERATING CASH FLOW, FREE CASH FLOW, & CASH LIQUIDITY



YEAR	1	2	3
OPERATING CASH FLOW	$2,620	$2,620	$2,620
FREE CASH FLOW	-$11,880	$2,620	$2,620
CASH LIQUIDITY BALANCE	-$11,880	-$9,260	-$6,640

G) 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.***

Capital Investment Cost	Crop establishment input: 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 (18,000.00) Wells 3 US$11,000.00 (21,000.00) Pumps 3 US$1,800.00 (21,000.00 solar) **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 (17,000 solar A/C) 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 (15,000 Solar

	pump) Land Preparation (25 acres) US$7,500.00 Crop establishment Input: 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***

H1) 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

Capital Investment Cost	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 $337,000**
Operating Cost	Establishment of farmer field trials to evaluate varieties – US$ 25,000. 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 programs 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**

Market Mapping for transfer and diffusion of clean, certified seed tuber Potato varieties

Summary, barriers and gaps

Reference Market mapping schematic for micro-propagation of clean, climate resilient, certified Irish potato seed-tubers in Annex II H2.

i. *Source Basic Seeds (Clean parent material):* Procured from potato breeding centres in the United States and/or the International Potato Centre in Peru (CIP). Private sector importers, GOB through MOA/UB, CARDI, others.
ii. *Import duties/taxes and subsidies:* Taxes may apply, but subsidies may be granted to importers which can be passed down to the farmers at the other end of the market chain.
iii. *UB micro-propagation laboratory:* Equipment and material will have to be procured in the capital cost for up-grading laboratory facilities, and fund must be available for first 2.5 years of operation and maintenance. Funds for expert consultant for developing production strategic workplan and guidelines for micro-propagation of 'Source Basic Seeds" to certified potato seed tubers for farmers,

must be part of the capital costs. Training of micro-propagation laboratory technicians and field workers, and farmer's outreach programme and technology awareness/education campaign, should be funded from capital cost.

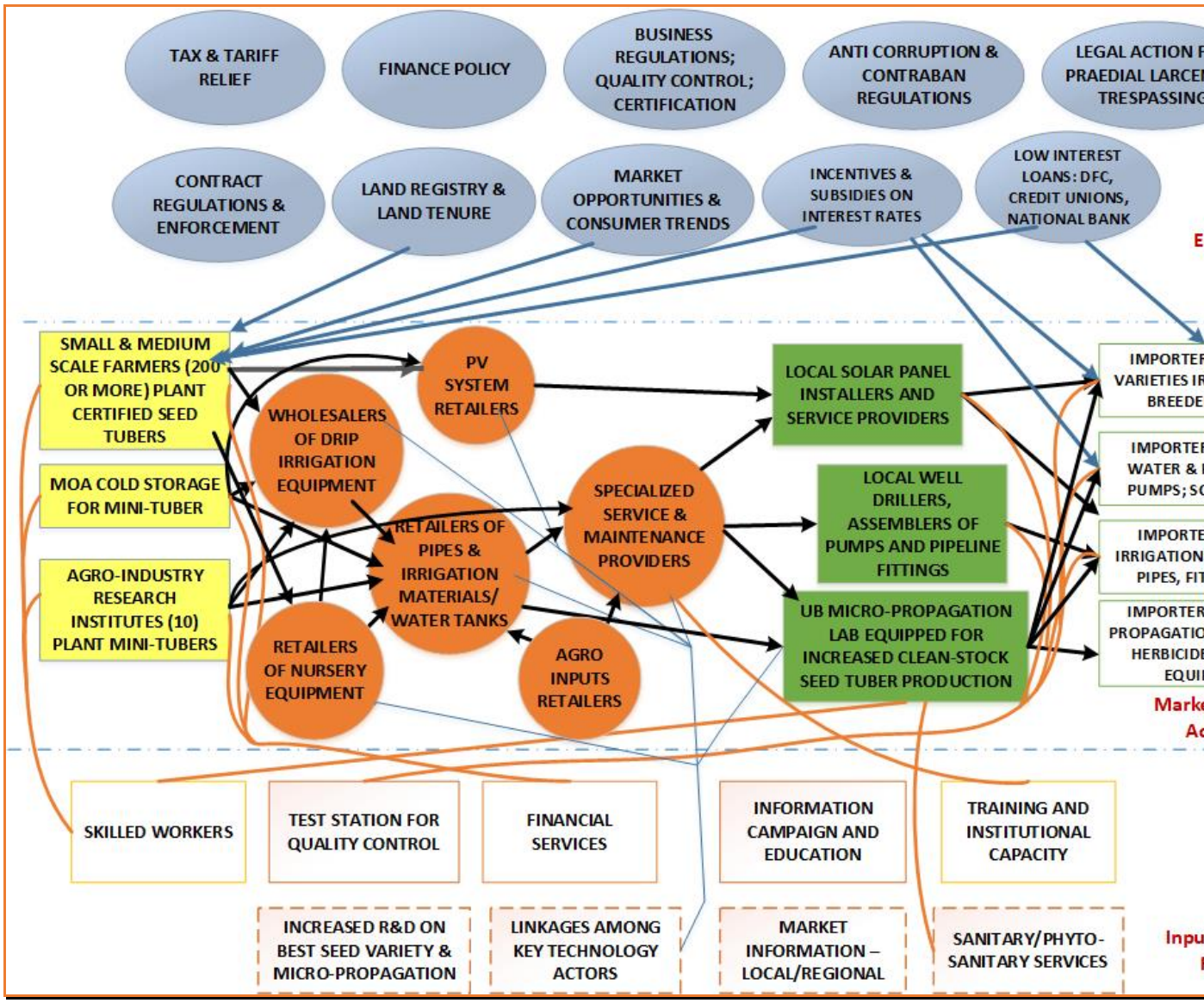
iv. *Importers and Retailers:* Equipment and spares for irrigation, fertigation, cover structures, nursery, and water pumping/harvesting and storage, shall be imported, and stocks available. Import taxes are mostly zero rated for irrigation and solar PV systems, but taxes are applied for certain components such as inverters, batteries, and miscellaneous spares.

v. *Input and Service Providers:* Generally available. Gaps exist in provision of information on technology and the changing market, and also networking among producers and service providers and importers.

vi. *Enabling Business Environment:* MOA and partners (CARDI, BELTRAIDE, IICA, DFC and others) are available to provide guidance and advise to farmers on issues related to affordable loans, other finance opportunities, the market, and policy changes. The gap here seems to be limited networking among main actors, the leadership role here is the MOA, whose extension service and policy office is closest to farmers. The Extension Service plays a crucial role and must be empowered (through training, increased capacity and public relations) to continue the good work of improving production among the small and medium scale farmers.

vii. The micro-propagation of climate resilient, Source Basic Seeds of Irish Potato is envisioned to become sustainable and profitable in the medium term as potato production increases, and market opportunities are secured.

Annex-II H2: Market Mapping for micro-propagation of clean, climate resilient, certified Irish potato seed tubers



(Source: After Nygaard and Hansen, 2015)

I) Irish Potato Clean-stock Seed-tuber Micro-propagation

(Source: UB Plant Micro-Propagation Laboratory, May, 2017)

Irish Potato Clean-Stock Seed-Tuber Production System			
Month	**Activity**	**Description**	**Institution / persons responsible**
0-3	**Source Basic Seed** Source "clean" parent material	Indexed (tested to be free of specified disease) potato tubers sprouted	Ministry of Agriculture / University of Belize / Belize Agricultural Health Authority
0-8	**Create Basic Seed**	If basic seed cannot be sourced production of virus-free potato plants (basic seed) using meristem culture / heat treatment. Process takes 4-8 months.	University of Belize micropropagation lab

8-20 (12 months)	**Shoot-tip multiplication**	Shoot tips introduced into tissue culture media (Murashige and Skoog without cytokinin) to produce large numbers of micro-cuttings. This sub-culturing is a continuous process.	
21-22 (2 months)	**Micro-tuberization**	Cuttings placed in cultures with high sucrose media in dark at or^{c} to induce tuberization. Process takes two months.	
23-26 (4 months)	**Micro-tuber storage**	Micro-tubers held in dry jars at 5-6 ^{o}C for 3-4 months to break dormancy	
27-30 (4 months)	Micro-tuber germination to produce **mini-tubers**	Plant micro-tubers in screenhouses in November to produce mini-tubers.	
31-38 (8 months)	**Mini-tuber storage**	Mini-tubers stored at 10 ^{o}C for 8 months.	Ministry of Agriculture
39-42 (4 months)	Mini-tuber germination to produce **certified seed-tubers**	Mini-tubers planted in farmer screen-houses in November to produce seed tubers.	Farmers – facilitated by Ministry of Agriculture
42-49 (8 months)	**Certified seed-tuber storage**	Seed tubers stored at 10 ^{o}C for 8 months.	Ministry of Agriculture
50	**Field planting** with quality **certified seed-tubers**	In November / Dec seed tubers distributed to farmers for field planting.	Seed-tubers distributed to farmers by Min Agric.
54	**Potato harvest**	In February / March potatoes are harvested and delivered to market.	Farmers

Summary

I) 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.

Feasibility of the implementation of the proposed improved irrigation technology intervention was calculated on the basis of tomato plants. Implementation of an improved irrigation system is economically feasible as it increases the yield by approx. 40 percent.

The commonly used water pumps fuelled with gasoline or diesel shall be exchanged with solar water pumps. Six solar pumps for 6 units of 1 acre each.

J) Crop Diversification and New Variety

Technology Application: Refurbishment of Seven Protective Structure Cooling Systems

Natural ventilation allows the greenhouse structure to ventilate and cool by natural air movement within and outside the structure. One Tropical Greenhouse shall receive 18 solar fans (9 intake and exhaust fans and 9 ceiling fans). The Tropical Greenhouse is already feasible on its own and is more feasible with ventilation.

The seven Bel Tunnels are economically feasible without fans. The investment costs of 9 solar fans (6 intake and exhaust fans, 3 ceiling fans), are very high considering the income that the farmers can create in these small units. To make the Bel Tunnel project more feasible ventilation needs to be reduced.

K) 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.

The commonly used water pumps fuelled with gasoline or diesel shall be exchanged with solar water pumps, 3 solar pumps for 3 units 6 acres each, one solar pump for 25 acres.
3 solar A/C each 18,000 BTU to replace the very inefficient cooling system at the storage house in central farm.
Energy saving up to 85 % or 29,000 kWh or 11,680 BZD per year

L) Crop Diversification and New Varieties

Technology Application:
Establish an in-country Irish potato clean-stock production unit to produce certified seed-tuber planting material varieties better suited to Belize's current and future climate

4 Solar-powered air conditioning units to replace inefficient units at the laboratory on the UB compound at Central Farm.
3 Solar cooling and irrigation systems with solar pumps and solar fans for Screen houses.
9 Solar-powered air conditioning units for 3 storage structures.

ANNEX III: LIST OF STAKEHOLDERS INVOLVED AND THEIR CONTACTS

List of Key Stakeholders for TNA-Belize. BA & EF for Agriculture, Water and Coastal & Marine Ecosystem Sectors: ADAPTATION Technology

Venue: Ministry of Agriculture Research and Development Unit, Central Farm, Cayo District

Date: Dec. 6, 2016

Sector	Name	Institution	Contact Information	
			Contact	Email Address
AGRICULTURE	Hector Reyes	CARDI	824-2934	cardi@btl.net
	Omira Avila	CARDI	608-1325	oavila@cardi.org
	Manuel Trujillo	MNRA Central Farm	650-0961	manuel.trujillo@agriculture.gov.bz
	Andrew Harrison	MNRA	828-5095	andrew.harrison@agriculture.gov.bz

	John Carr	Banana Bank Agriculture	832-2020	bbl@bananabank.com
	Hugo Rancharan	Belize Water Services Limited	634-1440	hugo.rancharan@bwsl.com.bz
	Keisha Rodriguez	BMDP/MNRA	615-3420	pp.urbanplanner@mnra.gov.bz
	Raul Villanueva	Belize Electricity Ltd.	610-2740	raul.villanueva@bel.com.bz
	Yvette Alonzo	IICA	822-0222	yvette.alonzo@iica.int
	Francis Arzu	Lands & Survey Dept	615-4572	plio@mnra.gov.bz
	William Can	Ministry of Agriculture, Extension	602-2068	jcan@agriculture.gov.bz jonathancan_60@yahoo.com
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	Stephen Williams	University of Belize Plant Propagation Lab	610-2737	swilliam@ub.edu.bz
	David Guerra	University of Belize Plant Propagation Laboratory	615-6677	dguerra@ub.edu.bz
	Jesse Madrid	Ministry of Agriculture	668-1437	Madridjess88@yahoo.com
	Gary Ramirez	Ministry of Agriculture, Research and Development Unit (RDU)	634-3929	gramirez@agriculture.gov.bz
	Christobal Teck	Ministry of Agriculture	634-9590	Christobal.teck@agriculture.gov.bz
	Clifford Martinez	DAC Ministry of Agriculture	629-8088	Clifford.martinez@agricultutre.gov.bz
	Oscar Salazar	RDU, Ministry of Agriculture	804-2079 804-2129	okisalazar@yahoo.com
WATER				
	Roland Rivers	Public Utilities Commission	651-3595	rrivers@puc.bz
	Wayne Cadle	Belize Electricity Company Ltd. (BECOL)	610-0844	wayne.cadle@becol.com.bz
	Edilberto Romero	Programme for Belize	227-5616	execdirector@pfbelize.org
	Ernest Banner	Rural Development	822-0073	ernest.banner@gmail.com coord.rural.dev@labour.gov.bz
	Tennielle Williams	MNRA Hydrology		Policy.publicliaison@mnra.gov.bz
	John Bodden	Public Health, MOH	670-4378	jbodden@health.gov.bz
	Anthony Flowers	Public Health Water Quality	223-1213	aflowers@health.gov.bz

		Lab		
	Cecy Castillo	University of Belize	625-6271	cacastillo@ub.edu.bz cecycas_bz@yahoo.com
COASTAL & MARINE ECOSYSTEM	Darlene Padron	MAFFESD	828-4794	sn.susdevofficer@ffsd.gov.bz
	Vivian Belisle-Ramnarace	Fisheries Department	224-4552	vr.ppv@ffsd.gov.bz vivian@fishries.gov.bz
	Eugene Waight	MAFFESD – KBA	626-1053	kba.po@ffsd.gov.bz
	James Azueta	Fisheries Department	620-2383	Jamesazueta_bz@yahoo.com
	Samir Rosado	Coastal Zone CZMA	223-0719	coastalplanner@coastalzonebelize.org
	Stacey Cayetano	Coastal Zone CZMAI	223-0719	gistechnician@coastalzonebelize.org
	John Reyes	Ministry of Tourism, Culture and Civil Aviation	227-2801	John.reyes@tourism.gov.bz
	G. Rosado	NPAS - MFFSD	824-0401	Co.npas@ffsd.gov.bz
FINANCE & PRIVATE SECTOR (Cross Cutting)	Nicole Zetina	BELTRAIDE	822-3737 622-8392	nicolezetina@gmail.com
	Amparo Masson	Office of the Prime Minister	610-2172	amparo.masson@opm.gov.bz
	Lianne Torres	BELTRAIDE	822-3737	lianne@belizeinvest.org.bz
	Carmen Silva	U.S. Embassy	822-4011 Ext. 4115	silviac@state.gov
	Marco Valle, Manager	ProSolar	832-2217	marco@prosolarltd.com
	Ramón Frutos	Lead Consultant	630 9724	ecosolrf@gmail.com; rfrutos01@yahoo.com

ANNEX IV: Gross Domestic Product by Activity

Table A-4.1 GDP 2002-2012 p by Activity – Current prices (Source: SIB, 2015)

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

Table A-4.2: GDP 2012 r -2014 p – Current prices (Source: SIB, 2015)

			($Bz Mn)
	2012r	2013r	2014p
Agriculture and forestry	344.9	333.5	356.1
Growing of crops; horticulture	273.0	253.2	257.8
Livestock farming	64.8	72.4	89.5
Forestry and logging	7.1	7.9	8.9
Fishing	66.2	100.1	102.7
Mining and quarrying	15.1	15.0	14.0
Primary industries	426.2	448.5	472.9
Manufacturing	379.1	321.6	293.9
Manuf. of food products and beverages	199.7	196.8	193.6
Manuf. of textiles, clothing and footwear	0.0	0.2	0.0
Other manufacturing	179.4	124.5	100.2
Electricity and water supply	70.6	107.7	130.9
Construction	87.8	91.2	110.6
Secondary industries	537.6	520.4	535.3

** r: reported, p: preliminary

Table A-4.3: GDP by Activity: 2012 r -2014 p ─ current prices - contribution to GDP

			(%)
	2012r	2013r	2014p
Agriculture and forestry	10.96	10.26	10.37
Growing of crops; horticulture	8.68	7.79	7.50
Livestock farming	2.06	2.23	2.60
Forestry and logging	0.23	0.24	0.26
Fishing	2.10	3.08	2.99
Mining and quarrying	0.48	0.46	0.41
Primary industries	13.54	13.79	13.76
Manufacturing	12.05	9.89	8.55
Manuf. of food products and beverages	6.35	6.05	5.64
Man. of textiles, clothing and footwear	-	0.01	0.00
Other manufacturing	5.70	3.83	2.92
Electricity and water supply	2.24	3.31	3.81
Construction	2.79	2.80	3.22
Secondary industries	17.08	16.00	15.58

(Source: SIB, 2015)

ANNEX V: List of Tax Exempted Goods

Table A-5.1 Tax Exempted Goods

Department of General Sales Tax

ZERO RATED GOODS

(TAXED AT ZERO PERCENT – NO GST ON THESE GOODS AS OF APRIL 1, 2010)

UNPROCESSED FOODS:

- Rice
- Flour
- Corn
- Fresh Meat (Mammal, Bird, or Fish)
- Edible Offal of Bovine Animals, Swine & Sheep
- Eggs
- Beans
- Fresh Fruits & Vegetables (Locally Produced)
- Salt
- Fresh Milk (Locally Produced)
- Tea

PROCESSED FOODS:

- Bread
- Corn & Flour Tortilla
- Sweet Bread & Bun (Locally Produced)
- Cooking Lard
- Margarine
- Baby Formula
- Sugar
- Condensed Milk
- Powdered Milk
- Cooking Oil
- Instant Coffee
- Chicken Sausages (Canned)
- Corned Beef (in Cans)
- Yeast
- Oats
- Luncheon Meat
- Potted Meat
- Chocolate Powdered Drinks
- Macaroni & Cheese
- Cereals
- Percolated Coffee
- Edible Meats of Swine Salted or in Brine (e.g. Pigtail)
- Edible Meats of Bovine Animals Salted or in Brine (e.g. Salt Beef)
- Soup & Broth in Solid or Powdered Form (including Ramen)
- Preparations of Malt Extract
- Any Live Bird, Fish, Crustacean, Mollusk or other Animal of a kind Generally Used as, or Producing, Food for Human Consumption

EDUCATIONAL ITEMS:

- Notebooks/Exercise Books
- School Bags
- Pencils, Crayons, Lead Pencils, Erasers, Pencil Holders for Use in Schools

MEDICINE:

- Analgesics (Pain Killers) - Liquids, Tablets, Capsules or Solid Dosage Forms for Oral or Rectal Use
- Cough & Cold Preparations (Liquid, Tablets, Capsules, Other Solid Dosage Forms for Oral or Nasal Use
- Diagnostic Testing Kits And Devices to Test Glucose in Blood and Urine
- Insulin
- Insulin Syringes with Needles and Devices 100 Units (1.0 Ml) Capacity, for the Administration of U-100 Insulin
- Oral Rehydration Salts & Solutions of W.H.O. Paramacopoeia Standard
- Oxygen
- Dialysis Fluids
- Anti – Retroviral Medicines
- Vitamins and Supplements

HOUSEHOLD ITEMS/SUPPLIES:

- Stoves/Rangers/Cookers
- Refrigerators (Domestic Use)
- Washing Machine (Domestic Use)
- Laundry Washing Soap Powder

AGRICULTURE:

- Barbed Wire
- Spare Parts for Tractors
- Irrigation Pipes & Hoses
- Cable for Banana Industry
- Hatching Eggs
- Concentrated Animal Feeds (Bovine & Swine)
- Animal Feeds for Bird, Fish, Crustaceans, Mollusks & Other Animals
- Seed & Means of Propagation of Plants Used to Produce Foods That are Zero-Rated
- Sugar Cane Loading Machines
- Land Preparation for Agriculture, Harvesting and Crop Dusting Services
- Fertilizers, Pesticides, Fungicides and Herbicides

UTILITIES:

- A Supply of Water (Other Than Bottled Water or Similar Containers) or Domestic Sewerage Services
- Butane Gas for Domestic Use

OTHERS:

- Frames for Eye Glasses

Consumers: Look for the Green GST Registration Certificate when you enter a Store. Always, ask for your GST Tax Receipt
Remember, every Retailer must utilize a programmable Cash Register or Point of Sale System

Contact Us At: Hotline - 222-5294; generalsalestax@gst.gov.bz; www.gst.gov.bz; Or Bureau of Standards, Hotline - 0800 283 5587

ANNEX VI: National Agriculture and Food Policy 2015-2920

(Ministry of Agriculture/GOB/FAO, January, 2015)

National Agriculture and Food Policy 2015 -2020: Belize

The Policy framework

1. **The overall goal of the policy:**

   To engender that environment conducive to 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. **Guiding principles:**

   Consistency, partnership and solidarity, sustainability, entrepreneurship, accountability and transparency, equity and inclusiveness, social responsibility, targets and phasing.

3. **Pillars of the Policy**

- Production, productivity and competitiveness enhancement;
- Market development, access and penetration;
- Food and Nutrition Security situation and improved rural livelihoods;
- Sustainable management systems and risk management; and
- Effective and efficient governance mechanisms

4. **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.

Agriculture Policy Framework Structure

Pillar	Pillar 1:	Pillar 2:	Pillar 3	Pillar 4
	Production, Productivity and Competitive Enhancement	**Market Development, Access and Penetration**	**National Food and Nutrition Security and Improved Rural Livelihoods**	**Sustainable Agriculture and Risk Management**
Strategic Objectives	**SO1.1** Rationalize the regime of investment incentives for the agriculture and food sector. **SO1.2** Promote the identification and prioritization of selective agriculture and food value chains and support the development of industry competitive investment plans **SO1.3** Reform agricultural education and training at all levels to increase long-term sector productivity **SO1.4** Innovate and generate technology for competitiveness, through Research and Development **SO1.5** Enhance extension services for improved technology transfer **SO1.6** Improve the infrastructure to support increased production and improved productivity	**SO2.1** Improve the market information and intelligence systems **SO2.2** Increase access to domestic and external markets by addressing enabling environment constraints. **SO2.3** Establish/strengthen linkages between agriculture and tourism, manufacturing and health to expand markets **SO2.4** Promote innovative marketing of products, both in the domestic and export markets, targeting institutional and household consumers.	**SO3.1** Increase production and promote diversification. **SO3.2** Promote livelihood options for the food and nutrition insecured. **SO3.3** Increase the participation of youth and women in the development process through empowerment programs **SO3.4** Promote linkage of small producers to market	**SO4.1** Promote best practices in disaster risk management (DRM) and climate change adaptation (CCA). **SO4.2** Create/strengthen pro-environment policies and institutions and promote integrated management of the environment. **SO4.3** Support adaptation and mitigation strategies as a means of enhancing the stability of food and nutrition security over time among the vulnerable groups as a result of financial and economic shocks. **SO4.4** Promote strategies to combat praedial larceny

Cross-Cutting	Governance
Strategic Objectives	SO5.1 Strengthen institutional capacity for better delivery
	SO5.2 Strengthen institutional mechanisms and integration processes
	SO5.3 Strengthen capacities of national, regional and international cooperation partnership
	SO5.4 Promote access to reliable, timely and accurate information for decision making

ANNEX VII: Weekly Average Retail Price BZ$ for Agriculture Commodities

Weekly Average Retail Price: 24th - 25th November, 2017					
Product	Unit of Sale	Average Price Today 24th - 25th November, 2017	Average Price last week 17th-18th November 2017	Tendency	Difference
BASIC GRAINS					
Rice	lb	1.23	1.23	=	0.00
RK Beans	lb	1.96	1.96	=	0.00
Black Beans	lb	2.00	2.00	=	0.00
White Corn	lb	0.44	0.44	↑	0.01
Yellow corn	lb	0.43	0.42	↑	0.01
VEGETABLES					
Celery	lb	2.79	2.68	↑	0.11
Broccoli	lb	3.36	3.21	↑	0.14
Yellow onion	lb	2.07	2.04	↑	0.04
White onion	lb	2.61	2.61	=	0.00
Habanero pepper	lb	3.43	3.57	↓	-0.14
Sweet Pepper	lb	4.57	4.82	↓	-0.25
Head letucce	Head	3.79	3.68	↑	0.11
Leaf Lettuce	Head	2.50	2.50	=	0.00
Potato (clean)	lb	1.57	1.54	↑	0.04
Potato (unwashed)	lb	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Cucumber	lb	0.96	1.04	↓	-0.07
Cabbage	lb	1.39	1.39	=	0.00
Tomato (Table)	lb	2.93	2.96	↓	-0.04
Tomato (Roma)	lb	2.44	2.69	↓	-0.25
Carrots	lb	1.46	1.43	↑	0.03
FRUITS					
Banana	Unit	0.12	0.12	=	0.00
Banana (Apple)	Unit	0.12	0.12	=	0.00
Coconut (dry)	Unit	1.11	1.11	=	0.00
Lime	Unit	0.21	0.22	↓	-0.01
Orange	Unit	0.15	0.15	↑	0.00
Papaya (Tainong)	Unit	3.55	3.70	↓	-0.15
Pineapple	Unit	3.11	3.07	↑	0.04
Plantain (green)	Unit	0.30	0.30	=	0.00
Plantain (ripe)	Unit	0.29	0.31	↓	-0.02
ROOTCROPS					
Cassava	lb	1.00	1.04	↓	-0.04
Coco yam	lb	1.75	1.75	=	0.00
Sweet potato	lb	1.50	1.46	↑	0.04
MEATS					
Whole Chicken	lb	2.70	2.70	=	0.00
Whole Fish	lb	6.68	6.68	=	0.00
Egg	Dozen	3.43	3.43	=	0.00
Honey	Quart	13.14	12.86	↑	0.29
Beef	lb	6.75	6.75	=	0.00
Pork	lb	5.89	5.68	↑	0.21

Exchange rate: BZ $2.00 = US $1.00

ANNEX VIII: List of Priority Commodities

Ministry of Agriculture, Belize, July 2017

Traditional Commodities

1. Sugar cane
2. Citrus
3. Banana

Grains:

1. Corn (yellow and white)
2. Beans (RK, Black and Blackeye)
3. Soybeans
4. Sorghum
5. Rice (milpa, mechanized irrigated, mechanized rainfed)

Vegetables:

6. Onion
7. Potato
8. Carrots
9. Tomato
10. Sweet pepper
11. Habanero pepper
12. Cabbage
13. Celery
14. Lettuce
15. Cauliflower
16. Broccoli

Meats and Dairy:

17. Poultry
18. Beef
19. Pork
20. Eggs
21. Sheep
22. Honey/beekeeping products
23. Milk

Fruit Tree:

24. Coconut
25. Soursop

Others

1. Aquaculture (Tilapia)
2. Tumeric
3. Yellow Ginger;
4. Plantain.

ANNEX IX: Strategic Management and Planning. Ministry of Agriculture, July 2017

Elements	Narrative Description
GSDS overarching goal:	The Growth and Sustainable Development Strategy (GSDS) states that the overarching goal of the Government of Belize is "to improve the quality of life for all Belizeans, living now and in the future".
GSDS focus area coinciding with agriculture ***CSF-Critical Success factor*** ***NC – Necessary Condition***	Of the four CSF that will achieve the overarching goal, the Ministry identifies the CSF1 "optimal national income and investment" as the specific area where it can contribute significantly to this goal through the following Necessary Conditions and actions outlined in the GSDS: • NC1.1 Penetrate export markets o Action 3: Achieve adequate standards and technical requirements for exports. • NC1.3.1 Improved competitiveness (including small firms and traditional sectors) o Action 3: Continue efforts to improve productivity and viability of the sugar, banana and citrus industries and other traditional sectors. o Action 4: Engage the private sector in discussing opportunities for expanding traditional agricultural production • NC1.3.4 Inclusive Growth (Growth and Equity) o Action 11: Identify and develop activities that can provide significant employment and earning opportunities to the poor and the vulnerable population. • NC1.3.5 Technological adaptation and innovation (including green technology) o Action 14: Build institutional capacity to encourage technological adaptation and innovation. • NC1.3.7 Prioritized Sectors o Action 32: Strengthen linkages between tourism and other sectors including agriculture and pursue rural development through tourism o Action 34: Develop a comprehensive strategy for increasing agricultural production and productivity. o Action 35: Significantly increase drainage and irrigation infrastructure, both on-farm and off-farm, and develop the necessary information tools(/base). o Action 38: Enhance research and extension services capabilities, especially with regard to identifying and supporting livestock production, the cultivation of non-traditional crops and new agro-processing activity. o Action 39: Strengthen the agricultural marketing system. o Action 40: Improve support systems and infrastructure to achieve greater exports of agricultural commodities. o Action 41: Development of infrastructure and enhanced systems to facilitate more efficient agricultural production, processing, and better packaging and handling for export as well as for domestic supply. o Action 42: Encourage and facilitate increased cooperation among farmers and communities with regard to production, land preparation, harvesting, transportation, storage, marketing, on-farm irrigation and drainage, sourcing inputs including labor, among others o Action 44: Enhance efforts aimed at reducing risk and achieving greater agricultural resilience to weather-related disasters and climate change.

	o Action 45: Establish adequate skills for the development of agriculture o Action 46: Mount a program to increase attractiveness of agriculture as an employment/business option.
Vision of Agriculture:	An Agriculture and Food Sector that is innovative, competitive, diversified and sustainable
Mission of Agriculture:	To grow and continue as a key economic pillar, ensuring food and nutrition security, diversifying business opportunities, reducing poverty and enhancing human resources capacity in a sustainable and competitive environment
Overall goal of Agriculture:	Position the agricultural sector to contribute more to the economy, foreign exchange earnings and savings, generate greater employment, expand business opportunities in a sustainable manner
National Targets (agricultural sector) as outlined in NAFP 2015-2030:	i. Sector Growth Rate – The average annual sector growth rate increased from the current average of 2.8 % to 4.0 %; ii. GDP – The Agriculture and Food Sector's contribution to GDP increased in real terms from approximately 13.0 % of GDP to 20 % of GDP; iii. Exports – The average annual growth rate in agricultural exports increased from 4.2 % to 5.5 %; iv. Imports – The average rate of growth in imports of food commodities decreased from 5.8 % to 3.5 % with a heavy focus on import replacement commodities; v. Direct Employment – The direct employment in the Agriculture and Food Sector increased to 25 % of total employed labor force; vi. Real Income – The real income of producers increased by 2.5 % per year; vii. Poverty – Poverty reduced through agriculture's contribution to improved livelihoods; viii. Food and Nutrition – Food and nutrition increased, resulting in a decrease in malnutrition; ix. Agriculture workforce – The productivity of the agricultural workforce increased; and x. Governance – The management and governance capacity within the agriculture sector increased.

Pillars of the NAFP 2015-2030, Thematic areas and focus areas	**Pillars**	**Thematic Areas**	**Specific focus areas**	**Lead Officer**	**Alternate**
	i. Production, productivity and competitive enhancement;	1. Diversification; value addition;	Beekeeping/honey Sheep Production Beef Cattle Swine, Poultry, Aquaculture, Fruit tree (Coconut, soursop, avocado) expansion; vegetables, grains, pulses, Value addition, Agro-processing	B. Esquivel, DOE	M. Trujillo, NCC

		Agriculture Health;	Pest and diseases, Traceability, Phyto sanitary services, Quarantine, Bio-safety, Ambulatory Services, Legislation and regulation	E. Cruz, BAHA MD	D. Castillo, NLC
		Science & Technology	Research, Development and Innovation, covered structure, fertigation, soil management, plant nutrition; IPM, germplasm banks	I. Sanchez, R&I Dir	D. Gillett, M&E
	ii. Market development, access and penetration;	2. Institutional strengthening – database management and market intelligence system;	Statistical data and information, forecasting, market information, farmgate prices, market prices, organization.	M. Matus, Policy Analyst & G. Murillo, Registrar.	F. Garnett, DAC S/C
	iii. National Food and Nutrition Security and improved rural livelihoods;	3. Food and Nutrition Security	Backyard and school gardens to support school nutrition programs, institutional strengthening, food security data and information	E. Montero, NCFNSC	F. Palacio, DAC O/W
	iv. Sustainable agriculture and risk management;	4. Water management and climate change	Irrigation systems, drainage infrastructure, wáter harvesting, land mapping, climate Smart agriculture, disaster recovery fund, renewable energy (solar, hydraulic), Resilience building	V. Pascual, WM/CC Dir	G. Ramirez, NHC
	v. Governance – accountability, transparency and coordination.	5. Strategic management and planning	Programming, projectizing, Monitoring framework, Evaluation, Results based budgeting, change management, communication, coordination, Legislation & Regulation; accountability seminars, annual reports.	A. Harrison, CAO/ Matus, Policy Analyst/SMT	C. Martinez, DAC Cyo
Main Programmes	National Livestock Program; National Horticulture Program; National Crops and Fruit Tree Program, National Aquaculture Program; National Agro-processing Program				
Support Programmes	National Extension Service Program; National Research and Innovation Program; Cooperative Program; Central Farm Agriculture Station and satellite stations; M&E; National Food Security and Nutrition Program; Water Mgnt and Climate Change Program; Strategic Planning; Policy and Statistics				

ANNEX X: Key Supporting Departments and Agencies in the Coastal Zone and Marine Sector

Ministry of Economic Development, Petroleum, Investment, Trade & Commerce

The Ministry of Economic Development, Petroleum, Investment, Trade & Commerce has responsibility for:

- Capital Budget Preparation and Management
- Corozal Free Zone
- Development Finance Corporation
- Development Finance Institutions and Multilateral Financing Agencies
- Economic Development Planning
- Public Sector Investment Programme Planning
- Social Investment Fund, and the
- Statistical Institute of Belize

Belize Customs and Excise Department

Comptroller's message:

"The role of the Belize Customs and Excise Department is to develop and implement an integrated set of policies and procedures that ensure increased safety and security, as well as developing the necessary platform to promote effective trade facilitation and revenue collection". http://custom.gov.bz.

A list of *Zero Rated* goods or imported goods that are tax exempted can be seen in Annex IV

Belize Trade and Investment Development Service

Belize Trade & Investment Development Service *(BELTRAIDE)* is a statutory body of the Ministry of Economic Development, Petroleum, Investment, Trade & Commerce of the Government of Belize. BELTRAIDE is charged with attracting highly qualified investments, developing small and medium enterprises, as well as, promoting "Made in Belize" products.
Its Mission is to enhance Belize's prosperity by fostering investor confidence, entrepreneurship, business growth and innovation. BELTRAIDE comprises of three departments, namely:

Protective Area Conservation Trust
The Protected Areas Conservation Trust (PACT) is a statutory body that was established by the Government of Belize in 1995 and governed by the Protected Areas Conservation Trust Act, following several years of consultation with various non-governmental organizations, government departments, the private sector and international conservation organizations. PACT opened its door in June 1996, having been endorsed through the USAID project in Belize on developing a National Protected Areas System Plan (NARMAP 1995).

PACT contributes to the sustainable management and development of Belize's natural and cultural heritage by providing financial support for protected areas. PACT is a bold and innovative strategy for non-traditional revenue generation and is primarily financed from collection of a conservation fee paid by

visitors upon departure from the country and receives a 20% commission from cruise ship passenger fees. Additionally, at least 5% of all revenues are deposited in an endowment fund, and also receives donations from individuals, foundations and corporation.

National Meteorological Service (Meteorology Department)

The National Meteorological Service of Belize is the leading governmental authority in the field of weather and climate. The mission of the Meteorology Department is to provide meteorological and climate-based products and services through systematic and accurate monitoring and data collection, reliable data analysis and timely dissemination of user-friendly information and bulletins on regular and emergency events and processes. The objective is to contribute to the safety and well-being of the People of Belize and the sustainable development of the country.

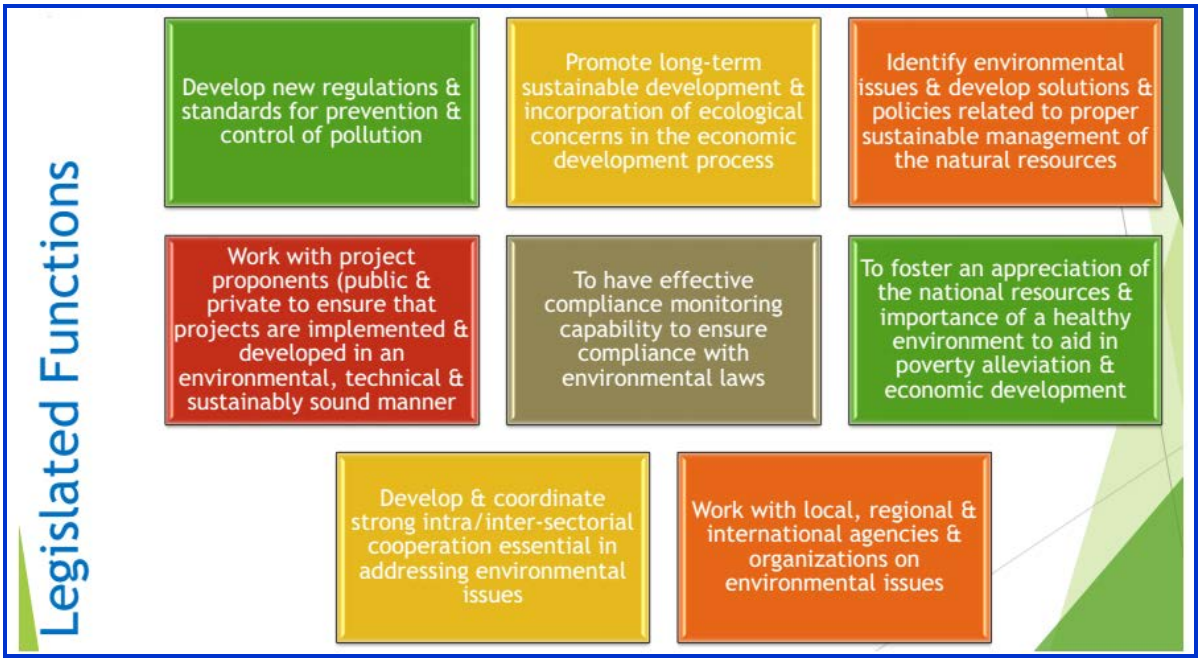
Belize is a member of the World Meteorological Organization and serves as the national focal point for the Inter Governmental Panel on Climate Change (IPCC). The National Meteorological Service has representation on the National Emergency Management Organization (NEMO), the national Environmental Appraisal Committee, the Belize national Climate Change Committee, to name a few. More information on the activities and services provided by the National Meteorological Services can be accessed from:
www.hydromet.gov.bz/.

Forest Department

The Forest Department is the institutional body charged with the management of the country's forests, specifically forests on national lands and forest reserves, including the clearing of mangrove forests in the Coastal Zone (GOB/MNRE, 2010). The Forest Department is authorized to issue and regulate licenses on these lands; it is also responsible for administering approximately half of all existing protected areas and is the focal point for several international conventions including CITES, UNCBD, and the RAMSAR convention on wet lands (Forest Department, 2006). The main legal instrument empowering the Forest Department is the 1927 Forests Act.

Department of the Environment

The Department of the Environment was legally enacted through the Environmental Protection Act of 1992, amended in 2009 with new regulations.



Legislative functions of the Department of the Environment, Belize 2014

Vision: To be leaders in environmental stewardship for sustainable development both nationally &regionally.

Mission: To ensure that Belize's development is sound through effective environmental management for present & future generations.

Environmental Protection and Sustainable Development

"The Environmental Protection Act (EPA) requires EIAs to be prepared by all persons who intend to undertake projects that may significantly affect the environment, and to follow the rules as set out in the EIA regulations…" (Brief guide to Environmental Clearance Process, DOE Brochure, 2015).
http://www.doe.gov.bz

The Belize Coast Guard

In accordance with the Belize National Coast Guard Service (Amendment) Act, 2016, provision was made for a change of name to the Belize Coast Guard, and clarification of duties and functions.

Subject to the provision of the Act, the Coast Guard is employed as military service organization, being the naval force for the defence of Belize, in relation to its maritime areas with powers to assist in enforcement of any laws relating to: fisheries protection; marine resources and environmental protection; safety of navigation including inland waterways and aids to navigation; maritime pollution, enforcement of maritime convention, among many others.

Pan American Development Foundation

The Pan American Development Foundation (PADF) has been working in Belize since January 2014. PADF provides community-based programme that generate economic opportunities, advance social progress, and help prepare for respond to disasters. In Southern Belize, the focus is on preparing for the effects of climate change through capacity building and training. Recent partners include the Government

of Taiwan, the U.S. Embassy in Belize, the Government of Belize, the private sector, civil society organizations, the Belize Trade and Investment Development Service (BELTRAIDE), and the Organization of American States.

Fishing and Marine Products Co-operatives

A co-operative is an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspiration through a jointly-owned and democratically-controlled enterprise (Department of Co-operatives, 2013). Co-operatives are enterprises that put people at the centre of their business rather than capital. In Belize, there are co-operative societies engaged in various economic sectors.

The existing co-operatives in Fishing and Marine sub-sectors are: National Fishermen, Northern Fishermen, Placencia Producers, and the Rio Grande Fishermen Co-operative.