Project Feasibility Study:

BUILDING THE ADAPTIVE CAPACITY OF SUGARCANE FARMERS IN NORTHERN BELIZE

Submitted to: Caribbean Community Climate Change Centre (CCCCC)

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ACRONYMS AND ABBREVIATIONS

ASR	AMERICAN SUGAR REFINING INC.
ARS/USDA	AGRICULTURE RESEARCH SERVICE OF THE US DEPARTMENT OF AGRICULTURE
BELTRAIDE	BELIZE TRADE AND INVESTMENT DEVELOPMENT SERVICE
BSCFA	BELIZE SUGAR CANE FARMERS AND ASSOCIATION
BSI	BELIZE SUGAR INDUSTRIES LTD.
CCCCC or 5C's	CARRIBEAN COMMUNITY CLIMATE CHANGE CENTER
CO_2	CARBON DIOXIDE
CSA	CLIMATE SMART AGRICULTURE
CSPCA	COROZAL SUGAR CANE FARMER ASSOCIATION
CPA	COUNTRY POVERTY ASSESSMENT
DFC	DEVELOPMENT FINANCE COOPERATION
EM	EXTRANEOUS MATTER
EPZ	EXPORT PROCESSING ZONE
Et	EVAPOTRANSPRATION
ETA	EVAPOTRANSPIRATION ACTUAL
ETP	EVAPOTRANSPIRATION POTENTIAL
EU	EUROPEAN UNION
FI	FINANCIAL INSTITUITION
FFS	FARMER FIELD SCHOOL
FDI	FOREIGN DIRECT INVESTMENT
GCF	GREEN CLIMATE FUND
GDP	GROSS DOMESTIC PRODUCT
GOB	GOVERNMENT OF BELIZE
HDI	HUMAN DEVELOPMENT INDEX
INM	INTEGRATED NUTRIENT MANAGEMENT
IRR	INTERNAL RATE OF RETURN
MSME	MICRO, SMALL, AND MEDIUM ENTERPRISES
NPK	NITROGEN, PHOSPHOROUS AND POTASSIUM
NSCGA	NORTHERN SUGAR CANE GROWERS' ASSOCIATION
OIRSA	INTERNATIONAL REGIONAL ORGANIZATION FOR AGRICULTURAL HEALTH
PE	PRODUCTION ESTIMATE
PSCPA	PROGRESSIVE SUGAR CANE FARMER ASSOCIATION
SCPC	SUGAR CANE PRODCUCTION COMMITTEE

SICB	SUGAR INDUSTRY CONTROL BOARD
SDG	SUSTAINABLE DEVELOPMENT GOALS
SIB	STATISTICAL INSTITUTE OF BELIZE
SIMIS	SUGAR INDUSTRY MANAGEMENT INFORMATION SYSTEM
SIRDI	SUGAR INDUSTRY RESEARCH AND DEVELOPMENT INSTITUTE
SPAC	SOIL-PLANT-ATMOSPHERE CONTINUUM
TAM	TOTAL AVAILABLE MOISTURE
UB	UNIVERSITY OF BELIZE
WD	WATER DEFICIENT
WS	WATER SURPLUS
WUE	WATER USE EFFICIENCY

Introduction and purpose of the feasibility study

Sugarcane farming and the production of sugar and related products is one of Belize's main industries. It accounts for 14 percent of all agricultural earnings and a similar share of goods export revenue. The industry has faced significant upheaval in the last 10 years. Reforms in the European Union (EU) sugar marketing regime have removed some of Belize's most significant sugar related trade preferences and since 2017 the industry has been increasingly exposed to price volatility in world markets. This, coupled with low overall yields and an increasing exposure to the impact of climate change has created uncertain times for the industry and the approximately 16 753 households or 15.5% of the household population of Belize who are directly or indirectly reliant on the sugar industry for the majority of their livelihood[1]. The sugar industry has embarked on a number of initiatives to try and stabilize and reverse this situation.

These initiatives have focussed on all aspects of the value chain and include initiatives such as investing in the manufacturing of direct consumption sugars, the introduction of new and improved agronomic practices to increase yields and productivity and investing in industry logistics to ensure more logistical efficiency in the industry.

Climate change is one of the biggest threats facing the industry despite the initiatives taken to build resilience. Climate change impacts the primary productive node (sugarcane growing) of the industry the most although all nodes in the sugar value chain are impacted by climate change in some way or another. The Caribbean Community Centre for Climate Change (CCCCC) have been approached by the industry stakeholders to develop a project to build the adaptive capacity of the sugarcane farmers of Northern Belize to the impacts of climate change. The project design has been developed through a participatory process with industry stakeholders and impacted farmers. Through this process a baseline assessment has been developed which describes the current situation in the sugar industry, lists the impacts that future climate change could have on the industry, describes barriers to change and suggested interventions to build resilience. Based on this baseline and a series of planning workshops held with different stakeholders, a draft project design was then developed along with a project theory of change. This theory of change (and the interventions described therein) is the basis on which the feasibility assessment has been undertaken. The feasibility assessment examines the technical appropriateness of the proposed interventions and then looks at the financial and economic feasibility of these interventions individually and as a whole. The feasibility study will also provide some insight on the following aspects of the project:

1. Ensure that the planned interventions against the expected climate change impacts in Belize will result in the required industry resilience
2. Access the financial viability and sustainability of the proposed interventions and the estimated internal rate of return of the GCF contribution
3. Access the additionality of each intervention as the basis for GCF grant intervention
4. Access the scale up potential of the proposed interventions

[1] https://publications.iadb.org/publications/english/document/The-Impact-of-Falling-Sugar-Prices-on-Growth-and-Rural-Livelihoods.pdf

5. Access the sustainability strategy of the interventions
6. Estimate the number of project beneficiaries and the GCF grant contribution per project beneficiary

Methodology to develop this feasibility study

1.1 Process to develop the feasibility study

The feasibility has been developed through rigorous farmer and stakeholder engagements which have helped identify the problems and barriers farmers are facing and will likely face in the future coupled to technology driven solutions based on best practice and peer review.

The process of developing the feasibility study began with the development of a concept note. This concept note framed the current baseline situation in the sugar industry from a production perspective, explained the possible impacts of climate change and proposed a series of interventions to build climate resilience among farmers. This concept note was then discussed in detail with farmers and stakeholders and based on these discussions and workshops a set of project interventions were confirmed and a theory of change was developed for the project. At the same time the best technical solutions were researched and agreed to support the identified project interventions. Specialist studies were also undertaken to access and develop an action plan relating to the social, environmental and gender aspects of the project.

This feasibility study brings these interventions together and assesses the project from a financial perspective in the context of the entire sugar value chain. The financial model that accompanies this narrative has been used to confirm the financial viability of the proposed interventions, to determine the allocation of financial resources (quantity) to the different interventions and to compile the overall project budget and spending plan.

Once the feasibility study has been discussed with stakeholders a final risk assessment will be undertaken before the full funding proposal is developed.

The Belize Sugar Value Chain

1.2 Nodes in the Sugar Value Chain

Understanding the Belize sugar industry and the different nodes in the value chain is a key element of the feasibility study. The different nodes of the value chain are extremely dependant on each other. Weakness and inefficiency in any one node will result in the whole industry being weak. From a feasibility study perspective, it is important to evaluate the robustness of the entire value chain even if the project interventions and investments are only taking place in one node (productive) of the value chain.

Figure 1 below shows a depiction of the Sugar value chain in Belize.

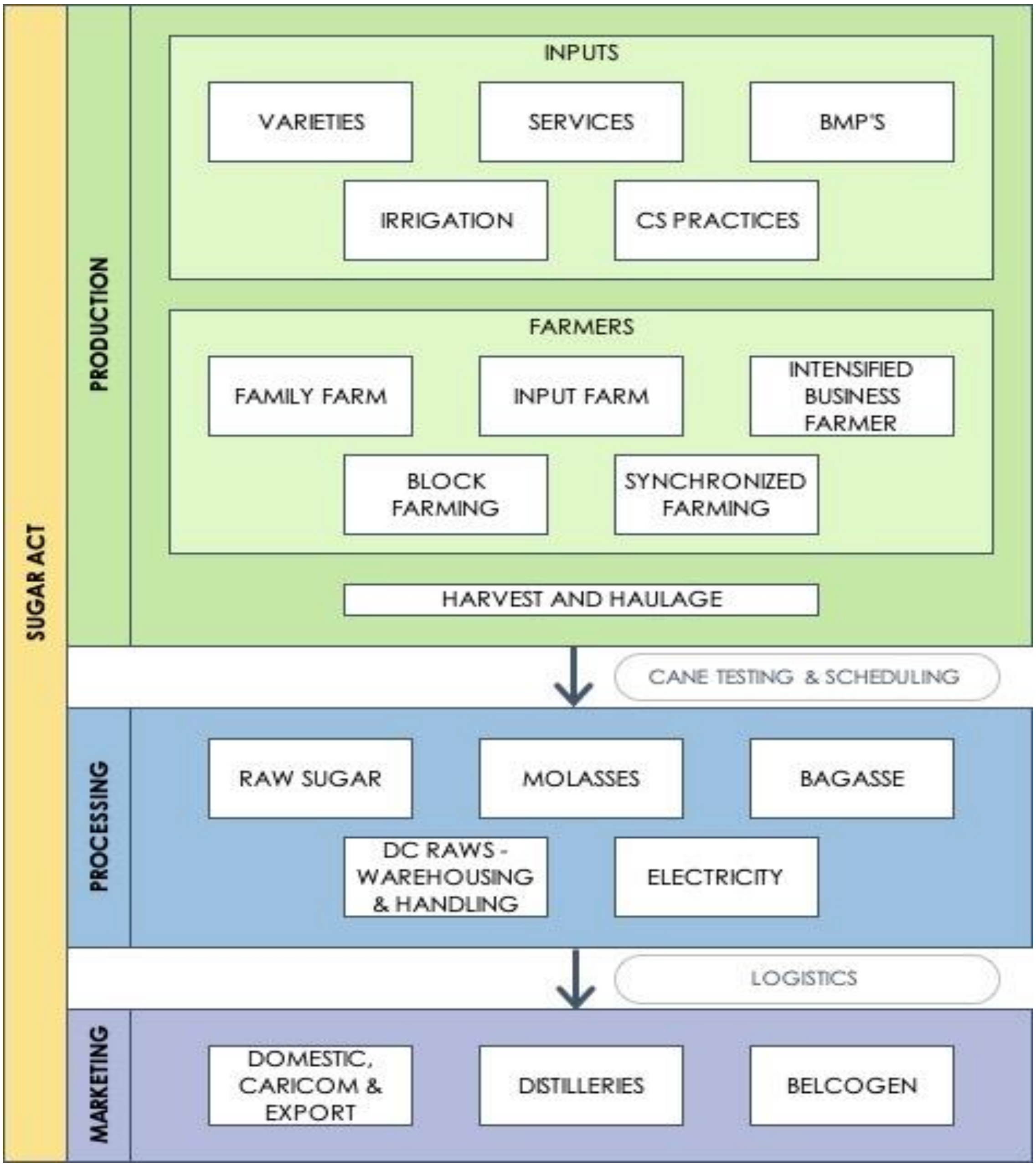

Figure 1: Belize Sugar Value Chain

The value chain has three primary nodes. The first is the farming node or the node of primary production. The second is the processing (grinding) node and the third node is the marketing node. At each node there is an element of value addition. This value is then divided between the farmers and BSI through a mechanism known as the division of proceeds (DOP)

While efficiencies of each node are important for the efficient operation of the entire value chain, the efficiencies of the operations that link each node are also important. The linkage between the productive and the processing node is the element of cane supply scheduling and cane testing. This requires robust information and management systems to be in place to ensure a continuous supply of cane at the factory gate and a clear and transparent payment system for the cane delivered. This also requires good communication between the mill and farmers to ensure that farmers know when and how much cane to deliver. Any bottlenecks in this regard can lead to a rapid decrease in cane quality affecting the famers and the mill.

The linkage between the processing node and the marketing node is the logistics needed to get the sugar to its customers.

The value chain is regulated through the sugar act. This is the instrument which assigns roles and responsibilities within the value chain and ensures that the strategic importance of the sugar industry in the economy of Belize is maintained. The act also describes the statutory institutions and the relationship between the different institutions within the Belize sugar industry.

The relationship between the farmers and the miller is probably the most important relationship in the sugar value chain. This relationship is governed commercially through the commercial agreement. This is the cane supply contract and is signed between each farmers association and BSI. The current commercial agreement was signed in 2015 and runs for 7 years expiring in November 2021 (negotiations for re-signing are under way)[2]

This agreement states the payment parameters, terms and conditions for farmers delivering to the mill and is aligned with the requirements of the sugar act. Payment in the sugar industry is based on the sharing of value derived between BSI and the growers. The value that is shared is the net stripped value of the sales of sugar and molasses. Net stripped value is defined as the value paid for the sugar and molasses (by local and international buyers) less the value that is agreed to be stripped out, being costs associated with achieving that value not associated directly to either the productive or processing node of the value chain. These costs include the following:

- Ocean freight
- Local freight and handling
- Brokerage and commissions
- Insurance
- Remittances and exchange charges
- Statutory deductions in respect of Sugar Industry Development Fund, cargo dues and other levies

[2] Update: 10/12/2021 Three of the four Associations have signed a new commercial agreement

- Bags, bagging costs and manufacturing allowance for all bagged and packaged sugars
- Supervision
- Stevedoring
- Laboratory and survey costs

These costs are generally associated with getting the sugar and molasses to the market and because they are stripped out of the total value of the sugar received before dividing up the proceeds, they are in essence shared 50:50 between miller and farmer.

The agreement states that the stripped value remaining is shared in a ratio of 65:35 between the farmers and the miller. This ratio is known as the industry division of proceeds (DOP) The division of proceeds payment mechanism is used by a number of sugar industries around the world and is generally viewed as an equitable way of ensuring fair value is received by both the farmers and the miller. In its purest form the ratio should reflect the relative costs of producing a ton of raw sugar to processing that ton of raw sugar taking into account capital employed and independent risk. In theory the DOP should be altered on a regular basis but in practice this is difficult to affect. Common practice is therefore only to look at the DOP when major changes occur in the structure or economics of an industry in any country.

The DOP around the world varies significantly from 45:55 (farmer: miller) in Uganda to 77:33 in Mauritius. One needs to be very careful when comparing the different DOPs from different sugar industries as many factors determine costs and risks. In general, however the 65:35 ratio seen in Belize is very much aligned with the DOP seen in most sugar producing countries.

The commercial agreement also describes payment terms and conditions. These terms and conditions in this agreement are very similar to those seen in other industries around the world and reflects the time that is taken between BSI receiving the cane from the farmer and when it receives payment for the sugar from its customers. It also reflects the fluctuations in the price of sugar between grinding seasons and also within any grinding season. Payments are made in three tranches. The first two tranches are made on a price estimate and the third payment is made on a reconciliation of all sugar produced in that season and the actual price received (balancing payment). Farmers also get paid based on the quality of the sugar cane delivered so farmers from different test groups get paid different prices at the end of the season. This is an internal adjustment amongst farmers, to reward those with better quality cane.

Belize farmers are among few in the world that apart from being paid for sugar and molasses also get paid for bagasse. Bagasse was seen in the past to be a "waste" product

The commercial agreement is further written to protect the interests of both the farmers and BSI in the delivery and grinding operation by describing the following:

1. Delivery methods and procedures
2. Cane testing procedures
3. Procedures for rejecting cane delivered to the mill
4. Factory performance parameters

While this feasibility study has not undertaken an in-depth value chain assessment of the Belize sugar industry, it would appear that the commercial arrangement governing the relationship between the miller and growers is equitable and aligned to international best practice. While there will always be short term tensions in this relationship these tensions are not considered a risk to the project.

The processing node encompasses all the activities that take place within the mill gate. The sugar mill has the capacity to crush at around 300 tons cane per hour, which equates to approximately 7,200 tons cane per day. The average milling season is around 185 days and usually starts in the middle of December and ends in the middle of June. This translates into an average crush of 1,3 million tons per annum of milling capacity.

The mill has three off-loading facilities, two short tail dumpers, a Cameco side lifting unit and a large gantry with storage pit. The cane is process via a milling tandem, whereby juice is extracted from the fibre by the application of pressure as the cane passes between pairs of rollers. The efficiency of the juice separation is determined by, amongst other factors, the physical properties of the fibre.

The capacity of the mill is determined by the ability of the rolls to accept the cane presented and transport it by the friction between these rolls. The capacity is governed by the quantity of fibre (and not cane), as the actual juice extracted, places no pressure on the rollers. The pressure alone does not extract all the cane juice; therefore water is added to extract more juice. The water mixes with the juice and a certain percentage of the diluted juice is expelled in each pair of rollers. The repetition of this process results in almost all the juice being recovered from the cane fibre.

When measuring fibre, all solids are included in the measurement, including sand, mud and extraneous matter. Thus, cane that is harvested under wet field conditions, often has a higher fibre% cane due to the levels of mud and sand that is delivered to the mill with the cane. This has a significant negative effect on the performance of the mill, both in terms of extraction and also throughput.

Under a climate change scenario, increased rainfall has a number of impacts. In summary of these are:

1. Changes in the days available for crushing. This can be either a late start to the season or an early finish (late and early rainfall respectively) or both. Consequently, if fewer days are available, then less cane can be crushed.
2. Harvesting in wet conditions results in higher mud loadings going into the mill, resulting in slower crush rates and lower quality sugar being produced.
3. Changes in crop size due to droughts impacts on when the mill opens and closes. Consequently, the average age of cane to be harvested in the following season is affected. Growers want to ensure that cane is harvested at its optimum age.

These can all have significant impacts on overall revenue for both miller and growers.

The marketing node is the node which ultimately determines the value to be divided in the value chain. This is a direct function of the price received for the sale of sugar and molasses by BSI. As mentioned in the introduction the marketing of sugar from Belize has changed since 2017 when the sugar reforms took place in the European Union. Prior to 2017 80-90% of all sugar produced was exported to the European Union with the balance being consumed locally, being exported to CARICOM and to the USA.

1.3 The international sugar marketing environment

The current marketing of sugar in Belize has shifted significantly, driven by two main factors. Firstly, the sugar reforms in the European Union have resulted in the dropping of the preferential price from the European Union and secondly the investment in the mill for the shift to producing direct consumption sugars. Sugar is one of the largest and most traded agricultural commodities globally, the commodity's usefulness as an additive in many foods and non-food industrial products (ethanol and energy products) is the major driver for its demand in the markets. About 110 countries produce sugar from either cane or beet, with cane accounting for nearly 80% of global sugar production. The top five cane producing countries are; India, Brazil, Thailand, China and the US. Aside from having the highest production output of sugar, some of these countries also have the world's highest population, allowing them some massive domestic demand. This domestic demand is a key factor in determining sugar price paid to farmers in any large sugar producing country, and is also a key distorting factor when such countries are able to achieve high prices domestically and can therefore afford to "dump" excess sugar onto a world market. Belize is one of many sugar producing countries in the world with a very small domestic market and is therefore very vulnerable to the world sugar price.

There are two major markets for sugar producing countries, one is the global market where sugar is traded in the NYSE under the Index Sugar #11 and the alternative is the sugar producing country's own national market where sales are subject to domestic demand, amongst other factors such government regulation of markets. The larger proportion of the demand stems from sugar as a food product, however, consumption per capita for sugar varies largely between developed countries like the US and developing economies like Belize and this is because sugar is more of a luxury good than a necessity. Therefore, developed economies consume more sugar per capita than developing economies, regardless of their respective domestic production levels. There is a huge disparity in the buying power of consumer groups between these two economy categories which can be attributed to differences in per capita incomes, which tend to be lower in poor countries and higher in developed countries.

The income disparities mean that cane producers and companies in developed countries are able fetch a premium for their sugar by selling within their domestic markets whilst cane producers in developing countries with more surplus for export remain at the mercy of the prevailing global price of the Sugar #11 Index. The Sugar #11 price index however, is very responsive to the forces of global supply and demand of the commodity and has zero regard for the production costs. During periods of excess supply, the price per unit of sugar will often fall below the production cost, when this happens, only cane producers in countries with large populations and enough domestic demand have insurance against the losses associated with this. Other market distortions in the global sugar market are a result of highly subsidised cane production in some countries, these result in overproduction which increases the amount of sugar available in the global market. The increase in supply drives the global price down, severely impacting small countries with surplus product to sell in the global market. Even with robust protectionism elements, small countries with excess production are always at the mercy of the Sugar #11 price index.

A sufficient domestic demand allows producers the liberty to supply their countries before they can look for outside markets. The countries with surplus sugar production output have robust regulatory frameworks in place to protect their local producers from cheap imports and ensure that they remain in business. The US for instance, uses a tariff structure to maintain the US domestic price of sugar at 92% higher than the Sugar #11 Price Index. Heavy import tariffs and quotas are also put in place by the state to deter the practice of 'dumping'. However, this is not always possible where countries are operating in the same "free-trade area". Also developing countries lack the economic muscle necessary for them to be able to subsidise their local producers, as a result the success of a small country producing surplus sugar is always a gamble against such odds.

It has been the preferential markets that have kept small sugar exporting countries afloat over the years. The EU has been one of the main export markets for sugar from developing countries, but exports have been declining due to low sugar prices in the EU and changes in the EU's sugar policies which include the removal of restrictions for domestic sugar beet production and ending preferential access for sugar imports from developing countries.

With such dynamics at play, the is an urgent need for sugar exporting developing countries such as Belize to restructure their strategies and figure out innovative methods to navigate the terrain of the merciless global sugar markets.

1.4 Belize sugar marketing outlook and initiatives

The international sugar market has been volatile over the last two years. Just as the international price of sugar began recovering from a low of 11 US c/pound in the beginning of 2020 to around 15 US c/pound, COVID struck collapsing the world-wide sugar market. Since the beginning of 2021 prices have begun to firm and is currently sitting on around 20 US c/pound as a result of higher oil prices which has meant that Brazil has moved a higher proportion of its crop into Ethanol production.

Figure 2: Historical sugar price

While this increase in price (which is forecast to hold in the short to medium term) will result in a positive increase in the price of sugar to farmers in Belize in the short to medium term. The exposure to the volatile world sugar market is the biggest single marketing risk facing the Belize sugar industry.

As mentioned previously Belize cannot afford to be overly exposed to the world sugar market. In order to mitigate this risk, BSI has invested BZ64 million over the last 7 years to expand the production of direct consumption sugar and has actively looked at expanding sales to new countries thereby spreading the risk. Production capacity at the mill is now between 130 and 160 000 mt. BSI now produces five different products from its mill. Raw sugar which now accounts for less than 50% of production (previously 100%), Demerara which accounts for approximately 40% of production, Plantation white which is the product that is mainly sold locally along with a bit of local brown. The last sugar product which is sold into the USA market is golden granulated. This product and market diversification strategy has resulted in farmers getting improved prices over the last two seasons these being BZ$2.4/ton cane in 2019 and BZ$3.27 in 2020. As the percentage of direct consumption sugars increases so these figures should improve.

Pre-2018 the marketing of sugar was far simpler as most of the crop was sold into the EU under a preferential price and quota regime. Now BSI has to continually and proactively look for new higher value markets for the sugar that it produces. If this marketing strategy is successful and higher prices are achieved, they automatically translate to higher prices to the farmer due to the value sharing structure of the industry as discussed earlier. This process however is very complex with a number of different and often competing factors that need to be taken into account in order to make good decisions. Some considerations that need to be taken into account includes the following:

1. Global trends in production and consumption. This creates the supply and demand curve which is critical in determining price. Global shocks such as the COVID pandemic is an example of demand side shocks while the impact of climate and climate change is becoming a prominent driver in supply side shocks,
2. The role of speculators and traders in the market. Sugar is the most traded commodity in the world and many people make money by trading, holding or speculating in the sugar market
3. Energy prices. This has a big impact as when energy prices go up Brazil is able to divert more of its sugar to ethanol causing the sugar price to rise. The increase in the sugar price that we are seeing now is closely linked to the price of crude oil being at a two-year high
4. Currency fluctuations and especially the fluctuation of emerging market currencies against the US dollar
5. Cost of freight and shipping

It is very difficult to get all of these factors right it is therefore important to act with caution when developing a marketing strategy by:

1. Ensuring marketing decisions are matched to production
2. Need to lock in a good percentage (25-30%) of the sugar before the start of the next crop

3. Price into evolving markets in small lots to spread the risk and gain market benefit

To manage all of these market risks information is critical. BSI has access to ASR market intelligence which is gathered from data from around the world. This decreases the market risk of both BSI and the farmers

BSI has, through its investment in diversifying its sugar offering and seeking new markets for its products, largely mitigated the sugar industries exposure and risk to the world market making the sugar industry more financially viable.

Project climate rationale and climate change impact on the sugar value chain

1.4.1 Belize: Anticipated Climate Change

Collectively, global warming and its effects are known as climate change. While there have been previous periods of climatic change, observed changes since the mid-20th century have been unprecedented in rate and scale. The rising average temperature of the earth's climate system, called global warming, is driving changes in rainfall patterns, extreme weather, arrivals of seasons, and more.

The most significant human influence has been greenhouse gas emissions, with over 90% of the impact coming from carbon dioxide and methane (important to note here that elevated CO_2 levels are predicted in all scenarios). Fossil fuel burning is the primary source of these gases; agricultural emissions and deforestation are also important. Land surfaces are heating faster than the ocean surfaces, leading to heat waves, wildfires, and the expansion of deserts. Increasing atmospheric energy and rates of evaporation are causing more intense storms and weather extremes, damaging infrastructure, and agriculture. Surface temperatures would stabilize and decline a little if emissions were cut off, but other impacts will continue for centuries, including rising sea levels from melting ice sheets, rising ocean temperatures, and ocean acidification from elevated carbon dioxide levels.

Mean temperature in Belize currently ranges from 27°C (max 30.1°C, min 22.6°C) along the coast to 21°C (max 25.3°C, min 17.7°C) in the hills, with the coldest month being January and the warmest temperatures experienced in May. The rainy or hurricane season occurs from June to November and brings approximately 60 inches (1,524mm) of rainfall in the north to 160 inches (4,064mm) in the south (Third National Communication, 2016). Belize's climate is changing, as validated by both the ECHAM5 and HadCM3Q11 climate models, which project an increase in temperature ranging from 2 to 4°C, over the entire country by 2060 when compared to the period of 1961-1990. In the case of precipitation, the models show increasing unpredictability of rainfall with an overall mean decrease over time. The ensemble A-OGCM projections show mean annual rainfall could decrease as early as the 2030s.

In contrast, mean seasonal rainfall will vary between a reduction of -26% during the months of February, March and April to an increase of +55%, by the 2090s (Third National Communication 2016). Changes in climate are also projected by The Climate Science Basis portal developed by SMHI on behalf of WMO/WCRP. These projections also show decreases in rainfall and an increase in mean temperature by the year 2100 under RCP 4.5 which will be accompanied by decreasing soil moisture, water discharge, and water runoff. As a result of these changes, water reserves, food production and livelihood systems will be put under considerable strain, which

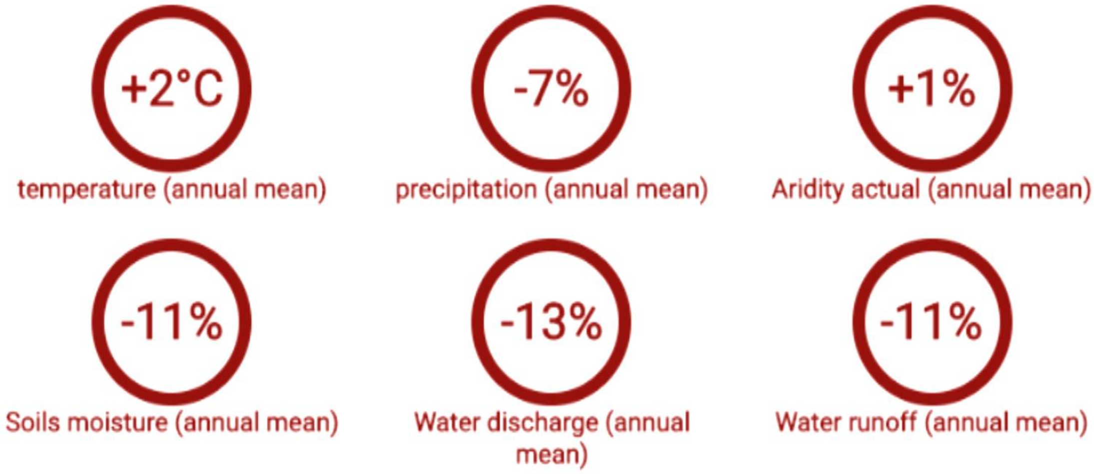

Figure 3: Predictions of climate change impacts

in turn will pose imminent threats to sustainable development. The following diagram clearly shows the climatic parameters that will need to be considered when developing strategies to build resilience (next 50 years) and ensure the sustainability of sugarcane growing in Belize.

Based on Figure 3: Predictions of climate change impacts**Error! Reference source not found.**, it is important to note that from a sugarcane cultivation perspective, all of these impacts centre on water and plant water availability. Therefore, any climate smart practices proposed need to focus on this aspect of cultivation and ensure a management regime where plant available water is not limiting.

While these figures represent the average change that can be expected over the next 50 years, the details with regards actual predicted impacts are even more alarming. The following table indicates the predicted change over time of temperature and rainfall.

Table 1: Temperature and precipitation changes over time

Time Period	Temperature change	Precipitation change
2020's	+1.5°C	+1%
2050's	+2.29°C	-10.6%
2070's	+3.04°C	-15.3%

Understanding the precipitation change is also important. While the average is decreasing significantly, rainfall patterns are also predicted to change with increased periods of intense rainfall and extreme and longer dry periods. The shifting rainfall patterns will possibly have a greater impact on the growing of sugarcane as the plant will be under moisture stress (either too much or too little) for more extended periods. The 2019/2020 season is a case in point with the impact of a dry period (drought) significantly impacting cane yield and quality. The timing of the rains may also shift which could impact on a number of farming operations

1.4.2 Impact of climate change on the production of sugarcane

Sugarcane grows by means of photosynthesis, a process in which the sun's energy is stored as photosynthate. It is a C4 carbon fixation plant; i.e. a plant which creates a four carbon as its basic sugar unit during photosynthesis.

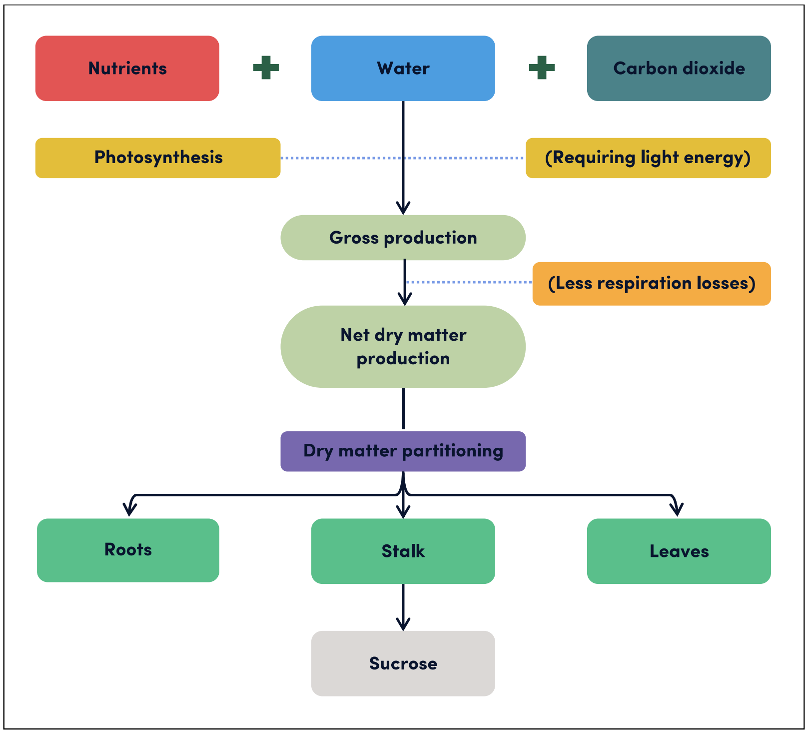

Figure 4: Sugarcane Soil, Plant Climate continuum

The green leaf contains cells with chlorophyll that regulates the photosynthetic reactions whereby light energy is used to combine water (and nutrients) with carbon dioxide from the air into carbohydrate (sugars). These sugars are then loaded into phloem cells and transported to various parts of the plant (**Error! Reference source not found.**). Sugarcane plants have a unique ability to store these sugars as sucrose in their stems. From this basic understanding of the sugarcane plant physiology, it is clear to see that climate influences plant growth and eventually the accumulation of sucrose in the plant. Understanding how a changing climate will affect this balance is critical in designing interventions to mitigate the effect of climate change on the plant.

Sugarcane crop physiology and climate

The main requirements for a high yielding sugarcane crop are water, heat, sunlight and adequate nutrition. Given the right combinations, together with deep soils and good management practices, biomass yields in excess of 35[3] tons per acre per annum are achievable on a commercial basis under ideal conditions. The best climate for growing dryland (rainfed) sugarcane is one with two distinct seasons: one warm and wet, for encouraging germination and vegetative development, followed by a cool, dry season to promote ripening and consequent accumulation of sucrose in the stalks.

Moisture supply from the soil to the sugarcane plant (through the root system) is continually in sync with moisture demand through transpiration losses through the stomata in the leaves to

3 Regional average (74.2 t ha-1) and world average (70.9 t ha-1) (Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT) 2015)

the atmosphere. If moisture from the soil is limiting, the cycle falls out of sync and the process of dry matter accumulation become sub-optimum. In many ways a sugarcane plant can be compared to a continuous column of water with a control mechanism at each end, the bottom end being the root/soil interface and the top end representing the stomata/atmosphere interface. Scientists refer to this highly dependent relationship between all three components as the 'soil-plant-atmosphere continuum' or SPAC.

Further important points include:

1. The atmosphere, comprising the combined effects of temperature, solar radiation and evaporation, can be considered the primary driving force controlling the rate at which moisture is absorbed, through the root system, into the plant and transpired through the leaf stomata of the crop.
2. Under good growing conditions the amount of moisture taken up through the roots from the soil is almost equal to the amount lost through transpiration from the leaf canopy (±98%).
3. The rate of transpiration can be controlled by closing the stomata, but this will reduce the crop's growth and development.
4. Moisture uptake through the roots is reduced when the soil cannot supply sufficient moisture to meet atmospheric demand.
5. The soil moisture supply to the sugarcane plant must meet moisture demand from the atmosphere to ensure maximum growth rate.

As can be seen from the above, any change in climate could put these balances out of sync resulting in increasing plant stress and decreasing production.

The impact of temperature on sugarcane crop growth

The most important external factors influencing germination and growth are: soil moisture, soil temperature and aeration. The optimum ambient temperature for sprouting is 28^{0}C to 30^{0}C and the minimum is 12^{0}C. Temperatures above or below will negatively affect the processes involved in the sprouting of the buds. Cultivar differences and cultural practices can modify this range slightly. The optimum temperature range for the germination of cuttings varies from 26 to 33 °C. In the south of Brazil, critical temperatures were found to be 19-20 °C (not irrigated) and 18-19°C (irrigated). This difference is due to soil temperature, which is considered to have a great impact on root growth

Temperatures below 20°C affect both the length of the growing season and the extent of ripening. Low temperatures often at night are the most effective way to ripen cane. Although fluctuations in temperature may have a positive effect on sucrose accumulation, a temperature of less than 5°C is potentially damaging to growth even for the coldest tolerant varieties.

The impact of solar radiation on sugarcane crop growth

Solar radiation drives photosynthesis, which results in sugarcane growth – provided temperatures and moisture is above the minimum threshold. A fully developed crop canopy ensures full utilization of incoming radiation. The sugarcane plant is one of the most efficient converters of sunlight into chemical energy stored in sugars, fibre and straw. These three products can yield 1,718 x 10^3 Kcal from one tonne of sugarcane harvested from the field, equivalent to 1.2 barrels of oil.

When temperature and moisture are not limiting factors in plant growth, solar radiation determines potential yield. The number of hours of sunshine has a significant effect on transpiration rate and sugarcane development. A cloudy day can halve the rate of transpiration and impacts on water requirement. Some plant breeders are looking at the merits of leaf geometry, as a potential criterion for selecting highly efficient photosynthetic sugarcane cultivars.

Effects of rainfall and moisture on sugarcane growth and sugar production

Moisture is important for sugarcane *growth* and a dry season is important for *ripening and harvesting* of the crop. If the dry season is too short, the cost of producing sugar becomes unsustainable as the cost of harvesting and transport increases when waterlogged fields make it challenging to get sugarcane out of the field, and the factory becomes expensive to keep running with less sugarcane. If the dry season is too long, which in many areas is the case, expensive irrigation systems have to be installed and maintained.

Annual crop water use can range from around 1,000 mm in the rain fed areas of South Africa to nearly 2,000 mm in extremely hot irrigated areas (e.g., the Ord in Australia and Mali in Africa). Crop water use is highly dependent on:

1. potential evaporation (Et),
2. solar radiation,
3. the amount and distribution of rainfall,
4. season, and
5. soil type.

A number of researchers have reported on the strong correlation between sugarcane yield and evapotranspiration. Most reports indicate that approximately 100 mm of water (effective rainfall or irrigation) is needed to produce 10 tc/ha (1 ML/ha/10 tc) The relation holds for the plant and first ratoon crops but reduces by an average of 10% for subsequent ratoons. Using this relationship, the achievable potential yield for plant or first ratoon crops can be determined from the equation:

$$\boldsymbol{Y = \frac{Et}{100} * 9.8 * 0.8}$$

Where:

1. Y = Yield (tc/ha/y), Et = (Eo*0.8)
2. Eo = Class A pan evaporation/y in mm fully replenished by rainfall and irrigation.
3. 0.8 is a factor that allows for incomplete canopy, fallow periods and drying off periods.
4. 9.8 represents the target yield of 9.8 tc/ha per 100 mm
5. Et has been obtained experimentally.

With good management practices, which include selecting a high potential variety, good weed control, well timed and properly placed nitrogen (N), phosphate (P) and potassium (K) fertilizer treatment, timely harvesting and controlled infield traffic, the same amount of water can potentially produce 12 to 15 tc/ha/100 mm water. That is why the project must provide the support needed to ensure that the Belize sugarcane farmers undertake the best agronomic practices using the best varieties so as to maximize their productivity.

The impact of climate change on the yield of sugarcane

Understanding the impact of predicted climate change, on sugarcane production in Belize is a complex issue with many variables. Many scientific papers have been written on the subject, considering a number of different climate change scenarios in different parts of the world. It is interesting to note that there are basically two broad themes in these papers. The first is the physiological responses to climate change in the absence of any water stress, and the second the impact of climate change on the available water for the plant. The reason for splitting these two scenarios is to reduce the number of variables the crop models need to deal with, to give the results some meaning. For the purposes of undertaking a vulnerability assessment for the Belize sugar industry based on the predicted climate change parameters, the impacts are summarized below.

Physiological response in the absence of water stress (assume management practices to alleviate any water stress)

Climate change scenarios, which predict increased temperatures and CO_2 levels (predicted in all cases) indicate an increase in yield and an increase in water use efficiency. Rates of photosynthesis, respiration, expansive growth and evapotranspiration are influenced by air temperature. Generally, increased yields are expected under elevated temperatures and CO_2 levels, due to increased growth and early canopying of the plant, leading to increased photosynthesis and evapotranspiration area of the plant. Evapotranspiration will increase under increased temperature, but the impact of this increase is decreased in the presence of high levels of CO_2. The effect on the plant's transpiration response is due to the mechanism leading C4 plants to partially close their stomata and increase stomatal resistance and leaf transpiration under elevated CO_2 levels. The lower stomatal conductance reduces sap flow and increases xylem potential, leading to an improved plant water status.

Therefore, under a climate change scenario of increased temperature and CO_2 levels, the overall plant response is increased yield (variable but up to 20%) and an increase in plant water use efficiency (WUE – defined as dry biomass produced per unit of transpiration). This could be as much as 30% depending on the climate model used. Both of these aspects indicate a positive correlation to the effects of climate change (temperature and CO_2 levels) on sugarcane yield.

Impact of climate change on plant available water

In order to understand the full effect of climate change on yield, how climate change impacts potential (ETP) and actual (ETA) evapotranspiration needs to be considered. Further, how it impacts water deficit (WD) and water surplus (WS) in the sugarcane growing environment needs to be understood. In most rain-fed sugarcane producing areas, rainfall inter-annual variability is the main cause of sugarcane yield fluctuation, since it affects the soil water balance and, consequently, the water availability for plants. So, any change in the water balance variables, mainly rainfall and/or evapotranspiration, will promote changes in the plant's water consumption. Generally, an increase in air temperature will lead to a higher evapotranspiration. In a non-changing rainfall regime or in a scenario of less rainfall this will promote an increase in the water deficit for plants and, as consequence, a decrease in crop yield by a reduced evapotranspiration. Also, any change in the rainfall regime, with an increase or a decrease in the precipitation amount will result in changes in the water balance with positive or negative impacts on agriculture.

From the results of the various studies that have been undertaken, it can be concluded that climate change, will impose an increase in potential and actual evapotranspiration. This would result in higher water deficits in all cases. This is concerning for sugarcane growers since it can reduce the yields of rain fed crops. Most studies point to an increase of 20% in evapotranspiration of the sugarcane plant for temperature increases of around 3 degrees Celsius.

Physiological response of sugarcane to flooding

While classified as a tropical grass, sugarcane does not perform well in wet soil conditions, and both surface and internal soil drainage should be of a high standard to enable optimum yield performance.

It is generally accepted that there should be no standing water left in a sugarcane field 48 hours after a flooding event. The plant's growth stops immediately after soil air is depleted. If a crop is recoverable or not, it will be dependent on how long it is exposed to a lack of air. Certain physiological changes take place in the compromised stalk, apical dominance is broken, and any accumulation of sugars begins to reverse, the crop will begin to lodge and as the sugar deterioration increases, the stalk will rot. While this is taking place, aerial roots will begin to form higher and higher up the stalk as the plant struggles to maintain life by re-rooting itself.

Aerial rooting is the sugarcane plant's survival response to anaerobic soil conditions and apical dominance will have been broken by the physiological effect of the crop standing in water for extended periods. The cane stalks will side shoot from below the growing point. As a result, the upper portions of the stalk will lose vigour and quality, and some stalks will desiccate completely.

Care should be taken to observe where the actual regrowth is taking place on the stalk. Each field and each variety need to be carefully assessed because regrowth from anything other than the apical point is undesirable from both a sucrose accumulation and a disease perspective. For these reasons, the sugarcane standing is deemed to be beyond use as seed cane and urgently requires harvesting. It should then be discarded to allow normal regrowth to occur. The sugarcane stools will recover to give a good ratoon crop provided the water does not stand longer than 1-2 weeks in the field.

In summary, vulnerability needs to be assessed against the following:

1. Potential yield increases due to increased photosynthesis and evapotranspiration as a response to increased temperature.
2. Increased Water Use Efficiency due to elevated CO_2 levels.
3. Increased Water Stress due to higher evapotranspiration levels (20%) which, unless replenished through use of irrigation or increased rainfall, could significantly reduce yield by up to 50% of current levels.
4. Significant yield decline and economic loss due to flooded sugarcane.

Based on the above and especially in the context of the soils in Belize unless interventions, as envisaged by this project, are implemented to build the adaptive capacity of farmers, then the changing climate will no longer support the growing of sugarcane in Northern Belize.

1.4.3 The impact of climate change on sugarcane operations and other nodes in the value chain

It is clear that climate has a significant impact on the physiological growth and production of sucrose in the sugarcane plant. Climate also impacts the physical operations and sugarcane production systems. Climate impacts the operations and production systems in the following key production areas:

Planting

Sugarcane needs to be planted every 5-10 years in Belize depending on crop vigour and soils in which the sugarcane is planted. Planting is one of the most significant operational activities undertaken on the farm. In order to plant, the old crop needs to be destroyed, the land needs to be prepared and clean seed cane needs to be planted in a seedbed with sufficient available moisture to ensure germination. Timing of activities is important in the replanting operation. Currently in Belize there is a planting window of four months when conditions are suitable for planting. The expected shifts in climate especially shifting rainfall patterns could shorten this window through longer periods of dry weather and make these operations more costly. Likewise, heavy rainfall in the planting window could make land preparation and planting more difficult and delay planting to such an extent that seed cane could become less viable or available.

Harvesting

Harvesting of sugarcane is the single biggest annual on farm operation. It occurs during the drier period as rainfall during the harvest time can be disruptive, costly and cause tremendous in field damage. This in field damage caused by machinery and equipment being used to load and carry the cane, damaging the sugarcane stool can result in the ratoon ability of the crop being reduced and being required to be replanted on a more regular basis. Rainfall in this time can also force harvesting to stop all together which can have the effect of shortening the milling season and causing carry over cane.

Cutting sugarcane requires high physical exertion from workers under intense and increasing heat, which is a big health risk. Occupational heat stress is a growing problem due to climate change, causing kidney disease and in many cases, death. Chronic Kidney Disease of non-traditional origin (CKDnT) is a fatal progressive loss of kidney function that has killed more than 20,000 people in a single decade in Central America alone[4]. An epidemic of chronic kidney disease of non-traditional origin (CKDnt) has occurred in regions along the Pacific coasts of Nicaragua, El Salvador, Costa Rica and Guatemala. The disease is not related to known causes of CKD, such as diabetes and hypertension, and is more common among young male

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[4] Ramirez-Rubio O, McClean MD, Amador JJ, Brooks DR. "An epidemic of chronic kidney disease in Central America: an overview" Postgraduate Medical Journal. March 2013 http://www.ncbi.nlm.nih.gov/pubmed/23417684 (not open access

agricultural workers, especially sugarcane cutters. Based on evidence from epidemiologic studies, CKDnt in Mesoamerica can be considered a work-related disease driven by heat exposure at work. A number of studies have taken place into CKDnt and while work is still ongoing, key findings are the following[5]:

- Sugarcane cutting in industrial agriculture requires high levels of physical effort. This physical activity could be compared to the first 12 hours of adventure racing, but occurs 6 or even up to 7 days a week, and during 5 to 6 months harvest.
- Evaluations across the work shift conducted in sugarcane cutters concluded that physical body changes were compatible with recurrent dehydration from demanding work in hot environments.
- Across the harvest, decline in kidney function was more severe in workers with a combination of exposures to high metabolic heat and high environmental temperatures.
- The proportion of workers newly developing kidney injury increased according to increasing physical demand in jobs done in the same environmental heat (dose-response).
- A water-rest-shade program in El Salvador reduced the impact in kidney function across shifts and its implementation stopped kidney decline in cutters over the harvest. In Nicaragua, in cutters with the highest physical workload, the water-rest-shade measures were not enough to prevent kidney function decline, suggesting the need for a more intense prevention for those groups.
- Higher heat exposure, low water intake and longer work weeks were associated with higher declines in kidney function over a 4-month period in brick making workers.

It is obvious from the above that this emerging condition will only get more serious as temperatures increase. Many industries are using the emerging evidence of the linking of CKDnt to manual cane cutting as one of the contributing factors in moving to mechanical harvesting.

Processing node (Grinding)

Rainfall in the harvest season not only effects on-farm operations but also grinding and milling operations. The main reason for no-cane-stops in any milling operation is weather related. No-cane- stops are a significant expense to the mill as stopping and starting a mill takes time and resources. Mud introduced into the mill as a result of rain during the harvesting window is also a major issue leading to reduced quality and increased cost of sugar production.

Industry planning and relationship between mill and grower

As discussed previously, climate change will impact sugarcane yields both positively and negatively depending on the specific climatic changes experienced at the time. Plant available moisture is the one aspect of climate that will have the biggest impact on yield and by inference fluctuating moisture levels will correlate to fluctuating yields. Fluctuating yields can have a large negative impact on the entire industry supply chain as it makes planning in the

[5] http://www.bonsucro.com/wp-content/uploads/2020/03/CKDnt-Paho-2020-iii.pdf

short term (season by season) and the long term very difficult. In years of good rainfall, the mill may not be able to grind all the cane available leaving carryover cane and financial loss to the farmers. In times of low rainfall, the mill will not have enough cane to grind meaning financial losses to the mill as well as the farmers. As these yield fluctuations increase due to climate change, so this uncertainty increases and makes both the mill and farmers reluctant to invest in their operations. This heightens tensions between the farmers and the miller and weakens the entire value chain. Building responses that stabilize yield fluctuations is therefore critical to ensuring a resilient value chain for the entire industry. This needs to be done through physical intervention on farm (moisture management) but also through the strengthening of information systems in the industry as well as enhancing the industry regulatory framework.

1.5 Other initiatives to build climate and financial resilience into the sugar value chain

Belize is not alone in facing climate and financial threats to its sugar industry. Many countries, developing nations in particular, are facing similar challenges especially those low-income countries which were heavily reliant on the preferential price received from the European Union. The price and climate impacts faced by these industries have forced many of these industries to undertake reforms in their industries. Many of these reforms have been in an effort to remain globally competitive and adapt to climate change. A good example of an industry that has undergone massive transformation is the Mauritius sugar industry which among a number of other competitive enhancing initiatives has reduced the number of mills in the industry from 12 to 3 over the last 10 years. These initiatives normally form part of an industry wide agreed strategic plan which is often endorsed by government.

Most of these strategic plans are premised on a number of pillars:

1. Support from government in recognition of the strategic importance of the industry in the country
2. Activities to improve the adaptive capacity and productivity of the farming sector including:
    a. New technologies
    b. New varieties
    c. Innovative data management and farmer finance systems
3. Activities to strengthen and improve governance of the entire value chain including reforms to the sugar acts (or creating acts where they do not exist in a country)
4. Activities to reduce overall cost of production thought the value chain in an effort to make the industry internationally competitive
5. Activities that align the sugar value chain with international standards on environmental and social activities in the value chain creating a competitive marketing environment
6. Diversification of products in the value chain including direct consumption sugar, ethanol, power generation and other products based on the utilization of sugarcane bagasse.

Belize has not developed a comprehensive strategic plan agreed by all stakeholders however the industry and the different actors in the industry have progressed by implementing activities from the different pillars. Of note the following activities have been undertaken in the past 10 years[6]:

1.5.1 General Mill infrastructure upgrades

In the five years (2008-2012) before ASR acquired a majority stake in BSI in October 2012, BSI milled an average of 1,002,744 metric tons (MT) tons of cane per crop producing an average of 95,859 MT of sugar. Since 2012, BSI has invested close to BZ$190 million to expand mill throughput, improve efficiencies at the mill and power plant, increase production of value-added sugar, modernize raw sugar logistics operations and improve environmental systems. These investments have resulted in improved cane preparation and throughput, increased recovery of sugars from 78.7% to 84.1%, reduced down time from 20% to 10% (which resulted in decreasing crop length by 10 days), and improved reliability. These investments have meant that from 2014 to 2019, BSI has ground an average of 1,266,032 million MT of cane producing an average of 140,115 metric tons of sugar. Farmers have benefited directly by being enabled to put an additional 2.01 million MT of cane through the mill over this period.

1.5.2 Mill upgrade to direct consumption sugars

Following changes to the EU market in 2017, which eliminated preferential pricing for raw sugar, BSI elected to invest BZ$32 million to transform the mill from a predominantly raw to food grade, direct consumption (DCS) sugar facility. DC sugars are value-added and attract a higher price than raw sugar. In the past two crops, cane farmers have benefitted through the commercial agreement that shares the improved value of DCS with farmers. In 2019, farmers earned BZ$2.40 more per ton of cane than would have been the case if this DC sugar had been sold as raw sugar. In 2020, the direct benefit from DCS was BZ$3.27. This additional benefit comes to farmers, after shipping costs and manufacturing allowance. In other words, had BSI not made that investment, farmers would have earned an annual average of BZ$2.75 less p er ton of cane without the DCS transformation.

1.5.3 Big Creek Port Upgrade

BSI has decided to invest BZ$30 million to move the bulk raw export operations from the offshore point at Anchorage near Belize City to the newly dredged port at Big Creek, Stann Creek. The investment will enable BSI to significantly increase loading rate from 500 to 5,000 tons per day. This will save money on freight and demurrage charges, resulting in savings of approximately BZ$1.4 million to cane farmers.

1.5.4 Development of smart sugar cluster

Since 2018 ripe.io (a private company specializing in using blockchain technology to drive technological change in the agricultural sector) has been actively working with the ASR Group and Belize Sugar Industries (BSI) seek to utilize ripe.io's distributed ledger technology and accompanying services in order to support, accelerate, and provide new capabilities to provide transparency, traceability accountability and security to the ecosystem of partners

[6] Source: BSI open letter to cane farmers-25 August 2021

involved in the sugar cane industry. This will improve transparency and trust to an ecosystem which provides income to many thousands of people in Belize. By bringing a shared system of records and data, we will enable lenders, farmers, agri-input services providers, associations, and the mill to have clear and dependable insights into the financial health of the sugar cane farmer, thus strengthening the financial ecosystem. With a healthier lending environment, farmers should benefit by having access to more competitive terms and conditions.

The core project goals are addressing the following challenges:

- Cane supply and cane payment trust issues between miller and farmers
- Lack of an organized, permanent, and interactive financial record keeping system between mill and farmers
- Cluster partners internal IT difficulties interacting with third parties due to security issues
- Lack of trust between financial institutions and farmers
- Lack of economies of scale resulting in high production cost
- Lack of digital identity for small-scale sugar cane farmers
- Limited farmer financial literacy for women farmers
- Continued low cane prices for farmers and stagnated support by commercial banks
- Aggregated data access and visibility for farmers and all of the supply chain participants (e.g., near real-time availability of delivery, quality and weight of sugar cane to the mill)

Project design to build adaptive capacity to these impacts

1.6 Introduction

The project design has responded to the predicted impact that climate change will have on the sugar industry in Belize. This design responds to the vulnerabilities in the productive node of the value chain as identified through the participatory stakeholder engagement process. The project design is aligned with the GCF investment criteria and uses the theory of change as the basic mechanism to determine how the project impacts will be achieved. The project design also looks at the project organizational structures and processes in order to develop a comprehensive budget for the project.

1.7 Alignment with IFC investment criteria

The project design foundation has been built around the four principles that the GCF wants to see in any agricultural adaptation project. These are the principles of local ownership, paradigm shift, additionality and scalability. These principles have been discussed in all of the stakeholder engagement sessions to create alignment of thought around the project design. Through these engagements it has been agreed that for this project, the following principles will be adopted:

1.7.1 Local ownership

It has been agreed that the sugarcane farmer should be the project entity that should receive the greatest proportion of benefit from the project. This is not a project that should focus on reports or research and development but activities should be designed to increase resilience of the farmers based on the identified vulnerabilities. Further it is agreed that the four farmers associations should be the focal point of the project design and "ownership" of the project should vest with them, with the project providing the framework, performance parameters and resources for them to take a leadership position in the project. During the stakeholder engagement it was agreed that the four farmer's associations would be designated as co-implementers of the project to ensure this focus on local ownership and that the project structure should reflect this.

BSI and SIRDI[7] will also ensure that the principle of local ownership is continued through these local institutional actors both as important stakeholders but also in their role as project executing entities.

1.7.2 Paradigm shift

The concept of paradigm shift is designed into the project in two main areas:

1. Introducing the concept of climate smart agriculture into the sugar industry and particularly with the farmers
2. Introducing a number of different farm models which will allow farmers to organize themselves differently in order to better adopt new technologies and practices that will increase their resilience to climate change.

The baseline assessment report spoke extensively to the concept of Climate Smart Agriculture (CSA) and explained that the concept is built around three pillars: Productivity, Adaptation and Mitigation. This project will introduce activities in each of these pillars as well as focussing on the fundamental attitude change needed for the farmers to understand the impacts of climate change on their lives and livelihoods.

Introducing new farmer models will be designed into the project through ensuring that the knowledge component of the project is holistic in nature and includes the social transformation elements alongside the technical elements needed to build resilience.

1.7.3 Additionality

The concept of additionality is a key concept to consider when designing the project. Many stakeholders believe that having an institution granting certain elements of the farming operation will build the farmers resilience. This however will not build resilience as it entrenches the status quo rather than introducing new activities and technologies which are needed to build long term resilience to climate change. The GCF will only fund activities that are additional to the business-as-usual case and that are directly linked to adapting the business-as-usual case to be more climate resilience.

The additionality from this project comes from two main interventions, firstly through the introduction of new technologies such as irrigation, and secondly through the addition of new

[7] SIRDI is the research and technical arm of the Sugar industry control board. They are responsible to provide technical advice and training to the sugarcane farmers

varieties into the industry through a large replanting program. While it is easy to see the additionality in the introduction of new technologies and activities it is less obvious through replanting (which is a normal activity) and introduction of new varieties into the industry.

The additionality in the replanting element of the project (which is proposed as the biggest element of the project) lies in where the risk and costs are taken in the introduction of new varieties to the industry. Presently the industry has a variety breeding program in place (this is fully described in the baseline assessment) This program has a five stage breeding process where up to 15 000 seedlings are received from Barbados and trialled under Belizean conditions. This results in a few 2-5 varieties being identified as potentially suitable. These varieties then go through a validation process with some on farm trials. Thereafter these varieties are ready to be taken up by farmers. The initial five stage trial process is a de-risking process and the costs for this are currently borne by BSI. The on farm validation process is a further de-risking exercise and the cost of this is currently borne by SIRDI and in some instances farmers bear some of the cost. The uptake of the newly identified varieties has been slow as the farmers still perceive there to be some risk associated with planting these varieties. Farmers are not prepared to take this risk and that is why B79474 still dominates the industry. Essentially the cost associated with the roll out of new varieties moves from BSI and SIRDI to the farmers who are unable/ unwilling to bear this cost. By the project granting a portion of the upfront replanting costs, individual growers will be more willing to take on the risk of planting these varieties. This will further de-risk these varieties under commercial on farm conditions (commercial stress testing). Should the varieties fail under this commercial testing, the individual has already been compensated. Should the varieties prove to have the yield and climate resilience characteristics that the industry desires, then the whole industry benefits with the introduction of a new variety. The additional risk/cost that the farmer bears as a result of planting of the new variety is an important element of project additionality.

1.7.4 Scalability

The Norther Belize sugar industry is approximately 75 000 acres in extent. The project will only directly benefit 10 000-15 000 acres of land. It is therefore critically important that the project creates the systems and capabilities that will allow the rest of the industry to transform to more climate resilient production systems. The outputs and systems that the project will develop to ensure this include the following:

1. Introduction of new climate adapted varieties that are accepted by the farmers and whose performance has been stress tested
2. Systems of ensuring good quality seed cane is available where it is needed when it is needed
3. Networks of contractors providing good quality of work, timeously and in a cost-effective manner
4. Systems of data management and linkages of the various on farm operations with financial institutions and contracting services (block chain)
5. Communications and early warning systems

1.8 Project Theory of Change

The Theory of Change (ToC) is a project management tool that enables project evaluators to see a compact and informative graphic that describes the impact that the project hopes to achieve. The ToC provides an indication of the project impact that will be delivered through a set of project outcomes, which in turn, will be achieved by completing the identified project activities.

These activities have been grouped into the three project components. The ToC diagram can be seen in Annex 2: Theory of Change.

A summary of each component and its activities are presented below:

Component 1: Increased adoption of climate smart practices (physical and mind set) with an increased mix of adapted varieties being planted.

Component 1 has replanting of new varieties as its main set of activities. The project design process has identified this component to build on and further capacitate the replanting program that exists, while ensuring the farmers are replanting according to CSA practices and the planting is in such a way as to enable mechanical harvesting to take place.

The component activities and outputs are as follows:

Activity	Output
Component 1	
1.1.1 Establish seed cane variety information database and working group 1.1.2 Farmer seed cane sensitization and training	Variety information release protocol and data sheet for each variety
1.2.1 Identify seed cane nursery sites and seed cane production collaborators and protocols 1.2.2 Training of seed cane nursery collaborators 1.2.3 Plant seed cane nurseries	294 acres of seed cane nursery developed and distribution systems in place
1.3.1 Develop standards for contractors for land preparation and planting 1.3.2 Identify and train suitable contractors on business practises 1.3.3 Establish digital marketplace for contractor to replant facilitated via technology-based solution(s) and systems 1.3.4 Training on Climate Smart Agriculture for replanting	10,000 acres of land replanted to climate adapted varieties

1.3.5 Replant fields that are selected based on predefined criteria	
1.4.1 Ensure fields are suitably prepared for Mechanical Harvesting 1.4.2 Identify clusters of fields for viable Mechanical Harvesting 1.4.3 Upscale green Harvesting Programme and associated delivery parameters 1.4.4 Training for displaced cane cutters	10,000 acres available and able to be mechanically harvested and 2,000 acres mechanically harvested
1.5.1 Identifying sources of financing and determining the criteria of financial inclusion	10 new contractors established
1.6.1 Develop soil management protocols for different residue and moisture regimes to be implemented at replanting and ratoon management	10,000 acres of improved soil health Management measures implemented at replanting and 5,000 acres implemented for ratoon management

Component 2: Stable yields, increased productivity, and a more resilient and consistent supply chain.

Component 2 has been developed to address the issue of moisture management.

Climate change has changed the environment under which the sugarcane farmers are farming in Northern Belize. Specifically, the rainfall variability has become more pronounced such that the farmers are experiencing severe droughts and flooding events, as seen in the 2019/2020 season. The farmers are vulnerable to these events due to not having the infrastructure to do effective moisture management.

In order to adapt against these climatic events, infrastructure is suggested to ensure the farmers can manage the moisture within their soils. This activity will implement the development of supplementary irrigation and surface drainage on selected plots. Additionally, as a result of providing additional moisture to the soil and the additional trash that exists as a result of component 1, an integrated pest management plan is suggested to enable farmers to rapidly detect and exterminate pests that are identified on their farms.

The activities and outcomes of the component is as follows:

Activity	**Output**
Component 2	
2.1.1 Develop criteria for irrigation and drainage to identify most vulnerable farmers and/or farms where conditions make implementation viable	Maps developed identifying available acres to develop drainage and irrigation for contractors

2.1.2 Develop system to allow contractors to develop drainage and irrigation	
2.2.1 Plan, design and develop irrigation and drainage design parameters 2.2.2 Support development of identified irrigation and drainage 2.2.3 Water management and irrigation scheduling training 2.2.4 Identifying sources of financing and determining the criteria of financial viability	Development of 1,000 acres drainage and 2,000 acres irrigation
2.3.1 Develop pest management protocols for different residue and moisture regimes	10,000 acres of land with improved Pest Management measures implemented

Component 3: Farmers increasingly using knowledge and knowledge systems to proactively (early warning, investing) build resilience to climate impact while at the same time transforming their farming systems to enable them to invest in on farm climate resilience building activities.

Component 3 has been designed to be an integral part of the sustainability plan for the project and has been designed as a set of activities that support efficient project and industry management. The component therefore helps strengthen the awareness of climate threats and risk reduction processes and helps generate and use climatic information for decision making.

Activity	**Output**
Component 3	
3.1.1 Development of industry forum to agree on transformation strategy 3.1.2 Development of CSA adaptation strategy and training for industry stakeholders	Industry aligned for transformation
3.2.1 Develop wholistic training strategy and training material to build climate resilience	System developed to introduce continuous learning
3.3.1 Equip and use industry tools to distribute climate related data for good farmer decision making 3.3.2 Integrate blockchain into industry tools	Industry tools used to increase the data available to farmers for decision making

3.4.1 Develop farming models through industry knowledge sharing 3.4.2 Training on acceptable farming models	Multiple farming models enabling knowledge sharing and increased purchase power
3.5.1 Develop risk mitigation system for climate variability	Climate risk financially based mitigation solution
3.6.1 Develop farmer economic and social vulnerability criteria 3.6.2 Identify Environmentally No-Go areas	Farmer vulnerability criteria developed and assessed and associated maps produced

1.9 Project implementation strategy

The project implementation strategy is primarily based on the independent functioning of the project management unit with the support of the co-implementors and executing entity under the guidance of a project steering committee.[8] The farmers associations have been designated co-implementors which is important for industry ownership and onboarding the new practices that the project is proposing.

The project implementation strategy can be defined at three levels from hereon, namely the preparatory phase, the in-field implementation phase and the monitoring and evaluation (M&E) phase. Using these three phases, the project management unit together with the guidance of a steering committee and the support of the co-implementors, will implement the project activities.[9]

1.9.1 Preparatory phase

The preparatory phase will form the majority of the first year of the project. During this time, industry tools will be further designed, developed and deployed, Farmer Associations will be trained on CSA practices, contractors will be identified and trained on CSA practises and industry alignment will be achieved on CSA practices by facilitating forums on industry transformation.

This preparation will ensure the necessary knowledge is obtained on the ground while ensuring the industry is appropriately capacitated to implement the project activities.

1.9.2 In-Field implementation phase

The in-field implementation will form the bulk of the project. It is proposed that for the implementation of project, activities will be broken down into different "lots". These "lots" will be released over the life of the project and the different farmers associations will be able to bid for each of the "lots" through a semi-competitive bidding process against pre-determined

[8] See Figure 3 for project Co-Implementors

[9] See Figure 4 for project flow diagram

criteria. This will ensure that the project is demand led and the farmers associations will be able to fulfil their role as co-implementers on the project.

The project steering committee will develop a set of criteria for each activity that will be implemented through a "lot" bidding process to enable the PMU to evaluate the bids fairly and transparently. This will include a number of criteria including:

- Farmer vulnerability,
- Alignment of transformational goals of the project,
- Gender and youth
- Equitable benefit across farmer associations for the project and each component
- Technical feasibility (soil, access to water, etc)
- Financial commitment (Co-funding from farmers and farmer associations)

1.9.3 Monitoring and evaluation (M&E) phase

Monitoring and evaluating of the project activities and the fund impact will be conducted by a combination of the project management unit and industry stakeholders, through the systems being established by the project. More specifically, the Smart Sugar Cluster, will enable the project and industry stakeholders to capture large amounts of data from project beneficiaries and in doing so, will allow for an effective monitoring and evaluation.

As part of the project implementation, the financial institutions will also be conducting their own due diligence before awarding loans. The due diligence will become a second level of M&E for the project and will ensure that the project impacts can be captured by an entity independent to the PMU.

The M&E activity will use the project and fund log frame to monitor the various activity outputs and project impact through the indicators identified.

1.10 Project organizational design

1.10.1 Project organogram

The project design has been a transparent and participatory process. It is therefore important that the project implementation will continue to be participatory and ensure the alignment of industry stakeholders.

The project organogram consists of a steering committee, the PMU, the experts that provide additional capacity and expertise to the PMU, the co-financiers and co-implementors and the accredited entity. The full organogram can be seen below:

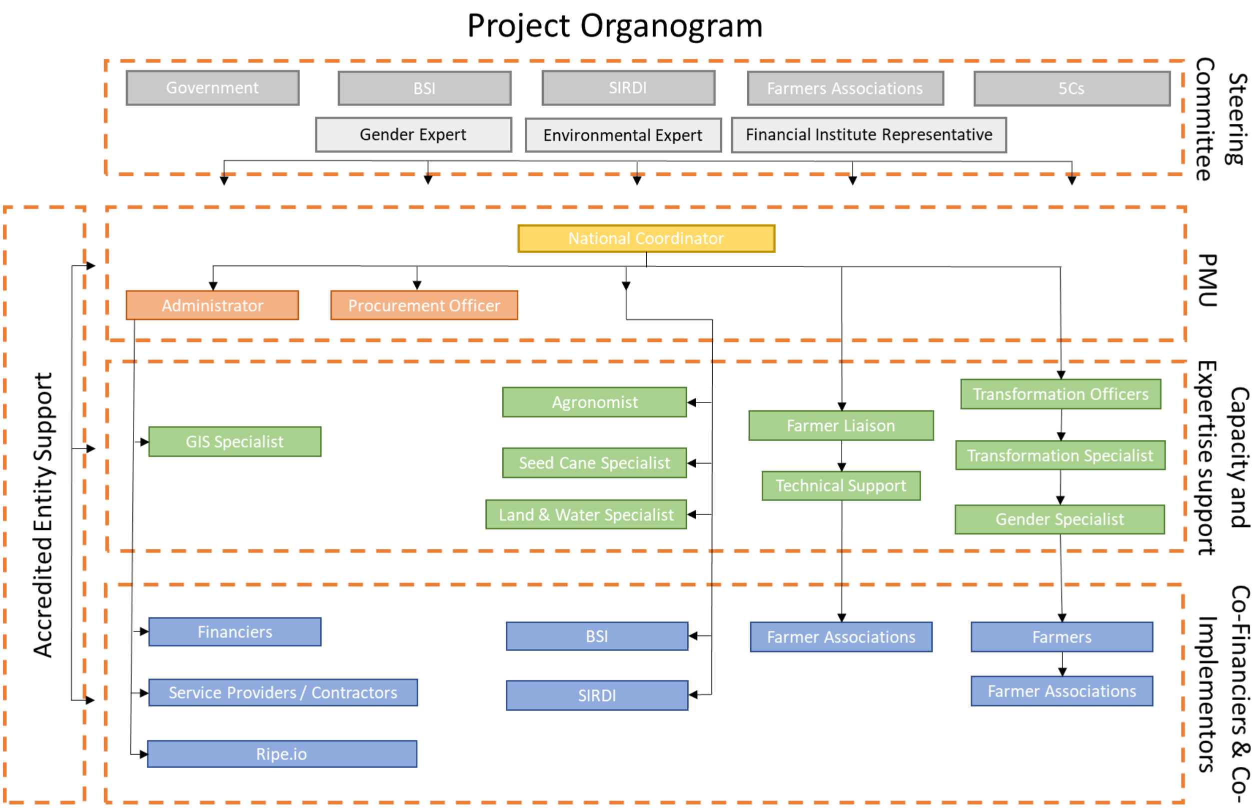

Figure 5: Project Organogram

The Steering Committee is the body providing overall guidance and oversight to the project. The board will be comprised of voting and non-voting members with CCCCC (directly or through the PMU) providing secretariat services to the project board. The project board will be comprised of the following institutional representatives:

- One member from each of the farmers associations
- One member from SIRDI
- One member from BSI
- One member from the ministry of agriculture

These members will comprise the voting bloc of the board- it is envisaged that voting may only be necessary to adjudicate on project resource allocation in the competitive bidding process (see draft project design report for more details).

The project board will also comprise non-voting members whose main purpose will be in an advisory capacity to the board. Non-voting members will represent the following broad constituencies:

- A gender expert and advisor
- An environmental expert and advisor
- Someone representing the financiers on the project

The project board will be expected to meet quarterly or as required. Minutes of the meetings should be available to all identified project stakeholders on request.

It is the responsibility of the project board members to inform and update its constituency on a regular basis regarding project activities.

The PMU will see to, and manage, all project management activities. The PMU, through the national coordinator will work closely will all the arms of the project stakeholders, capacitated by the experts, and supported by the co-implementor and CCCCC.

1.10.2 Project process flow

The project has been designed with the principle that utilizing technology will support the sustainability of the project interventions and of the sugarcane sector in Norther Belize. The project process flow has been developed, as seen in Figure 6: Project Process Flow Diagram.

The process flow is discussed in four levels, as depicted in the figure by the various colours. These four processes are: Establishment and training, Bidding process and loan application, Service delivery and M&E and payment.

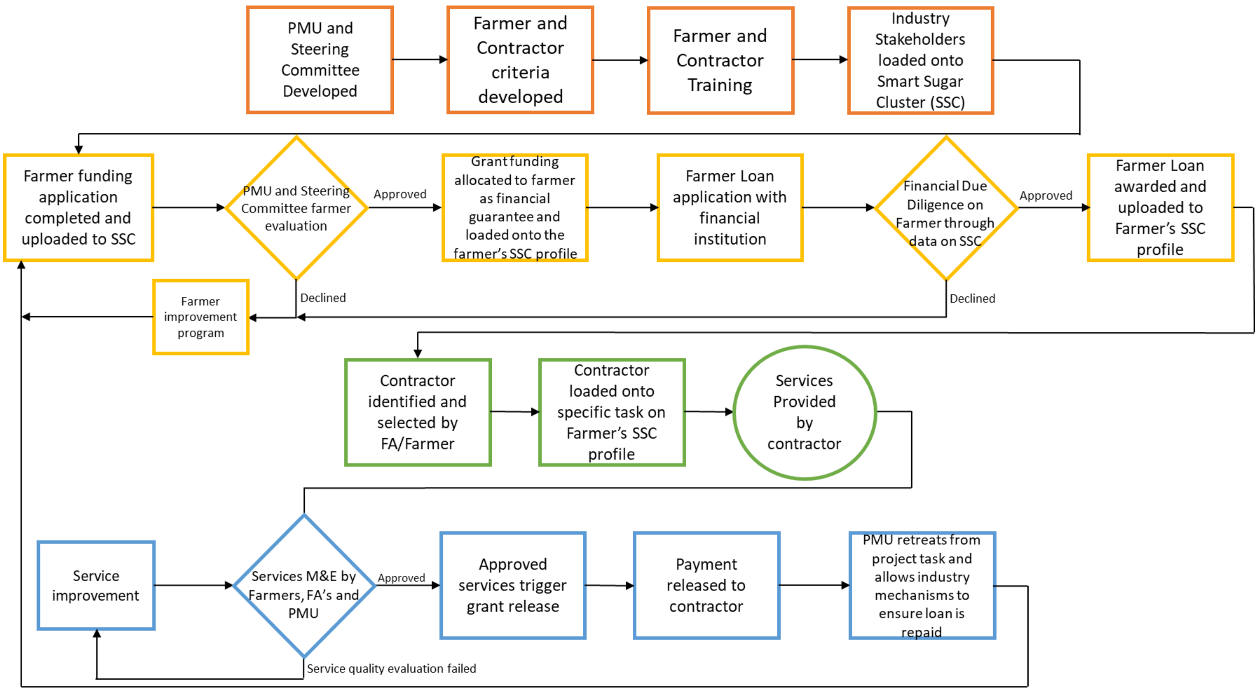

Figure 6: Project Process Flow Diagram

Establishment and training

The first step in the project process ensures the basic structures are set up that will enable the facilitation of the project activities. This process includes setting up of the steering committees, determining the various criterions for bid evaluations, training of farmers and contractors and the capacitating of the Smart Sugar Cluster.

Ensuing that the first step is completed early in the project's lifetime will allow initial project learnings to be incorporated into the implementation phases. Additionally, successfully training farmers and contractors on the new technologies and practices will reaffirm that the industry is comfortable with the transformation.

Bidding process and loan application

Once the framework for implementation has been defined and a list of farmers and contractors have been trained and uploaded onto the Smart Sugar Cluster, the technology that will help facilitate the bidding process, then the bidding process will start.

The PMU will release "lots" to the Farmer Associations and with the support of the transformational officers, will be able to complete a proposal to bid for support. Evaluating against the criteria set by the steering committee, the PMU will either award or reject the farmer association's proposal. If rejected, they will be able to reapply to the same "lot" if there is funds or area left to be distributed. If the farmer association is successful in their application, then they will be granted the funds, initially as a guarantee, until they have secured a loan for the co-funding component of the activity (where necessary).

Only once the farmer association has successfully accessed loan funds, will the grant component be transformed from a guarantee into a deposit on the loan, effectively reducing the loan amount by the grant portion. This process will be managed and monitored by the Smart Sugar Cluster.

Service delivery

After the financial institutions conduct their due diligence and the farmer association is awarded the loan, specific contractors can be identified to conduct the services.

A process of identifying the contractors will be conducted by the farmer associations to ensure responsibility lies with the farmer associations to ensure activities are implemented according to criteria developed. Once the contractors are uploaded onto the digital platform and liked with the farmer for the specific task, the service can be delivered.

M&E and payment

The ultimate responsibility of the task being completed according to specification will remain the farmer's. However, to ensure traceability and, a series of M&E process will be deployed to ensure that the services delivered were implemented according to specification, including through the PMU, the financial institution's M&E and the contractor's reporting.

Once the task is signed off by the PMU, the system will trigger a payment to be released to the contractor, through the Smart Sugar Cluster, from the loan account that was funded by both the financial institution and the grant funds.

1.10.3 Project roll out and timelines

The project roll out follows the implementation strategy. This strategy focuses on building capacity at the front-end of the project to ensure the project activities have sufficient local implementation knowledge and capacity to be implemented successfully.

The project timeline has been developed and can be seen in Annex 3: Timetable at project-programme level. The project timeline is an important project management tool for the PMU to understand the allocation of funds, as the budget is guided by the timeline and therefore the "Lot" frequency and acreage is dependent on the timeline.

1.10.4 Project ramp up, exit and sustainability strategy

The project design foundation has been built around the four principles that the GCF wants to see in any agricultural adaptation project. These are the principles of local ownership, paradigm shift, additionality and scalability. These principles have been discussed in all of the stakeholder engagement sessions to create alignment of thought around the project design.

The sustainability of the project relies on the local ownership and scalability of the project interventions. Systems developed in component three has specifically been designed to ensure an increasing ability of the local industry to onboard new processes and technologies that the project will introduce while building the foundations for systems that could be scaled across the industry.

The project's exit strategy will rely on both the systems being developed and the social structures it will establish.

The following project outputs will ensure a smooth project exit, sustainability and ramp up:

Broader base of seed cane varieties

BSI and SIRDI has developed a sugar cane seed cane variety roll out program that continuously identifies, tests, and verifies new sugar cane varieties in the Belizean conditions. Under the project preparation facility, this program has been capacitated and is on the cusp of delivering numerous new, viable, seed cane varieties.

Not only has the seed cane variety program been ongoing for several years, but it also forms part of a larger seed cane variety group that spans the entire Caribbean. There is a level of accountability from the region that ensures countries like Belize are continuously searching for, and testing, varieties. The increased frequency of seed cane varieties that are verified and tested, the better it will be for the regional industry as a whole. The existing program allows Belize to draw on varieties from these different countries and is selected through the seed cane verification program.

Furthermore, over and above the training and awareness campaigns to ensure farmers onboard the new varieties, the project will support FA's as the project co-implementors to become seed cane nurseries that supply the industry with new fresh see cane. These seed cane nurseries will become independent entities and remain sustainable after the project exits.

Development of new contractors

A key project strategy is to develop and train local contractors. These contractors will be responsible for land preparation and planting-the main project component. These contractors who will run and own their own business and equipment and will be available to service the farmers after the project has ended.

Smart sugar cluster

The Smart Sugar Cluster is a fundamental intervention that will help ensure the sustainability of the project, but also the industry. Ensuring that data is readily available to all the necessary stakeholders will become a key factor inbuilding an efficient and effective sugarcane production sector in the future. The system is cloud based and the data that sits in the cloud is owned by the collector the data.

This system has the opportunity to bind an industry that has faced divisions as a result of political alignment and miscommunication. By ensuring that necessary data is correct and transparently available to the correct stakeholders will reduce the number of disputes and increase the overall efficiency. The ability to integrate the financial institution's processes into the system, will ensure that future transactions made, will require the system, ensuring it's sustainability.

Climate smart agricultural practices

The project will recommend several CSA practices through training and implementation of new technologies. These are for example, minimum tillage, supplementary irrigation, soil health measures through effective microbials and mechanical green cane harvesting.

The project design has ensured that the industry has access to all the knowledge and service providers required to develop and scale these activities as required within the project timeline and post project. Therefore, once the project closes, the service providers and contractors will be fully capacitated to deliver the CSA services.

The social structures that the project will develop to help build long lasting sustainable development and continued resilience in the sugarcane industry in Northern Belize, includes:

Variety co-ordination and release committee

This is a technical committee established to provide key technical support to the major component of the project. This committee will review the information received from the variety breeding and validation program and will advise on varieties ready for release.

Industry transformation forum

The project proposes a number of transformational changes to the Belize sugar industry in response to the impact of climate change. These changes need to take place in the physical, institutional and financial domain. These changes to the industry will be difficult and will need a broad coalition of support from a range of stakeholders. The project therefore has a specific activity looking at developing an industry transformation strategy and thereafter a forum to provide critical insight and thinking into the transformation process. This forum will also allow stakeholders to design future industry projects and initiatives building on the start made by this project.

Technical assessment of proposed project activities

This chapter looks at understanding and accessing some of the key technical recommendations contained in the project activities. This chapter should be read in conjunction with the project baseline assessment, produced March 2021 which contains a more detailed assessment of the technologies discussed. Information contained in this chapter only reflects updated work that has occurred since the baseline assessment was produced.

None of the technologies proposed in the project design are new in that they have not been implemented in either Belize or in other sugar industries in other countries. There is therefore no technology risk in any of the activities of the project. In some instances, some of the technologies may need to be adapted to suit conditions in Belize. And in the variety roll out which is the anchor activity an assessment needs to be made to ensure suitable varieties will be available for project roll out.

1.11 Component 1: Climate smart agronomy

Component 1 has its desired outcome a move towards climate smart production practices which will move farmers to a production system which is more efficient (get more from less), builds adaptive capacity and reduces their carbon footprint. Key to this component is the replanting and subsequent ratoon management of fields using a larger number of sugarcane varieties which are better adapted to the Belize conditions than existing varieties. Another significant climate smart practice which will be introduced in this component is the preparation for green cane harvesting which has a number of environmental and physical production benefits. The project will need to develop the systems of seed cane production (the right quantity, quality and the right time and place) and the processes to identify the most vulnerable farmers and ensure that they can be assisted. These processes will include identifying possible contractors to carry out the work in order to ensure that planting is carried out to the standards required. The re-planting exercise will also need to be carried out in such a manner that the fields are properly prepared for the green cane harvesting to follow.

1.11.1 Introduction of climate and site adapted varieties into the Belize sugar Industry

Climate Rationale for introducing new climate adapted varieties into the Belize sugar Industry

The industry is presently dominated by one variety, B79474, making up 60% of the area under sugarcane (although this could be higher as 14% of the industry is planted to “unknown” varieties). This reliance on one variety without taking climate change into account makes the industry vulnerable. The rule of thumb in any sugar industry is that the industry should not plant more than 20% of the area under cane to one variety[10]. There are a number of reasons for this which includes ensuring that the industry has a number of varieties that mature at different time of the crop harvesting season ensure even cane supply of good quality cane to the mill and the threat that new pests or diseases could impact different varieties differently.

The baseline assessment mentions two areas of vulnerability for the sugar industry based on the expected impacts of climate change which an expanded industry variety pool will address. These are vulnerabilities are associated with harvesting, haulage and grinding due to poor field access and mud in the cane deliveries due to shifting rainfall patterns and the increase in pest and diseases both of which will become more pronounced under climate change.

An expanded variety pool in the industry with some early, some mid and some late maturing varieties in balance, will not only improve quality and productivity but will also allow the

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[10] IFC: Good Management Practices Manual for the Cane Sugar Industry, 2011: Jan Meyer, Peter Rein, Pete Turner, Kate Mathias

grinding season to be managed so as to better avoid high rainfall times. An expanded variety pool will also ensure that if new pests and diseases become prevalent as a result of climate change as is predicted then the risk of this event will be spread.

Coupled to this, by the project making the investments in the systems and processes needed to ensure that the current breeding program delivers varieties to the industry on an ongoing basis as climate and/or the pest and disease regime changes, new varieties bred to address these factors will be made available to the industry on an ongoing basis.

Technical evaluation of introducing climate adapted varieties into the Belize sugar industry

There are three elements that will ensure that this component achieves its objectives. These are:

1. **New varieties available:** The development of a number of varieties well adapted to the current (and future) climatic conditions in Belize.
2. **Access to good quality seed cane:** The roll out of these varieties to ensure that farmers have access to enough clean seed.
3. **Systems in place to prepare and plant:** The implementation of systems to ensure that the seed is planted in the correct manner to allow maximum production of sugar/acre (Also in such a way to ensure the possibility of green cane harvesting).

Climate resilience and varieties

The project concept note talks about climate resilient varieties being introduced through the project. Technically it is not possible to label any single variety as climate resilient. Varieties have different characteristics and perform better or worse under different and changing climatic conditions and in different soil types. Climate resilience through varieties is built up by having a number of varieties available to farmers each with their own strengths and weaknesses. By having a number of different varieties available the varietal base becomes more climate resilient. Of importance for this project is the fact that the varieties that will be released through the varietal breeding program have been selected in the current climate (including the 2019 drought). This makes them potentially more suited to the Belizean climate than an imported variety might be. Also, the fact that the varietal breeding program is on-going means that future varietal releases will be adapted to future climate change. Therefore, the project strengthening of the varietal breeding program and setting up the systems for varietal release will not only help in the short term but in the long term as well.

It needs to be appreciated that even with a good varietal base, climate resilience is not guaranteed as crop husbandry factors also contribute significantly to building resilience. The concept note recognizes this, and climate resilient crop husbandry is a key component of the project.

Overview of sugarcane varieties in Belize

The Belize sugar industry has a 30-year history of cane varietal research. It is a member of, and holds a leadership role, in the West Central Indies Sugar Cane Breeding Station and Evaluation Network in Barbados. Prior to this partnership, all new varieties came from places of origin as bud chips or vegetative material and were quarantined at the Agricultural complex of Ministry of Agriculture, Agriculture Section, Central Farm in Cayo District. At this time Belize relied on importation of varieties from Jamaica, Canal Point, Puerto Rico and Barbados, who were willing to supply advanced stage material for evaluation under the Belizean climate, and growing conditions. The field-testing program was different than it is today, but had the same basic goals:

- screen for disease,
- grow on typical soils in comparison with best performing commercial types,
- after three years of testing roll out seed for line trials in different growing areas, and
- distribute pure seed of the best performing varieties to growers for commercial propagation.

Today the program screens parental lines through the addition of family selection, has a larger number of seedlings (20,000 +), and relies on a four-stage screening process. This program takes about 8-10 years, at which time the variety upon exit of Stage IV is ready for release, if its disease resistance and performance has been equal or better that the commercial standards (CP72-2086 and B79-474).

The current pace of this program aims to screen 8-10 varieties in the final Stage IV every year. For this breeding program a 30,000:1 success ratio is low and requires considerable effort, but it is considered worthwhile as the outputs of the program are varieties that have been evaluated under Belizean conditions. A summarized pathway showing the BBZ BSI Variety Selection program is shown in Figure 7. This shows the two options available, namely, the conventional breeding program and secondly, the fast-track varieties from other countries.

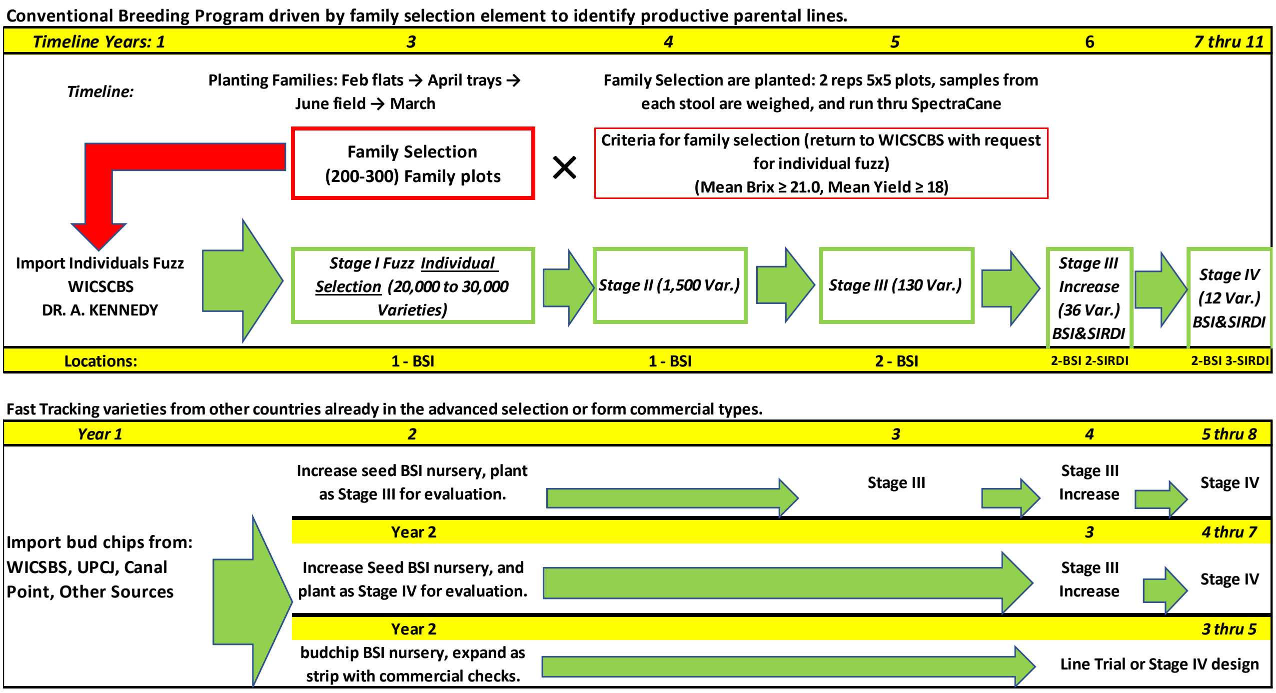

Figure 7: BSI variety selection program

This program screens for the following desired variety characteristics:

1. **Disease resistance.** All varieties released are screened for resistance to common diseases (Smut, Brown Rust, Orange Rust, and Others). Systemic diseases (Ratoon Stunting Disease RSD, Leaf Scald LS, and Yellow Leaf Syndrome YLS) assay are being recommended but have not been done to date.
2. **Fibre % cane equal to and not or less than the check variety B79-474.** High Fibre sugarcane will reduce factory throughput and reduce farmer's access to sell cane within the proposed lower rainfall months and harvest season (November – June 15th).
3. **Shows stable production trends** over the range of typical soils in cane, and under natural rainfall regime. Production as measured in Tons Cane Hectare, and kg Sugar per Ton of Cane.
4. **Robust root system (stool)** that regrows with a minor decline for 5-8 consecutives harvests or ratoon crops.
5. **Provide growers with a choice** to achieve a variety composition that is composed of both early maturity and late season. An increase of Early Maturing Variety composition would increase cane quality early and allow Tower Hill to start in mid to late November reducing the risk of stand over cane. A similar trend is seen in late season, indicating both a need for late season or cane variety that holds its quality for the entire season.

Despite this work to develop new varieties, the Belize sugar industry is still dominated by a few varieties, and B79-474 is most prevalent. It is both high yielding (Tons Cane per Hectare - TCH) and has high sucrose content. It is a mid to late season variety and seems to be susceptible to excessive moisture stress. The dominance and overall performance of this variety has resulted in farmers being reluctant to introduce newer varieties onto their farms. This variety will always be the benchmark against which other varieties are evaluated, both in the variety breeding program and by the farmers themselves.

The variety testing program currently has 8 varieties ready for release. These are as follows:

1. BBz081124: The variety is a mid-maturing variety appropriate for clay soils
2. BBz09626: The variety is a mid-maturing variety appropriate for clay soils
3. BBz09612: The variety is a mid-maturing variety appropriate for clay soils
4. BBz09592: The variety is a late-early variety appropriate for clay soils.
5. BBz08353: The variety is a mid-maturing variety appropriate for clay soils
6. BBz07155: The variety is a mid-maturing variety appropriate for sandy soils and clay soils
7. BBz07144: The variety is a mid-maturing variety appropriate for sandy soils and clay Soils
8. BBz07015: The variety is a mid-maturing variety appropriate for sandy soils and clay Soils.

A variety information sheet for each of the above varieties is attached as

Annex 1: Seed Cane Data Sheets.

Based on the above it can be concluded that the variety breeding program currently being undertaken in Belize will produce varieties that will be better suited to the changing climate conditions that will be experienced in Belize. This coupled with the project investments to be made in the seed cane nurseries along with the project strategy of ensuring the development of local contracting services will ensure that the aim of getting the right varieties available, clean seed available at the right time and the right place and farmers' fields replanted in the correct manner is achieved. This will build the resilience of the entire industry by increasing the number of varieties planted across the industry.

1.11.2 Mechanical Green Cane harvesting

The move to Mechanical Green Cane Harvesting is a complex one with a number of positive and negative outcomes[11].

The GCF investment will not be used to actively support the transition but will be used to create an enabling environment to move to mechanical green cane harvesting should the industry choose to move that way. In creating the enabling environment, the project will ensure the following:

1. That the replanting is done in such a way (spacing, density, land preparation) to allow for mechanical green cane harvesting
2. The contractor training includes mechanical harvesting training
3. The co-financing includes finance for mechanical harvesting
4. The industry transformation plan includes consolidation of farms for efficient mechanical green cane harvesting.

Mechanical green cane harvesting is one of the components of the project that leads to a reduction in the green house gas emissions from the cane farming operations.

Climate rationale for moving to mechanical green cane harvesting.

The pre-harvest burning of sugarcane is one of the most sensitive environmental issues faced by cane growers, in addition to releasing CO_2, sugarcane burning also results in acidic fine article emission, which has negative impact on air quality and human health (Allen et al., 2004). The green cane harvesting presents not only environment benefits but also agronomic benefits.

From the studies listed in the table below it is evident that the elimination of burning practices will mitigate GHG emissions

The table below lists studies that have been done on comparing Burning to no burning of sugar cane

Table 2: Burning vs No burning of sugar cane research

Reference	Focus of the Analysis	Location	Key Findings
Eduardo Barretto de Figueiredo*,	Greenhouse gas emission associated	Brazil	The results of this study suggest that the most important reduction in greenhouse gas emissions from

[11] See project Environmental and social management Plan for more details

	with sugar production in southern Brazil		sugarcane areas could be achieved by switching to a green harvest system, that is, to harvesting without burning.
Shaochun Ma et al (2013)	Sugarcane Harvesting System: a Critical Overview	Kansas City, Missouri	The elimination of burning practices before sugarcane harvest has been and will led to more sustainable harvesting systems, green cane harvesting, which has lower impact on nearby communities and environment.
Bordonal et al. (2013)	GHG emission reductions due to the change from burned harvest to green harvest	São Paulo (Brazil)	Suggests that green harvest with crop rotation and reduced tillage could result in a mitigation potential of 70.9 Mt CO2eq up to 2050
Bordonal et al. (2013)132	GHG emission reductions due to the change from burned harvest to green harvest and changes in management practices	Southern Brazil	Suggests that changes to management practices (green harvest, tillage, crop rotation strategies) can contribute considerably to achieving Brazil's GHG reduction goals
Tiago Santos Telles (2012)	Effects of sugarcane harvesting with burning on the chemical and microbiological properties of the soil	Brazil	Soil chemical fertility under the sugarcane without burning was better than under sugarcane with burn.
Roundtable on Sustainable Biomaterials (RSB) and the South African Canegrowers Association (SA Canegrowers),	The viability of South African sugarcane ethanol as feedstock for sustainable aviation fuel production	South Africa	The hypothetical dryland green cane harvesting scenario shows that by avoiding burning through green cane harvesting, total GHG emissions can be reduced by 8.2 g CO2 / kg cane wet (19%) when compared to current preharvest burning practices.
Wilaiwan Sornpoon et al	Estimation of Emissions from Sugarcane Field Burning in Thailand Using Bottom-Up Country-Specific Activity Data	Thailand	This study showed that green cane harvesting reduced GHG emissions in Thailand but it is highly recommended that sugarcane producing countries conduct field surveys to collect these country-specific data

A number of studies have been done to compare the GHG impact of mechanical green cane harvesting when compared to the conventional burn, hand cut and windrow, grab load harvesting system.

The table and graph below show 7 scenarios as that were used in a model based on conditions in South Brazil. As can be seen in the graph, no burn mechanical harvesting has less impact on GHG emissions compared to burning and mechanical cutting

Table 3: Mechanical Harvesting study outputs

Scenario	1	2	3	4	5	6	7
Pre-Harvesting	Burned	Green Cane	Green Cane	Burn	Green Cane	Green Cane	Green Cane
Harvesting Method	Manual	Manual	Manual	Mechanized	Mechanized	Mechanized	Mechanized
Trash recovery	No	No	Baling System	No	No	Baling System	Integral Harvesting System

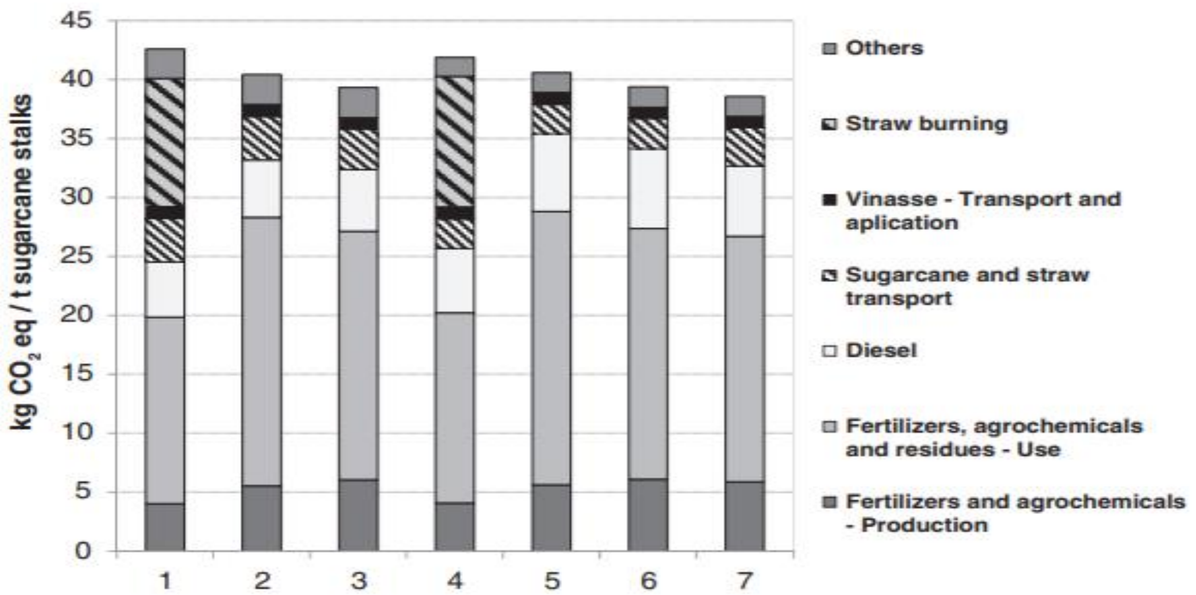

Figure 8: CO2 emissions for sugarcane production

The table below lists studies some of the research that has been done on comparing the impact of Mechanical harvesting compared to Hand harvesting on GHG emissions

Table 4: Impact of Mechanical Harvesting vs Manual Harvest

Reference	Focus of the Analysis	Location	Key Findings
Terezinha F. Cardoso,	Economic, environmental, and social impacts of different sugarcane production systems	Brazil	Study confirmed that mechanized - no- burn scenarios presented the best sustainability performances. However, the result could vary depending on local conditions
ELLA Brief Policy	From manual to Mechanical harvesting: Reducing environmental	Brazil	Mechanisation of sugarcane harvesting in Brazil has been shown to decrease environmental impacts

	impact and increasing cogeneration potential		and waste, while also increasing efficiency,
James T. L. K. Y. Kong-Win Chang	Comparative energy and greenhouse gas analysis between small- and large-scale sugarcane production In Mauritius	Mauritius	On a per hectare basis, mechanical fertilization, electricity-driven irrigation through center pivot and mechanical loading consumes less energy input and release less GHG emissions than manually conducting these operations. Full mechanization of operations is strongly advised whenever possible. In the case of small-scale cultivation where mechanical operations are not attractive due to practical and economical constraints, regrouping adjacent small plots to form large fields are strongly encouraged

It is very clear from the many studies looked that the future of sugarcane harvesting is in green cane mechanical harvesting. This method of harvesting has the benefit of not only reducing GHG emissions, but also improve efficiencies, improving soil health and reducing the risk of injury to cane cutters health.

1.11.3 Improved soil health

Climate Rationale for the activity

Soils are composed of mineral and organic materials. The mineralogy of the soil comes basically from the parent material of the soil. In the case of the soils in the northern sugar belt, these are characteristic of a calcitic formation with heavy clay and low organic matter percentages and hence a high water-holding capacity during the rainy season and less so when evapotranspiration exceeds rainfall during the dry summer months in Belize. The organic components of the soil naturally come from the vegetative and macro and micro biotic organisms including dead animals as they decompose. In soils under sugarcane crop production this organic material component principally is derived from harvest residue from the sugarcane crop.

The nutrients that are naturally derived from a soil come from both the soil minerals and from the organic components of the soil. As the organic component decompose by means of the micro and macro biology within the soil, a very important source of nutrient is released and becomes available to the plant. The soil organic matter also plays a key role in the cation exchange capacity of the soil. That is, the capacity of the soil to hold or release nutrients applied to the soil through fertilization or that derived from decaying or decomposing organisms and organic matter including the sugarcane trash left in the field after harvest. The soil organic matter also plays a key role in conserving moisture within the soil. Moisture is necessary for the decomposition process of organic material and for the movement of mineral elements in the plant; more so, moisture is important for the lifeform survival within and hence the biological health of the soil that is being negatively affected by current agricultural practices in tandem with negative climate change effects.

With the very practice of annual burning during sugarcane harvest, the soil continues to lose its organic matter component. With burning coupled with increases in heat index due to climate change within the sugarcane producing areas, a majority of the micro- and macro-biology from within the root rhizosphere or root zone are being lost. The natural biology, which takes time to repopulate upon burning, are responsible for naturally converting organic material, through decomposition, to soil organic matter, which is reflected as percent organic matter (i.e., %OM) in soil chemical analysis. The need to increase soil organic matter through organic material amendments and micro-biology augmentation by means of biofertilizer (i.e. beneficial organisms) applications after burning or after green cane harvesting will allow for the conservation of soil moisture and nutrient lost, which is very important for the management and improvement of soil health and fertility under the current "burn to harvest system" and to avert the negative effect of Climate Change that is causing, 1) continual nutrient lost through leaching during the rainy season and evaporation during the hot and dry season and, 2) soil biological lost due to heat exposure and irrational chemical application in the current northern sugarcane production system.

Technical evaluation of the proposed use of beneficial microbials to improve soil health

The use of both chemical fertilizers and organic amendments in the form of biological fertilizers and green covers (i.e. green cane residue and cover crops) in an Integrated Nutrient Management (INM) approach are suitable combinations complementing each other to improve and or sustain soil health and fertility. The Food and Agriculture Organization (FAO) have concluded that the synergistic effect of optimizing chemical fertilizer input use and maximize production while sustaining the same without impairing soil health, crop quality or any other environmental aspects in the long run is certainly a plus to the INM[12]. With this in mind, the following actions are recommended to improve soil health and fertility as a response to climate change.

Application of biofertilizers (i.e. beneficial microbes):

- Use of decomposing microbes to transform organic green material to soil organic matter.
- Use of nitrogen fixing microbes to increase transformation of elemental nitrogen from the air in order to increase natural soil nitrogen fertility hence the possible reduction of chemical fertilizer use.
- Mechanical and/or manual application of microbes at cane seed planting and ratooning and over green cane trash left in the fields after harvesting.
- Dosage dependent on microbial formulations used.

Application of Organic Fertilizers (Vinasse/Organic Acids):

- Vinasse and or Organic acids to be applied in absence of composting material.

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[12] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/integrated-plant-nutrient-management/ipnm-what/en/

- Application of Vinasse and or Organic acids should be done simultaneously or in combination with beneficial microbes
- Mechanical and/or manual application of microbes at cane seed planting and ratooning and over green cane trash left in the fields after harvesting.
- Dosage is dependent on quantity available.

The use of microbial technology to increase decomposition and allow for the increase in soil organic matter is important to reduce the effect of the current negative impact of Climate Change under sugarcane production in Belize. Beneficial microbes are important for the accelerated decomposition of organic material that is needed to improve soil organic matter percentage that is lost due to negative climate impact on the soil. As the soil organic matter increases and the bio-renovation capacity of the soil improves, the soil's ability to withstand negative changes in climatic conditions will improve.

Decomposition of celulitic/organic material such as sugarcane trash have been studied in many areas and it has been found that initial microbial decomposers are fungus such as *Trichoderma sp., Fusarium sp*. and *Aspergillum sp.;* while proteins and starch within such materials are decomposed mainly by *Bacillus sp*.; hemicellulose are attacked by Actinomycetes such as Streptomyces sp. (Arevalo, 2002) and (Bonilla, 1996) and yeast such as *Saccharomyces sp.* (Hsie et.al., 1984).

Sugarcane production requires a high level of nitrogen (N); extraction of 100 tons of sugarcane can remove up to 105kg of nitrogen of which 60kg represents removal from the stalk alone (Quintero, 1999). Importantly however, there are 79% elemental nitrogen in the air that the plant cannot extract on its own but through biological fixation of this nitrogen by means of microbes associated with the sugarcane plant, it can. Studies in Guatemala (Perez et. al., 1999) and South Africa (Purchase, 1980) respectively have shown that the sugarcane plant can capture up 20-60% of the Nitrogen required for optimal growth and fix 25kg N /ha/year through the biological fixation of nitrogen by means of the *Azosperillum sp* bacteria. Important to note as well is that *Azosperillum sp* in combination with organic fertilizers can allow for up to 50% mineral nitrogen application reduction (Toledo, 1997).

It is also known that vinasse, a by-product of rum distillery from molasses, can cause to increase natural microorganisms within the soils (Cholozzi-Filha, et. al., 1996). Vinasse contains high level of sugars, resins, organic acids and amino acids (Menezes, 1990) and high levels of potassium (K) at 41kg/m^3 in vinasse having 55% soluble solids (Quintero, 2003). Additionally, vinasse serves well in decomposing organic waste material to make compost while it also aids in solubilizing nutritional elements in the soils due to its direct effect on increasing microbial population within.

The addition of organic materials along with necessary decomposing microbes and nitrogen fixing bacteria are a necessary combination to improve the soils' health and fertility of the Northern Region Sugarcane Industry. A healthy soil will allow for improve water efficiency use and conservation while increasing the sugarcane plant's ability to efficiently use the nutrient employed through fertilization or that which is naturally available in the soil. A healthy soil hence is better able to withstand the negative effects of climate change currently being experienced in the sugarcane industry.

The use of microorganisms as biofertilizers has demonstrated beneficial effects on plant growth and is an alternative to chemical fertilizers (Busato, J et. al., 2005). The incorporation of biofertilizers (i.e. beneficial micro-organisms) in the production of sugarcane have had very positive results in crop production in Latin America although limited peered review information exists in the literature on use in commercial sugarcane production. Information available however shows that beneficial microorganism plays a key role in the rate of organic material decomposition hence their use to increase green material decomposition after green cane harvesting (Saucedo, S. 2009). Because of their capacity to convert unavailable and nutritionally important elements into available ones, beneficial microorganisms also play an important role in the efficient uptake of nutrients and as an alternative, they increase plant resistance to adverse environments (Narula, N et. al, 2000). Beneficial microbes are a factor in suppressing soil borne diseases, increase tillering and increase root growth, allowing for much needed moisture from the depths of the soil profile especially during the dry months. Incorporating beneficial microorganisms in the form of biofertilizers will then indirectly improve the soils' moisture holding ability as the beneficial microbe contribute to the increase soil organic matter percentage needed through the sequestration of carbon within these sugarcane producing soils while helping to reduce chemical fertilizer inputs overtime.

How are effective microbes going to allow for carbon sequestration and soil health?

Carbon sequestration is a process where atmospheric carbon is removed from the air and stored in the soil carbon pool; in this case, as soil organic matter, which is reflected as soil organic matter percentage within soil analysis done on soil samples taken from within the fields. Under this process, the plant (i.e. sugarcane) captures carbon from the air, uses it as the building block of its cells for growth and as well, the plant also interchange this carbon through its root system in the form of sugars for use by soil microbes, which then supplies the plant with the nutrients it needs to grow. As the microbes die, organic carbon assimilated becomes a part of the soil carbon pool or in other words, the carbon from the air becomes sequestered in the soil carbon pool.

So, how else does beneficial microbes allow for carbon sequestration and a healthy soil? Beneficial microbes are the basic form of life in the soil and their presence signifies a soil that is alive and functioning. Beneficial microbes are responsible for the decomposition of the green organic materials that remain after green cane harvesting in the field. Saucedo S. in 2009 has shown that the carbon/nitrogen ratio of decomposed green trash in sugarcane fields was significantly different in value where the combination of Effective Microbes has been applied on green cane trash (C/N = 34) compared to the control (C/N = 41.6) where no beneficial microbes were added. This he concluded was a positive effect of the biotransformation of the green harvest trash by the beneficial microbes. This in essence is the sequestration of the carbon used in the building block of the cell for growth of the sugarcane that has been bio-transformed by the beneficial microbes to carbon now assimilated within the soil carbon pool.

There are many factors that contribute to the determination of a soil being healthy. For the purpose of this sugarcane project, improvement in soil health should be considered where the biotransformation of green trash is improving in time and where the soil organic matter percent increases over time. Both of these indicators are factors of atmospheric carbon being sequestered within the soil carbon pool and importantly a factor of microbial bio-renovation of the soils on which sugarcane is being grown.

What impacts are expected in sugarcane upon use of these microbes?

Beneficial microbes being proposed for use in sugarcane production in this project are those that are able to take advantage of the available green cane harvest residues along with those that will bring nutritional support for the biotransformation and nitrogen fixation in order to improve the physical, chemical and microbiology of the soil.

Some of the expected results upon the use of these effective microbes would be

- Efficient time reduction of green cane trash in the field by 100% compare to non-use (i.e. from 8-12 months to 4-5 months).
- Increase in soil organic matter percentage by projects end.
- Reduction in the use of chemical fertilizers by those farms that are currently using the optimal amount of fertilizer nutrients needed for commercial sugarcane production.
- Increase tillering and germination of the sugarcane plant from both plant cane seeds and ratooning stubs.
- Increase root growth and root health (i.e. less disease presence),
- Reduction in abiotic stress (i.e. water stress during summer and insect pest pressures)
- Improve soil workability in time (i.e. machinery efficiency in preparing the soil due to less compaction)
- Increase in per acre production
- Increase sugarcane quality (i.e. increase brix & pol)

In Colombia, with the incorporation of effective microbes and vinasse in commercial sugarcane production during observation from 2001 through 2007, the production of sugarcane measured in Tons of Cane per Hectare per Month (TCHM) have maintained above 10 TCHM compared to production being less than 10 TCHM on the same farm from 1995-2000 with the same plant cane since 1995 (Saucedo, S. 2009).

In Belize in 2014, adding Effective Microorganism (EM) and humic acid in commercial sugarcane production have concluded observed production increased by 10 tons per acre (Quiroz, L. et. al., 2014).

How much less inorganic fertilizer do we think we will need in a healthy soil?

Sugarcane production requires a high level of nitrogen (N); extraction of 100 tons of sugarcane can remove up to 105Kg of nitrogen of which 60kg represents removal from the stalk alone (Quintero, 1999). Importantly however, there are 79% elemental nitrogen in the air that the plant cannot extract on its own but through biological fixation of this nitrogen by means of microbes associated with the sugarcane plant, it can. Studies in Guatemala (Perez et. al., 1999) and South Africa (Purchase, 1980) respectively have shown that the sugarcane plant can capture up 20-60% of the Nitrogen required for optimal growth and fix 25kg N /ha/year through the biological fixation of nitrogen by means of the *Azosperillum sp* bacteria. Important to note as well is that *Azosperillum sp* in combination with organic fertilizers can allow for up to 50% mineral nitrogen application reduction (Toledo, 1997).

It is also known that vinasse contains high level of sugars, resins, organic acids and amino acids (Menezes, 1990) and high levels of potassium (K) at 41kg/m^3 in vinasse having 55% soluble solids (Quintero, 2003). Additionally, vinasse serves well in decomposing organic waste material to make compost while it also aids in solubilizing nutritional elements in the soils due to its direct effect on increasing microbial population.

With the information presented above and from experience in commercial production of sugarcane using effective microbes, along with nitrogen fixing bacteria and organic matter bio-transforming bacteria in Colombia, very positive results have been obtained in reducing synthetic nitrogen fertilizers while ensuring that such was not at the cost of production reduction. Saucedo S. in 2009 concluded that with the addition of beneficial microbes including diazotrophic or nitrogen fixing bacteria in sugarcane production, nitrogen synthetic fertilizer use can be reduced by 30%.

In Colombia, with the incorporation of effective microbes in commercial sugarcane production during observation from 2001 through 2007, the production of sugarcane measured in Tons of Cane per Hectare per Month (TCHM) have maintained above 10 TCHM compared to production being less than 10 TCHM on the same farm from 1995-2000 with the same plant cane since 1995.

Based on the above assessment it is clear to see the following:

1. That there is a clear climate impact on the soils in northern Belize which will be exacerbated through climate change.
2. That the improvement of soil health through the use of beneficial microbials coupled with the lack of burning and the move to green cane harvesting will have a significant positive impact on productivity and will be a foundation element in the move towards a more climate smart farming system.
3. A healthier soil will need less inorganic fertilizer to achieve the same crop yield.
4. A healthier soil will increase the carbon sequestration of the crop residue.

1.12 Component 2: Moisture management

The biggest impact that climate change will have on sugar cane yield and productivity will be as a result of changing and erratic rainfall patterns with subsequent moisture stress or flooding inhibiting plant growth and production. This will require the increasing use of irrigation and drainage to mitigate this impact. Irrigation and drainage as tools to modify the growing environment in sugarcane are technologies that are used all over the world.

A full technical evaluation of the suitability of irrigation and drainage was undertaken in the baseline assessment for this project.

Key findings from this evaluation which have relevance for the feasibility study includes the following:

1. Under current rainfall conditions, there are four months of the year when current rainfall does not meet crop water demand.
2. This will increase under all climate change scenarios.
3. Current rainfed climatic yield potential ranges from 39 tons/acre to 47.5 tons/acre depending on soil type.
4. The climatic yield potential under irrigation ranges from 61.8 tons/acre to 63.3 tons/acre depending on soil type.

5. This gap will increase under changing rainfall patterns.
6. Currently supplementary irrigation is required but this may change as the impact of climate change takes place.
7. N-Drip, drip irrigation is the best irrigation delivery solution.

As part of the feasibility assessment, a test site was identified in the Corozal district. This site was selected based on the following criteria:

1. Size of block
2. Relatively flat
3. Distance to water source
4. Suitable soils

Based on this, a detailed irrigation was undertaken and costed[13] for inclusion in the feasibility assessment.

[13] See Financial Feasibility Model for irrigation costing

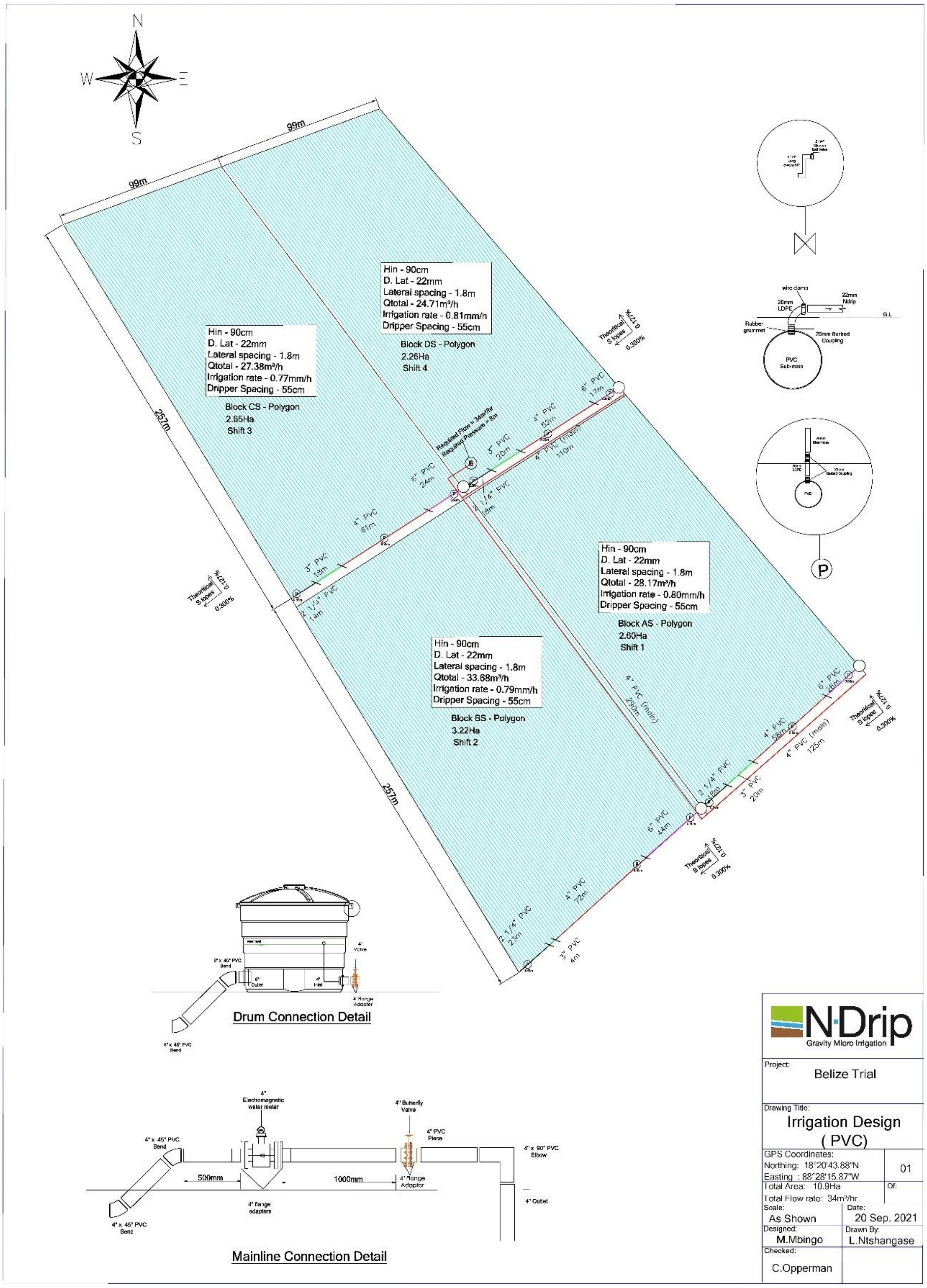

Figure 9: Detailed N-Drip irrigation design for identified location

Financial and Economic assessment of project activities

1.13 Financial assessment

The financial assessment is used to show the current financial state of the farmers and establish the direct financial impact that the project will have on their farming operations and to show the return on investment that the project funds will have the project is successful in its application.

The financial assessment has been developed using a combination of industry experience, desktop research and industry data that was collected through a series of stakeholder engagements. The financial assessment's foundations are based on the assumptions that have been established through the data collection process and ultimately informs the financial model. These assumptions are key to ensure the accuracy and validity of the model. Furthermore, a process of stakeholder engagements and data validation workshops were used to ensure the industry is comfortable that the assumptions used provide a satisfactory indication of the conditions on the ground. It is also important to note that a financial model aims to provide a wide range of scenarios, since no farmer is the same.

The financial model builds out a number of scenarios starting with the Business and Usual (BaU) cases. These cases provide an indication of a typical sugarcane farm in Northern Belize. Based on the engagements, it was identified that there is a stark difference between the current practises of the farmers and the best practises. The variance in practice is a result of a risk mitigation measure that the farmers have installed as a result of low yields and highly volatile sugar prices. As a result, the farmers have reduced their inputs by 50%. This scenario paints a dire picture.

The best practices scenario shows that the farmers are not providing their soils and sugarcane the opportunity to be sustainable and produce high yields. It is also clear from the cashflow models that the farmers are reducing their inputs to ensure they continue earning a higher income to support their livelihoods, however, this is not sustainable and will lead to a continuous reduction in yield and income.

Table 5: Production Costs per Acre in USD, Yield and Profit and Loss for Current Practices and Recommended Practices

Cost	Current Actual	Recommended Current
Land Prep & Planting	$431,67	$466,67
Ratoon Management	$157,50	$208,58
Harvesting and Haulage	$179,07	$282,03
Average Yield (LT/acre)	13	20
Average P/L per acre	$116,27	$87,03

Climate change has already affected the sugarcane farmers in Northern Belize, however it is difficult to model the exact impact that the climate will have on the farmers in the future as there are a number of variables involved. To give an indication of the impact of climate change on yield and revenue, we have used the IPCC (SSP) climate models to predict the potential impact the temperature and rainfall will have on the sugarcane yields and potential income of the farmers. The three IPCC (SSP) climate models used, provide an indication of potential low, medium and high impact climate scenarios and their resulting impact on the sugarcane yields and revenues.

Using the climate models as a basis for temperature and rainfall to estimate potential sugar cane yields and working off the current scenario for the potential impact that climate might have on sugarcane, the climate financial model is able to depict the potential impacts on the farmers as a result of climate change.[14]

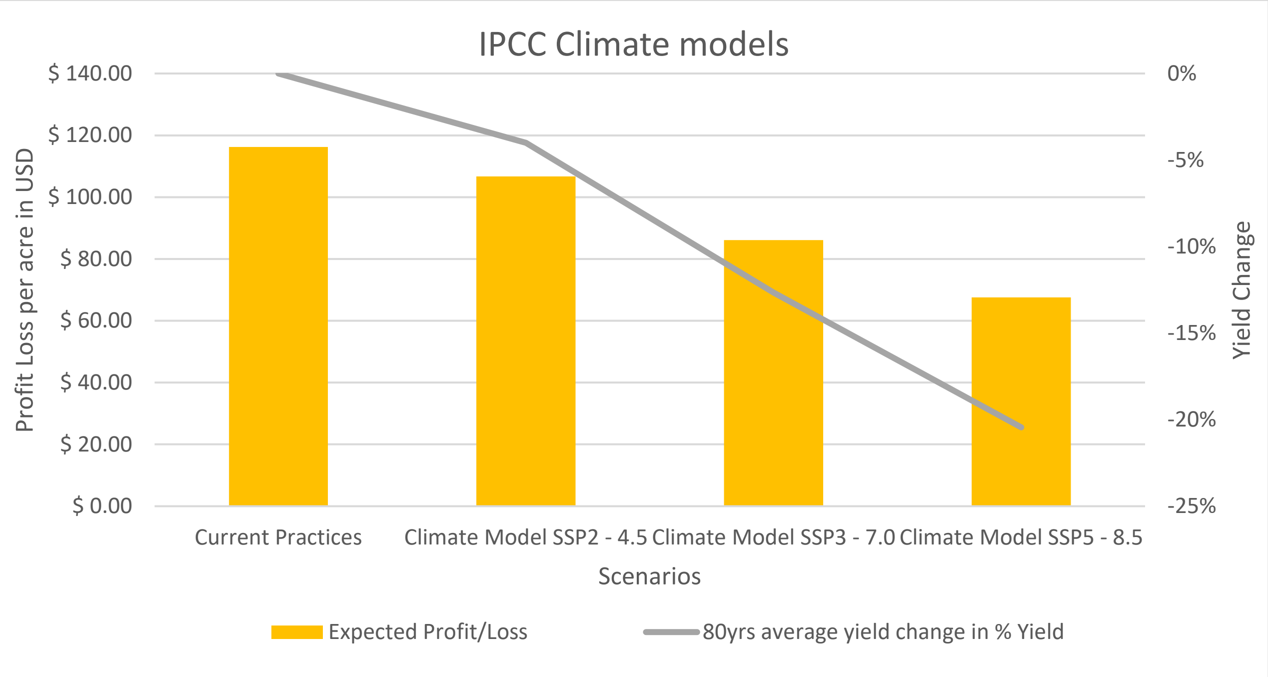

Figure 10: Current Practices scenario continued with varying climate scenarios

Based on this it is clear that without any project intervention, even under the best climate change scenario, the sugar industry will be largely impacted[15]. Therefore, the project's

[14] Note that this is the outcome if no action is taken, and all the other conditions and inputs remain the same

[15] Note that although the best case only shows a 5% reduction in yield, this reduction will be largely carried by the smallest and most vulnerable farmers.

interventions will be extremely important to help the industry adapt against the impacts of climate change and ensure the industry becomes more resilient.

The financial model looks at the impact of the various components and activities that the project design has developed. Activities from components 1 and 2 have direct impacts on the yields, and therefore the profit per acre, and have been modelled to determine the Internal Rate of Return (IRR)on those components.

Table 6: Production Costs in USD per Acre, Yield and Profit and Loss for Current Practices, Component 1, Component 2 and for Full Project Implementation

Cost	**Current Actual**	**Component 1**	**Component 2**	**Full Project Implementation**[16]
Land Prep & Planting	$431,67	$808,86	$471,62	$438,71
Ratoon Management	$157,50	$290,74	$413,91	$413,91
Harvesting and Haulage	$179,07	$298,45	$407,38	$428,97
Average Yield (LT/acre)	13	24	28	33
Average P/L per acre	$116,27	$108,39	$131,58	$218,65

Based on the assumptions made for the current practices and the various component activities that make up the full project implementation, IRR's have been developed over a 10-year period. The following three tables show cashflow predictions that has been used to calculate cashflows for Component 1 and 2 and for the Full Project Implementation scenario.

Table 7: Cashflows for Component 1 in USD

Component 1										
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
Total Costs	$3,730.13	$1,940.36	$1,886.81	$1,837.01	$1,790.70	$1,231.23	$1,191.18	$1,153.92	$1,119.28	$1,096.26
Grant Costs	$284.56	$284.56	$284.56	$284.56	$284.56	$0.00	$0.00	$0.00	$0.00	$0.00
Partner Costs	$231.83	$231.83	$231.83	$231.83	$231.83	$0.00	$0.00	$0.00	$0.00	$0.00
Farmer Costs	$3,213.74	$1,423.97	$1,370.42	$1,320.62	$1,274.31	$1,231.23	$1,191.18	$1,153.92	$1,119.28	$1,096.26
Revenue	$607.17	$2,400.00	$2,040.00	$1,897.20	$1,764.40	$1,640.89	$1,526.03	$1,419.20	$1,319.86	$1,227.47
Cashflow	-$3,122.96	$459.64	$153.19	$60.19	-$26.30	$409.65	$334.85	$265.28	$200.58	$131.21

[16] The Full Project implementation include the GCF grant funding component and therefore only depicts the cost to the farmers

Table 8: Cashflows for Component 2 in USD

Component 2										
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
Total Costs	$2,859.34	$1,731.82	$1,658.73	$1,590.75	$1,527.53	$1,387.21	$1,332.53	$1,281.68	$1,234.39	$1,202.97
Grant Costs	$81.39	$81.39	$81.39	$81.39	$81.39	$0.00	$0.00	$0.00	$0.00	$0.00
Partner Costs	$0.14	$0.14	$0.14	$0.14	$0.14	$0.00	$0.00	$0.00	$0.00	$0.00
Farmer Costs	$2,777.82	$1,650.30	$1,577.20	$1,509.22	$1,446.00	$1,387.21	$1,332.53	$1,281.68	$1,234.39	$1,202.97
Revenue	$2,464.00	$2,912.00	$2,475.20	$2,301.94	$2,140.80	$1,990.94	$1,851.58	$1,721.97	$1,601.43	$1,489.33
Cashflow	-$395.34	$1,180.18	$816.47	$711.19	$613.27	$603.74	$519.05	$440.29	$367.04	$286.36

Table 9: Cashflows for Full Project Implementation in USD

Full Project Implementation										
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
Total Costs	$4,265.17	$2,426.37	$2,349.40	$2,277.82	$2,211.25	$1,583.60	$1,526.03	$1,472.48	$1,422.68	$1,389.60
Grant Costs	$442.71	$442.71	$442.71	$442.71	$442.71	$0.00	$0.00	$0.00	$0.00	$0.00
Partner Costs	$233.52	$233.52	$233.52	$233.52	$233.52	$0.00	$0.00	$0.00	$0.00	$0.00
Farmer Costs	$3,588.94	$1,750.13	$1,673.17	$1,601.58	$1,535.01	$1,583.60	$1,526.03	$1,472.48	$1,422.68	$1,389.60
Revenue	$2,732.80	$3,449.60	$2,932.16	$2,726.91	$2,536.03	$2,358.50	$2,193.41	$2,039.87	$1,897.08	$1,764.28
Cashflow	-$1,532.37	$1,023.23	$582.76	$449.09	$324.78	$774.90	$667.38	$567.39	$474.40	$374.68

Using the above cashflows, Internal Rates of Returns are calculated to determine the effectiveness of the investments. Investments that have IRR's below 10% in emerging markets are often too risky and often do not have the necessary socio-economic benefit to warrant the risk. The project's various IRR's are as shown in the table below.

Table 10: Component 1 & 2 and Full Project Implementation IRR for a 10 Year Investment

	Component 1	**Component 2**	**Full Project Implementation**[17]

[17] The Full Project implementation include the GCF grant funding component and therefore only depicts the cost to the farmers

IRR – 10 yrs	-8%	271%	409%

The project intervention shows a clear return on investment which shows that the level of investment that the GCF will incur, is both viable and sustainable moving forward. However, due to the status of farming operations and the state of both the soils and the existing sugarcane stools, farmers have generally not been able to fund and implement the activities that the project is proposing themselves.

Climate change will therefore have an increasing detrimental impact on sugarcane production as a result of the practices of famers, as is currently being seen between the current scenario and best practices scenario. It is therefore expected that yields will decline as a result of aging cane stools, increasing pests and increased variability of rainfall, resulting in further reduction of inputs by farmers due to reduced income and cashflow constraints.

If we assume that farmers do not change their practices or behaviour, then together with expected increase in the spread of Pests & Diseases (P&Ds), we could expect climate change to potentially destroy the entire industry within 20-40 years (See red lines in Figure 11: Yield impact from climate change (Theoretical and Actual) vs GCF Implementation).

It is also important to note that within Figure 6, the GCF Implementation impacts are shown with a varying impact. This variability within the yield impact is to show the impact of the industry continuously adapting and re-investing to the industry. For example, at this stage as a result of the climatic conditions, supplementary irrigation is required during the occasional dry months to ensure the sugarcane is not under moisture stress. If however, in 30 years' time when the rainfall variability has increased and full irrigation is required, farmers do not investment in full irrigation technologies, the sugar cane yields could see a drop in production once again.

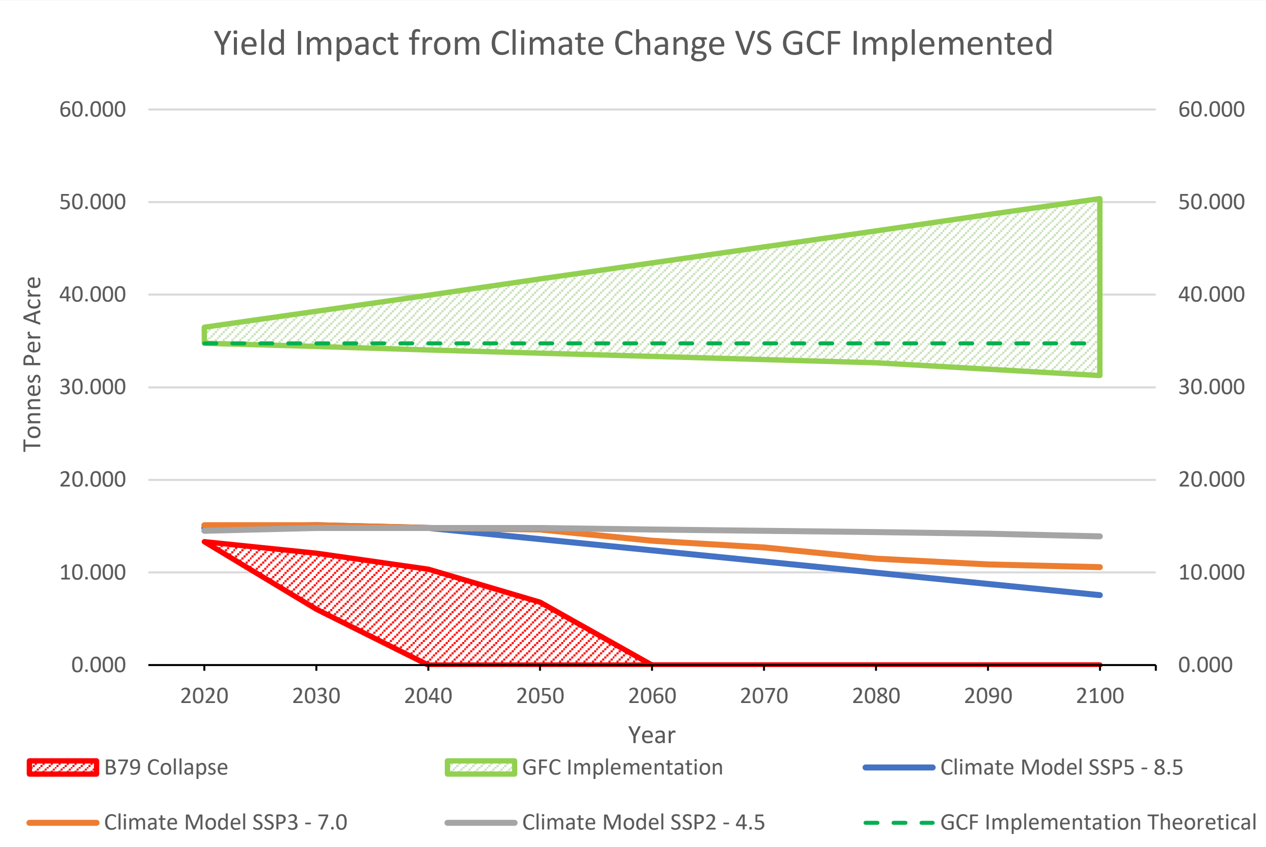

Figure 11: Yield impact from climate change (Theoretical and Actual) vs GCF Implementation

Throughout the project design, systems development has been considered to ensure that industry stakeholders are able to continuously improve and reinvest where necessary to ensure the industry can achieve the upside that climate change has to offer.

1.14 Economic assessment

1.14.1 GHG calculations

The project is implementing adaptive activities that helps improve the resilience of the farmers. Each of the adaptative activities have an effect on the amount of carbon emitted per acre, either positively or negatively.

In general, as suggested by the environmental impact assessment, the project and its activities have a low environmental impact. For each adaptative activity the carbon emissions per acre per year was identified and multiplied across the project area (10 000 acres) to determine the total impact that the project will have. These adaptative activities and their impacts on the carbon emissions are seen below:

Table 11: CO2 emissions reduction and increase as a result of project activities

Activity	Description	CO_2e
Component 1		

Green Cane Mechanical Harvesting	Green cane mechanical harvesting has a range of effects on the carbon emission contributions relative to the BaU case. These include: increased emissions due to the mechanical harvester, Increased emissions due to the increased weight of haulage, Carbon off-set of not burning the sugarcane.	26,017 Tonnes CO_2e sequestered
Minimum Tillage	Currently the farmers are using heavy tillage which upsets the soil composition. Minimum tillage will reduce the CO2e and help the soil act as a carbon sink.	8,270 Tonnes CO_2e sequestered
Reduced Fertilizer	By reducing the tillage and increasing soil health measures, the soil will over time become healthier, required less fertilizer.	6,256 Tonnes CO_2e sequestered
Additional Trash for Bioenergy[18]	Due to green cane harvesting, the additional trash can be used to fuel the bioenergy plant to produce electricity.	2,490 Tonne CO_2e sequestered from electricity production
Component 2		
Irrigation	Supplementary irrigation is required to minimize the moisture stress. Irrigation requires electricity to pump the water from reservoirs to the nozzles and onto the field. The system suggested is a low pressure system that will use a solar pump.	0 CO_2e

As a result of the project interventions, a total of 50 571 Tonnes of CO_2e will be sequestered per year on the 10 000 acres of project affected land.

1.14.2 Social Cost of Carbon

Determining the economic cost of carbon helps project assessors and climate specialists to understand the direct climatic impact that the project will have. To do this, the social cost of carbon determined which is directly linked to the GHG emissions that are either emitted additionally, or sequestered, because of project interventions.

The social cost of carbon is developed by taking into account the measurable impacts that climate change has on economic outcomes, including agriculture productivity, damages caused by sea level rise, and decline in human health and labour productivity. By taking all

[18] Note that additional investment will be required to unlock this carbon saving since the bioenergy plant is at capacity

these components into account, scientists and economists have come up with a range of costs per tonne of carbon emitted from US$51 – US$202[19].

Taking project duration, total area of impact and the economic cost of a tonne carbon emitted, a sensitivity table has been developed to describe the potential economic cost, or in this case saving, that the project will have. Based on the calculations, the following was found:

Table 12: Economic impact of project interventions on project and total area for 5 and 50 years

	US$51,00		**US$202,00**	
Total Economic savings	**70,000 Acres**	**10,000 Acres**	**70,000 Acres**	**10,000 Acres**
Project Implementation lifetime (5yrs)	$90 922 323,66	$12 895 685,58	$360 123 713,34	$51 077 029,16
Project Full lifetime (50yrs)	$909 223 236,64	$128 956 855,81	$3 601 237 133,37	$510 770 291,62

1.15 Co-Funding requirements and commitments

Within the GCF guidance documents, it has been specified that there is no minimum amount of Co-financing required for a Funded Activity, and no specific sources of Co-financing that must be complied with. It is suggested that whenever possible, Funded Activities should seek to incorporate appropriate levels of Co-financing to maximize the impact of GCF Proceeds. Bearing in mind that while desirable to demonstrate alignment of interests between the GCF and AEs, and country ownership by developing countries, Co-financing may not always be achievable or realistic.

While maximizing Co-financing is desirable, GCF will avoid using Co-financing metrics as stand-alone targets since maximizing climate mitigation and adaptation results does not necessarily equate with minimizing or optimizing spending on climate mitigation and adaptation. Co-financing ratios as well as expected levels of Mobilized Private Finance or Leveraged Private Finance should therefore not become stand-alone targets, as this may disincentivize GCF from financing projects/programmes with strong impact potential and high paradigm shift potential.

In the case of this project, during the design of the project and the various stakeholder engagements, it was made clear that co-funding would be required, but that the co-funding component would represent no additionality cost. This means that the project would only expect the farmers (and industry) to continue doing what they are already doing, or in some cases what they should be doing.

The commitment from industry stakeholder was therefore used as a measure to ensure a more sustainable outcome.

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[19] https://iopscience.iop.org/article/10.1088/1748-9326/ac1d0b#erlac1d0bbib14

The financial and economic feasibility are both key tools to help identify areas where co-funding is required, the level of co-funding that is required (% of total cost) and the total financial value that will be required. Therefore, for each funding activity a rational was developed to guide the level of GCF funding based on the additionality of that activity.

The specific implementation-based activities that will result in on-the-ground development, which has been modelled out in the financial feasibility model to determine the number of areas that can be impacted by the project, has been defined below:

Table 13: Additionality acreage impact and level of funding and co-funding requirements in USD

Additionality Activities	Cost per acre	Number of acres	% Grant Intervention	Value of GCF Financial Support	% Co-Funding	Value of Co-Funding	Source of Co-Funding
Activity 1.4.1: Land Prep for mechanical harvesting	$60,00	10,000	100%	$600 000,00	0%	$0,00	-
Activity 1.2.3: Establish new cane nurseries	$1 681,97	294	100%	$494 498,05	0%	$0,00	-
Activity 1.3.5: Replant with different Varieties	$648,24	10,000	40%	$2 592 950,99	60%	$3 889 426,48	FA's (Self-funded, Bank Loans, FairTrade Levies)
Activity 1.4.3: Upscale green Harvesting Programme and associated delivery parameters	$360,00	2000	0%	$0,00	100%	$720 000,00	FA's (Self-funded, Bank Loans, FairTrade Levies)
Activity 1.6.1: Soil Health - Plant	$100,63	10000	100%	$1 006 250,00	0%	$0,00	FA's (Self-funded, Bank Loans, FairTrade Levies)
Activity 1.6.1: Soil Health - Ratoon (5yrs)	$437,50	4000	50%	$875 000,00	50%	$875 000,00	
Activity 2.2.2: Drainage	$17,50	1000	50%	$8 750,00	50%	$8 750,00	FA's (Self-funded, Bank Loans, FairTrade Levies)
Activity 2.2.2: Irrigation	$1 691,86	2000	50%	$1 691 862,58	50%	$1 691 862,58	FA's (Self-funded, Bank Loans, FairTrade Levies)

Activity 2.3.1: Integrated Pest Control (5yrs)	$165,00	4000	50%	$330 000,00	50%	$330 000,00	FA's (Self-funded, Bank Loans, FairTrade Levies)

In addition to the direct impact activities, several systems and system supports have been designed into the project to ensure the project's interventions remain sustainable. The activities that require direct intervention from the project to build or capacitate existing systems are as follows:

Table 14: Systems development funding support and co-funding in USD

Additionality Activities	Total cost	% Grant Intervention	Value of GCF Financial Support	% Co-Funding	Value of Co-Funding	Source of Co-Funding
Systems Development						
Activity 1.3.3: Establish digital marketplace for contractor to replant facilitated via technology-based solution(s) and systems	$27 000,00	100%	$27 000,00	0%	$0,00	-
Activity 3.3.1: Equip and use industry tools to distribute climate related data for good farmer decision making	$30 000,00	100%	$30 000,00	0%	$0,00	-
Activity 3.3.2: Integrate blockchain into industry tools	$300 000,00	100%	$300 000,00	0%	$0,00	SIRDI, BSI
Support Systems / Mechanisms						
Activity 1.5.1: Contractor Loan Guarantee Support	$1 500 000,00	0%	$0,00	100%	$1 500 000,00	DFC
Activity 3.5.1: Develop risk mitigation system for climate variability	$40 000,00	0%	$0,00	100%	$40 000,00	FA's, SIRDI

Furthermore, costs have been developed for each activity that requires training, the skills required to implement, manage, and monitor each activity, the project management unit (limited at 5% of total GCF funding) and the Accredited Entity costs (fixed at 8.5% of GCF funding). The full breakdown of costs per activity can be seen in the Project Budget.

The project is applying through the Simplified Application Process (SAP) and has been allocated a maximum total of $25 m. Based on the Project Budget, which is informed by the

Financial Feasibility Model, the project is expecting a total of **US$ 11 279 765 .00**[20] in co-funding from industry stakeholders.

The project requires written commitment from project beneficiaries and co-implementors to continue to fund activities that they should already be doing and in doing so, commit to the co-funding requirements of the project budget.

Project risk assessment and risk mitigation plan

Project risks have been discussed at every stage of the project design as a standard item on the design workshop agendas. A risk register has been maintained thought the process and where appropriate, project activities have been designed to mitigate these risks.

Those risks that cannot be mitigated by project activities have been transferred to the project risk assessment and mitigation plan which is attached as annex 7

Summary and conclusion

The sugar industry is one of most of the important industries in Belize directly or indirectly employing 15% of the country's population. The industry has faced a number of challenges in the last 10 years which has weakened it from a commercial and operational perspective. Realizing these threats, the industry has made a number of changes and investments which are beginning to make it more commercially viable. The impacts of climate change, especially on the productive node (farmers) of the value change is however making these recovery efforts more difficult to achieve. This impact, coupled with the need to recover the years of lost investment in the productive node means that some external support will be needed to help the farmers invest in the new technologies needed to build resilience to climate change.

The project has been designed in a participatory manned and has looked at the expected impacts of climate change on the sugar industry and designed a set of activities to address these impacts. The activities identified meet the GCF investment criteria of:

1. Local ownership
2. Paradigm shift
3. Additionality
4. Scalability

These criteria have been built in the design through the project organizational structure and strategy. Important in the project design is that while the GCF investment will only impact 10 000 acres of the industry directly, by setting up the systems and introducing new varieties into the industry the entire 75 000 acres of the industry will benefit.

[20] Co-funding identified as of 12/10/2021. Further Co-funding could come from Ripe.io, DFC, and the Government

Financially the GCF investment shows an IRR of 19%. This is an acceptable financial rate of return for an agricultural investment such as this. The project also shows a positive economic rate of return with carbon dioxide savings in a number of the proposed activities.

Annex 1: Seed Cane Data Sheets

1.16 Annex 1.1: BBz07015

1.17 Annex 1.2: BBz07144

1.18 Annex 1.3: BBZ07155

1.19 Annex 1.4: BBz08353

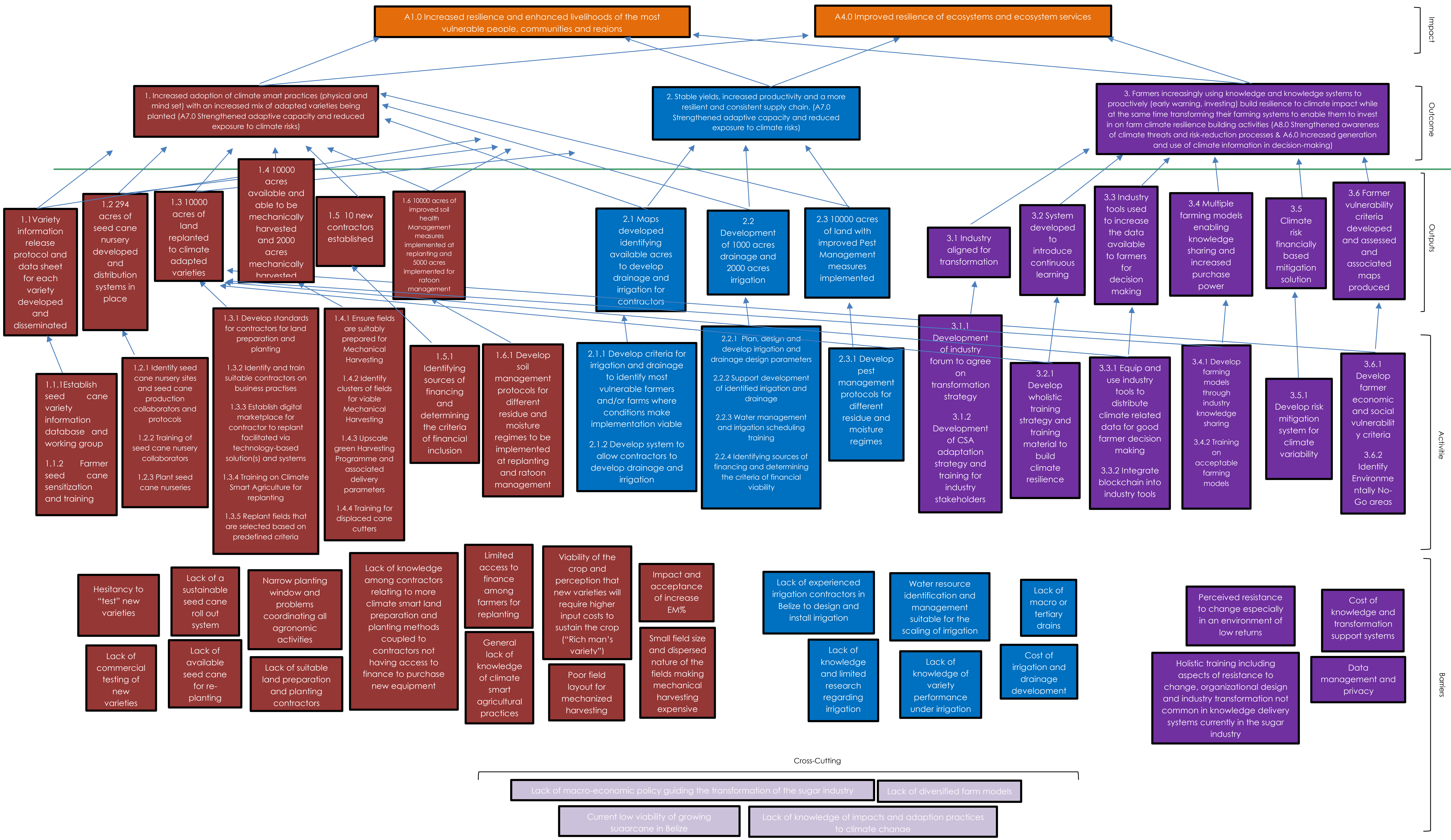
1.20 Annex 1.5: BBz09592

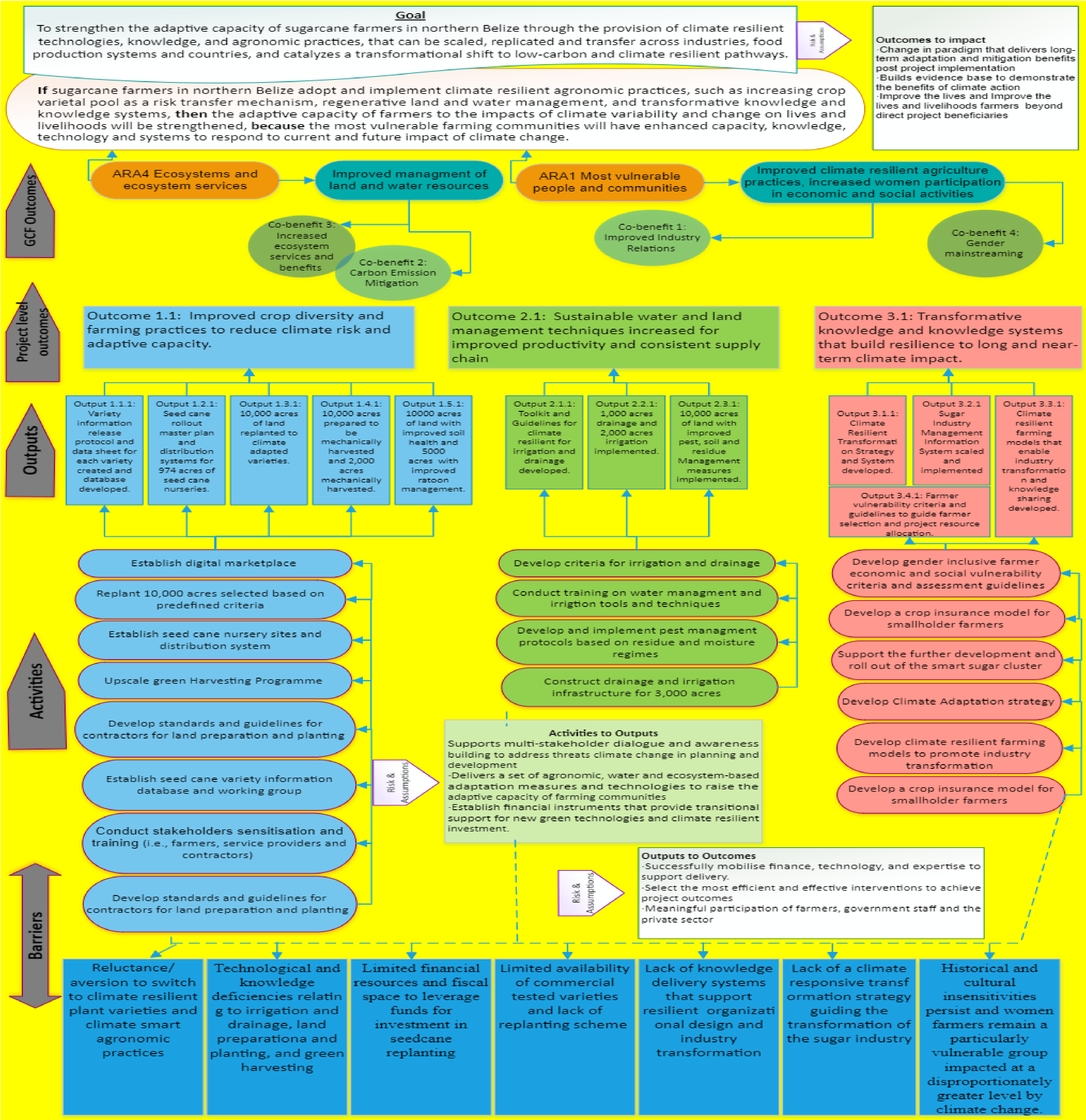
1.21 Annex 1.6: BBz09612

1.22 Annex 1.7: BBz09626

1.23 Annex 1.8: BBz081124

Annex 2: Theory of Change




Goal
To strengthen the adaptive capacity of sugarcane farmers in northern Belize through the provision of climate resilient technologies, knowledge, and agronomic practices, that can be scaled, replicated and transfer across industries, food production systems and countries, and catalyzes a transformational shift to low-carbon and climate resilient pathways.
Risk & Assumptions
Outcomes to impact
-Change in paradigm that delivers long-term adaptation and mitigation benefits post project implementation
-Builds evidence base to demonstrate the benefits of climate action
-Improve the lives and Improve the lives and livelihoods farmers beyond direct project beneficiaries
If sugarcane farmers in northern Belize adopt and implement climate resilient agronomic practices, such as increasing crop varietal pool as a risk transfer mechanism, regenerative land and water management, and transformative knowledge and knowledge systems, then the adaptive capacity of farmers to the impacts of climate variability and change on lives and livelihoods will be strengthened, because the most vulnerable farming communities will have enhanced capacity, knowledge, technology and systems to respond to current and future impact of climate change.
GCF Outcomes
ARA4 Ecosystems and ecosystem services
Improved managment of land and water resources
ARA1 Most vulnerable people and communities
Improved climate resilient agriculture practices, increased women participation in economic and social activities
Co-benefit 3: Increased ecosystem services and benefits
Co-benefit 2: Carbon Emission Mitigation
Co-benefit 1: Improved Industry Relations
Co-benefit 4: Gender mainstreaming
Project level outcomes
Outcome 1.1: Improved crop diversity and farming practices to reduce climate risk and adaptive capacity.
Outcome 2.1: Sustainable water and land management techniques increased for improved productivity and consistent supply chain
Outcome 3.1: Transformative knowledge and knowledge systems that build resilience to long and near-term climate impact.
Outputs
Output 1.1.1: Variety information release protocol and data sheet for each variety created and database developed.
Output 1.2.1: Seed cane rollout master plan and distribution systems for 974 acres of seed cane nurseries.
Output 1.3.1: 10,000 acres of land replanted to climate adapted varieties.
Output 1.4.1: 10,000 acres prepared to be mechanically harvested and 2,000 acres mechanically harvested.
Output 1.5.1: 10000 acres of land with improved soil health and 5000 acres with improved ratoon management.
Output 2.1.1: Toolkit and Guidelines for climate resilient for irrigation and drainage developed.
Output 2.2.1: 1,000 acres drainage and 2,000 acres irrigation implemented.
Output 2.3.1: 10,000 acres of land with improved pest, soil and residue Management measures implemented.
Output 3.1.1: Climate Resilient Transformation Strategy and System developed.
Output 3.2.1 Sugar Industry Management Information System scaled and implemented
Output 3.3.1: Climate resilient farming models that enable industry transformation and knowledge sharing developed.
Output 3.4.1: Farmer vulnerability criteria and guidelines to guide farmer selection and project resource allocation.
Activities
Establish digital marketplace
Replant 10,000 acres selected based on predefined criteria
Establish seed cane nursery sites and distribution system
Upscale green Harvesting Programme
Develop standards and guidelines for contractors for land preparation and planting
Establish seed cane variety information database and working group
Conduct stakeholders sensitisation and training (i.e., farmers, service providers and contractors)
Develop standards and guidelines for contractors for land preparation and planting
Develop criteria for irrigation and drainage
Conduct training on water managment and irrigtion tools and techniques
Develop and implement pest managment protocols based on residue and moisture regimes
Construct drainage and irrigation infrastructure for 3,000 acres
Develop gender inclusive farmer economic and social vulnerability criteria and assessment guidelines
Develop a crop insurance model for smallholder farmers
Support the further development and roll out of the smart sugar cluster
Develop Climate Adaptation strategy
Develop climate resilient farming models to promote industry transformation
Develop a crop insurance model for smallholder farmers
Activities to Outputs
Supports multi-stakeholder dialogue and awareness building to address threats climate change in planning and development
-Delivers a set of agronomic, water and ecosystem-based adaptation measures and technologies to raise the adaptive capacity of farming communities
-Establish financial instruments that provide transitional support for new green technologies and climate resilient investment.
Risk & Assumptions
Outputs to Outcomes
-Successfully mobilise finance, technology, and expertise to support delivery.
-Select the most efficient and effective interventions to achieve project outcomes
-Meaningful participation of farmers, government staff and the private sector
Risk & Assumptions
Barriers
Reluctance/ aversion to switch to climate resilient plant varieties and climate smart agronomic practices
Technological and knowledge deficiencies relating to irrigation and drainage, land preparationa and planting, and green harvesting
Limited financial resources and fiscal space to leverage funds for investment in seedcane replanting
Limited availability of commercial tested varieties and lack of replanting scheme
Lack of knowledge delivery systems that support resilient organizational design and industry transformation
Lack of a climate responsive transformation strategy guiding the transformation of the sugar industry
Historical and cultural insensitivities persist and women farmers remain a particularly vulnerable group impacted at a disproportionately greater level by climate change.

Annex 3: Timetable at project-programme level

COMPONENTS/OUTPUTS	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Component 1**																				
Output 1.1: Variety information release protocol and data sheet for each variety developed and disseminated																				
Activity 1.1.1: Establish seed cane variety information database and working group																				
Activity 1.1.2: Farmer seed cane sensitization and training																				
Output 1.2: 294 acres of seed cane nursery developed and distribution systems in place																				
Activity 1.2.1: Identify seed cane nursery sites and seed cane production collaborators and protocols																				
Activity 1.2.2: Training of seed cane nursery collaborators																				
Activity 1.2.3: Plant seed cane nurseries																				
Output 1.3: 10000 acres of land replanted to climate adapted varieties																				
Activity 1.3.1: Develop standards for contractors for land preparation and planting																				
Activity 1.3.2: Identify and train suitable contractors on business practices																				
Activity 1.3.3 Establish digital marketplace for contractor to replant facilitated via technology-based solution(s) and systems																				
Activity 1.3.4: Training on Climate Smart Agriculture for replanting																				
Activity 1.3.5: Replant fields that are selected based on predefined criteria																				
Output 1.4: 10000 acres available and able to be mechanically harvested and 2000 acres mechanically harvested																				
Activity 1.4.1: Ensure fields are suitably prepared for Mechanical Harvesting																				
Activity 1.4.2: Identify clusters of fields for viable Mechanical Harvesting																				
Activity 1.4.3: Upscale green Harvesting Programme and associated delivery parameters																				
Activity 1.4.4: Training for displaced cane cutters																				

Output 1.5: 10 new contractors established																				
Activity 1.5.1: Identifying sources of financing and determining the criteria of financial inclusion																				
Output 1.6: 10000 acres of improved soil health Management measures implemented at replanting and 5000 acres implemented for ratoon management																				
Activity 1.6.1: Develop soil management protocols for different residue and moisture regimes to be implemented at replanting and ratoon management																				
Component 2																				
Output 2.1: Maps developed identifying available acres to develop drainage and irrigation for contractors																				
Activity 2.1.1: Develop criteria for irrigation and drainage to identify most vulnerable farmers and/or farms where conditions make implementation viable																				
Activity 2.1.2: Develop system to allow contractors to develop drainage and irrigation																				
Output 2.2: Development of 1000 acres drainage and 2000 acres irrigation																				
Activity 2.2.1: Plan, design and develop irrigation and drainage design parameters																				
Activity 2.2.2: Support development of identified irrigation and drainage																				
Activity 2.2.3: Water management and irrigation scheduling training																				
Activity 2.2.4: Identifying sources of financing and determining the criteria of financial viability																				
Output 2.3: 10000 acres of land with improved Pest Management measures implemented																				
Activity 2.3.1: Develop pest management protocols for different residue and moisture regimes																				
Component 3																				
Output 3.1: Industry aligned for transformation																				
Activity 3.1.1: Development of industry forum to agree on transformation strategy																				

Activity 3.1.2: Development of CSA adaptation strategy and training for industry stakeholders																				
Output 3.2: System developed to introduce continuous learning																				
Activity 3.2.1 : Develop wholistic training strategy and training material to build climate resilience																				
Output 3.3: Industry tools used to increase the data available to farmers for decision making																				
Activity 3.3.1: Equip and use industry tools to distribute climate related data for good farmer decision making																				
Activity 3.3.2 Integrate blockchain into industry tools																				
Output 3.4: Multiple farming models enabling knowledge sharing and increased purchase power																				
Activity 3.4.1: Develop farming models through industry knowledge sharing																				
Activity 3.4.2: Training on acceptable farming models																				
Output 3.5: Climate risk financially based mitigation solution																				
Activity 3.5.1: Develop risk mitigation system for climate variability																				
Output 3.6: Farmer vulnerability criteria developed and assessed and associated maps produced																				
Activity 3.6.1: Develop farmer economic and social vulnerability criteria																				
Activity 3.6.2: Identify Environmentally No-Go areas																				
Project Monitoring*		Inception Report			APR				APR		Interim Evaluation		APR				Completion Report			Final Evaluation

APR = Annual Performance Report

**In addition to this monitoring requirements, the Funded Activity is also subject to financial reporting per the AMA/FAA, such as Unaudited/Audited Financial Statements, Financial information reports, and other reports as defined in the FAA.*

*** For those that do not have component, sub-outputs can be used.*

Annex 4: Project Log Frame

1.24 Fund Level Logframe

5Cs Fund Level
Logframe (GCF templ

1.25 Project Level Logframe

5Cs Project Level
Logframe (SAP templ

Annex 5: Financial Feasibility Model

CCCCC project
feasibility financial mo

Annex 6: Project Budget

CCCCC Project
Budget_Final.xlsx

Annex 7: Project Risk Assessment

5Cs Project Risk
Assesment.docx

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