Office of Climate Change
Ministry of the Presidency

UNEP DTU
PARTNERSHIP

Technology Needs Assessment Adaptation

FINAL REPORT

Identification and Prioritisation of Adaptation Technologies for Guyana

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Acronyms

AWS	Automatic Weather Station
BA	Barrier Analysis
BoS	Bureau of Statistics
CARICOM	Caribbean Community
CCCCC	Caribbean Community Climate Change Centre
CDB	Caribbean Development Bank
CDC	Civil Defence Commission
CDIP	Community Drainage and Irrigation Project
CPACC	Caribbean Planning for Adaptation to Climate Change
CRSAP	Climate Resilience Strategy and Action Plan
DI	Drainage and Irrigation
DTU	Technical University of Denmark
ECLAC	Economic Cooperation for Latin America and Caribbean
EDWC	East Demerara Water Conservancy
EST	Environmental Sound Technology
ET	Evapotranspiration
EWS	Early Warning System
FAO	Food and Agriculture Organisation
GCCP	Global Climate Change Project
GCM	General Circulation Models
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GLSC	Guyana Lands and Surveys Commission
GoG	Government of Guyana
GRDB	Guyana Rice Development Board
GuySuCo	Guyana Sugar Corporation
Ha	Hectares
IMF	International Monetary Fund
INC	Initial National Communication
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IRWR	Internal Renewable Water Resources
LCDS	Low Carbon Development Strategy
MMA/ADA	Mahaica, Mahaicony, Abary/Agriculture Development Authority
MCA	Multi Criteria Analysis
MOA	Ministry of Agriculture
MoPI	Ministry of Public Infrastructure
MOTP	Ministry of the Presidency
MPI	Multidimensional Poverty Index
NAC	National Adaptation Consultant
NAP	National Adaptation Plans
NAREI	National Agricultural Research and Extension Institute
NASAP	National Adaptation Strategy and Action Plan
NCS	National Competitiveness Strategy
NDIA	National Drainage and Irrigation Authority
NDS	National Development Strategy
NGO	Non-Governmental Organisation
NIDRMPP	National Integrated Disaster Risk Management Policy and Plan
NLUP	National Land Use Plan
NTC	National TNA Committee
NWC	National Water Council
OCC	Office of Climate Change
PM	Project Manager
PRS	Poverty Reduction Strategy
RWH	Rain Water Harvesting
SMS	Short Message Service
SNC	Second National Communication
SWG	Sector Working Group
TAP	Technology Action Plans
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
WB	World Bank
WUA	Water Users Association

Executive Summary

The Intergovernmental Panel on Climate Change (IPCC) (2000), in its special report on Methodological and Technological Issues in Technology Transfer, defines technology as *"a piece of equipment, technique, practical knowledge or skills for performing a particular activity".* The UNDP Handbook for Conducting Technology Needs Assessment for Climate Change (United Nations Development Programme (UNDP, 2010), defines the concept of technologies for adaptation very generically as *"All technologies that can be applied in the process of adapting to climatic variability and climate change".* A United Nations Framework Convention on Climate Change (UNFCCC) report on the development and transfer of technologies for adaptation to climate change proposed the following definition*: "the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change"* (UNFCCC 2010) (UNEP DTU, MCA Guideline, 2015).

In 1992, the Government of Guyana (GoG) became a signatory to the UNFCCC and has successfully completed numerous initiatives towards the implementation of the convention. Through the preparation of the Initial and Second National Communications (INC and SNC), Guyana has built significant capacity in greenhouse gas inventories (GHG), mitigation and vulnerability assessments of key sectors, public awareness on climate change and, assessment of technology and capacity needs. Through other programmes, capacity has strengthened in early warnings and disaster management, weather forecasting, sea defence infrastructure, construction of new canals, installation of pumps for drainage and irrigation, research into new varieties of rice and sugar and, to a lesser extent, other crops and livestock.

This Technology Needs Assessment (TNA) Report is the first of three reports aimed at prioritising technologies for adaptation in Guyana. It is the outcome of a stakeholder-driven, participatory process to identify and assess technologies that will contribute to national development goals, strengthen Guyana's adaptive capacity against the negative impacts of climate change and prepare the country to take advantage of opportunities which may occur.

The TNA process, thus far, drew significantly on previous assessments from the national adaptation strategies, Guyana's Low Carbon Development Strategy (LCDS) and current initiatives, namely, the Draft Climate Resilience Strategy and Action Plan (CRSAP), Guyana's Agriculture Diversification Strategy and, sector programmes/projects. Much of the country's development priorities over the past two decades, have been guided by key strategies, such as, the National Development Strategy (NDS), Poverty Reduction Strategy (PRS) and the LCDS.

In recent years, the GoG has committed to pursuing economic development in a sustainable manner. This includes, building a "green economy" through the adoption of clean energy sources and the sustainable utilisation of its natural resources as stated by His Excellency President David Granger (Ministry of the

Presidency (MOTP), 2016). According to the Presidential Adviser on Environment, Rear Admiral Gary Best (Ret'd.), *"the green economy targets low emissions across all sectors, through vertical and horizontal policies and actions".* Transitioning towards renewable sources of energy is a critical component of Guyana's 'green development thrust. Investments in solar, wind, hydropower and biomass have been cited as vital and must be amplified in the short to medium term. To date, numerous initiatives have been launched towards the pursuit of "the good life in a green economy" goal, including, the development of a multi-faceted 'Green Development Plan'. President David Granger stated that this plan incorporates actions on clean energy, coastal zone management, solid waste management, management of protected areas, protection of biodiversity, wildlife and the development of ecotourism (MOTP, 2016). Plans are also underway to establish a number of designated green towns across the country.

The methodology applied in this first stage of the TNA included a thorough participatory process with key stakeholders and the use of a multi-criteria analysis for the prioritisation of technologies. Technologies application on a national scale were examined, as well as, more localised diffusion in the short/medium/long term. Previous assessments and development strategies, as well as, potential climate change impacts on the selected priority sectors have been reviewed and discussed with stakeholder groups. Incorporating the economic, social, environmental and development factors, and guided by Guyana's vulnerable sectors identified in the SNC and the Intended Nationally Determined Contributions (INDC) to the UNFCCC, three (3) priority sectors were selected for the adaptation assessment, namely, *Agriculture, Water Resources and, Coastal Zone and Low-Lying Communities.*

Following the identification of the priority sectors, long lists of technologies for each sector were prepared for review by the Sector Working Groups (SWG) and short-lists were developed using the following three (3) pre-screening criteria:

- **Technical potential**: The applicability of the technology to the adaptation need, including the local skills and resources.
- **Climate Resilience**: The extent to which the technology will promote climate resilience; and
- **National Development Priority**: The technology synergy with national development priorities/strategy.

The prioritised sectors and short-lists were endorsed by the National TNA Committee (NTC) at meetings held during the period November 2015 to January 2016. The following is a list of the twelve (12) priority technology options within the three prioritised sectors, which were identified for further analysis:

1. **Agriculture:**

- Varietal development of saline tolerant crops;
- Freshwater harvesting for inland Regions: Empoldering of water collection areas;
- Composting of agricultural solid waste (crop & livestock); and
- Agro-meteorological system for forecasting and early warning.

2. Water Sector

- Rainwater harvesting;
- Ground water mapping and modelling;
- Surface water mapping and modelling; and
- Geographic Information Systems (GIS) mapping and modelling for water catchment protection.

3.* Coastal Zone and Low-Lying Communities*:

- Mapping and modelling of coastal processes for the construction of seawalls and groynes;
- Energy efficient mobile pumps for flood control;
- National early warning system for flood and drought; and
- GIS technology to operationalise land use plan.

Technology factsheets were then prepared for each of the prioritised technologies. The factsheets provided relevant information on the technology type (hardware/software/orgware), technical applicability, the main adaptation and development benefits and, scale of application within the context of current and future climate change impacts.

Applying a Multi-Criteria Analysis (MCA) tool provided by the United Nations Environment Programme-Technical University of Denmark (UNEP-DTU) partnership, the technology options were further prioritised. In the MCA, three criteria categories were used: Cost, Adaptation Benefits and Development Benefits. A list of 10-12 criteria was prepared for each sector under the three criteria categories. These were presented to the respective SWG, which then identified 7-10 criteria to be applied in the MCA. The main objective of the final selection was, to ensure that each criterion was measurable, independent and relevant. Each criterion was then assigned a weight to determine its relative importance against the other criteria. Using the Likert scale of measurement, a qualitative value measure was applied for the weights (5 - less important, 10 - important and 15 - more important). The total sum of the weights for all criteria equated to 100.

Following the assignment of weights, there was the scoring of technologies. A performance measure scaling was applied using a sliding scale of 20-100, where the lowest preferred value was 20 (very low), 40 (low), 60 (moderate), 80 (high) and the highest preferred value was 100 (very high). This performance measure was assessed using the information presented in the technology fact sheets, available country knowledge and relevant input from experts. Finally, sensitivity analyses were conducted to evaluate the robustness of the results, relative to the weights and scores applied and other uncertainties. In the final output, eight (8) technology options were prioritised to proceed to the next stage of the TNA. The following is a list of the final options:

1. **Agriculture Sector**
   (i) Freshwater harvesting for inland Regions: Empoldering of water collection areas; and
   (ii) Agro-meteorological system for forecasting and early warning.

2. **Water Sector**
   (i) Ground water mapping and modelling;
   (ii) Surface water mapping and modelling; and
   (iii) GIS mapping and modelling for water catchment protection.

3. **Coastal Zone and Low-Lying Communities Sector:**
   (i) Mapping and modelling of coastal processes for the construction of seawalls and groynes;
   (ii) National early warning system for flood and drought; and
   (iii) Energy efficient mobile pumps for flood control.

The next phase in the TNA process will be to conduct a Barrier Analysis (BA) for the eight prioritised technologies. This will be followed by the preparation of a Technology Action Plan (TAP).

Chapter 1: Introduction

1.1 About the TNA project

Technology Needs Assessment as referenced by the UNDP and defined by the UNFCCC, is a "set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of Parties other than developed country Parties, and other developed Parties not included in Annex II, particularly developing country Parties". It includes different stakeholders engaged through a consultative process to identify barriers to technology transfer and measures to address these barriers through sectoral analyses. This process allows for the use of soft and hard technologies, identification of regulatory options, the integration of national sustainable development priorities and, the development of financial incentives and capacity building.

The TNA is implemented in phases. Phase 1 or the first generation of climate TNAs was completed during the period 2001 to 2007, with support from the Global Environment Facility (GEF) and implemented by the UNDP and the UNEP. The current project, Phase II or the second generation of TNAs is currently being implemented with support from the GEF through its Strategic Program on Technology Transfer and collaboratively by UNEP-DTU.

Guyana is among twenty-six (26) countries globally and one of seven (7) countries in the Latin America and Caribbean Region participating in the second phase or second generation of the TNA process. The Office of Climate Change (OCC), Ministry of the Presidency (MOTP) is the national implementing institution. The TNA has both, an adaptation and mitigation component, which is being completed through contracted services of an adaptation and mitigation consultant for the respective component.

The purpose of the TNA project is to identify and analyse priority technology needs that will form a portfolio of Environmental Sound Technology (EST) projects and programmes, and to facilitate the transfer of, and access to, knowledge and experience during implementation. In addition to the integration with national development priorities, the TNA process provides an opportunity to find synergies with other processes and mechanisms under the UNFCCC, such as, the Intended Nationally Determined Contributions (INDC) and National Adaptation Plans (NAPs). The main steps and objectives of the TNA project are:

A. To identify and prioritise through country-driven participatory processes, technologies that can contribute to the adaptation (and mitigation) of Guyana, while meeting the national sustainable development goals and priorities. The outcome of this step is presented in this TNA report;

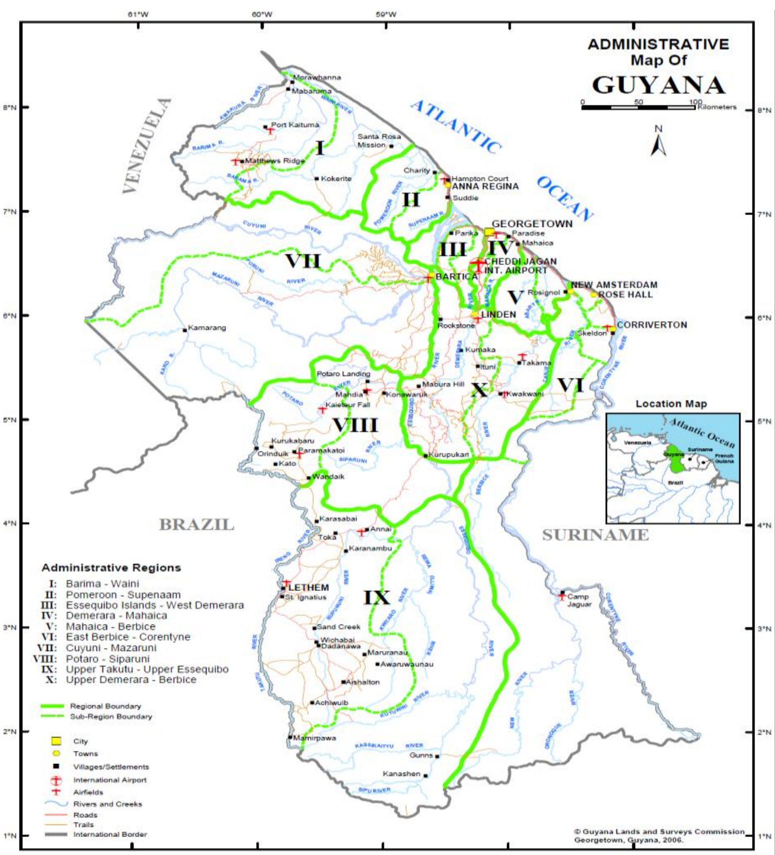
B. To identify barriers hindering the acquisition, deployment and diffusion of prioritised technologies; and

C. To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption and diffusion of selected technologies in Guyana.

This TNA Report for adaptation is the first main deliverable of the TNA Project by Guyana.

1.2 Country Information and Existing National Policies related to Technological Innovation, Adaptation to Climate Change and Development Priorities

The Co-operative Republic of Guyana is a low-lying coastal state, situated on the northern shoulder of South America, bordered by the Atlantic Ocean in the north, Brazil to the south, Suriname to the east and Venezuela to the west. The country has a total area of approximately 21.5 million hectares (ha), with forested area occupying approximately18.48 million ha (GoG, 2015). With a population of 746,955, Guyana has a low population density of 3.5 persons per km^2 (BoS, 2012). The combined coastland regions have 9.6 persons per km^2, while the four hinterland regions occupying more than two-thirds of the total land area of the territory, have less than one person per km^2(BoS, 2012). **Map 1** below shows the ten administrative regions of Guyana.



Map 1: Administrative regions of Guyana.
Source: Guyana Lands & Surveys Commission.

Guyana has rich biodiversity and natural resources, as well as, fertile agricultural lands and minerals on which the country is economically dependent. Agriculture and activities in the natural resources sector are the country's largest economic earners. Twenty-eight percent (28%) of Guyana's total Gross Domestic Product (GDP) in 2015 was attributed to industries in the agriculture, forestry, fishing and mining sectors, whereas, bauxite, sugar, rice, gold and timber accounted for 83% of exports (WB, 2016). These sectors combined provide the largest share of direct employment in the country (WB, 2016).

Using the Multidimensional Poverty Index (MPI)[1] as a measure to determine the incidence and intensity of poverty, and based on the most recent survey available for Guyana's MPI's estimation (2009), it was found that 7.8% of the population is multi-dimensionally poor, while 18.8% live near multi-dimensional poverty (UNDP, 2015). The report concluded that the intensity of deprivation (poverty) experienced by people in multi-dimensional poverty is 40% (UNDP, 2015). In 1999, a Living Conditions Survey to measure the impact of economic and social programs on poverty indicated a reduction in poverty levels from 43 percent in 1992 to 35 percent, of which, 19 percent were living under conditions of extreme poverty (WB, 2016; IMF, 2002).

Climate change is expected to have significant impacts on the agriculture and water sectors, in particular, and this is evident in the recent, extensive dry period experienced in the country during the period 2015-2016. The impact on the coastlands will have consequences for the country's GDP which is directly related to agriculture, forestry and fishing sectors (GoG, 2012). At the global level, the Intergovernmental Panel on Climate Change (IPCC) has, in recent years, provided decisive scientific evidence that, increased anthropogenic activity resulting in increased greenhouse gas (GHG) emissions, is responsible for the observed changes in climate. The consequences for small, vulnerable countries such as Guyana are life-threatening. At the Regional level, the Caribbean Community (CARICOM), which Guyana is a member of, is responsible for less than 1% of the global GHG emissions. However, the Region with its unique socio-economic and geophysical characteristics, is extremely vulnerable and will be severely impacted.

Despite the many challenges (economic, technical, human resources etc), Guyana is committed to addressing the issues associated with climate change. Significant efforts have been made to define adaptation priorities and develop policies, strategies and actionable initiatives, including, shore zone protection and monitoring, crop diversification, water conservation and management, energy efficiency and renewable energy (AP, 2011). In particular, the GoG in recognising the need for a long term vision, has charted a path towards a climate resilient economy through a green economy plan. This plan is expected to build on previous initiatives, such as the LCDS.

Over the past decade, several documents were prepared to assist in combating climate change, namely, National Climate Change Adaptation Policy and Implementation Plan (2001), a National Climate Change

[1] MPI was introduced in 2010 by UNDP in its preparation of the Human Development Report. MPI identifies multiple depravations in the same households in its three (3) dimensions - education, health and living standard. Each dimension has its own indicators that collectively total ten (10).

Action Plan (2001) and a Coastal Zone Management Plan (2002). However, the formalisation and implementation of those plans were not sustained. In 2009, the GoG, recognising the role of forests in climate change mitigation and the urgency to cost adaptation measures, as well as, to prepare a comprehensive adaptation policy, launched the LCDS. In the absence of a comprehensive climate policy, the LCDS provide an overarching framework to develop a climate-resilient economy. It outlined the approaches for a low carbon, low deforestation, and climate-resilient development pathway and highlighted the importance of climate change adaptation, through resilience building of critical thematic areas, such as, infrastructure (drainage) upgrades to protect against flooding and specific strategies targeting hinterland adaptation (AP, 2011; GoG, 2013; GoG, 2015).

The National Disaster Risk Management Policy (2013) and National Integrated Disaster Risk Management Plan and Implementation Strategy (2013) together with the National Adaptation Strategy and Action Plan (NASAP) (2009) for the Agriculture Sector, provide guidance to national policy initiatives related to adaptation. The Policy and Plan focuses on identifying and preventing risks, risk transfer, preparedness and recovery, while the NASAP aims to reduce climate risks in the sector and, outline initiatives and measures to improve the ability of the sector to adapt to changes. Guyana has also prepared a National Science and Technology Policy (2014). The policy is intended to support national development planning and identify national priority areas where science and technology inputs would be required to make substantial impacts.

More recently, in 2014, the GoG commenced the preparation of a Climate Resilience Strategy and Action Plan (CRSAP) for Guyana. This Strategy parallels the LCDS to provide a roadmap until 2020 for implementation across the five (5) pillars of adaptation as identified in the SNC. The five pillars around which adaptation options can be built for Guyana are:

1. Information, research and systematic observation.
2. Institutional framework and capacity building, education and awareness
3. Policy, legal framework and tools to integrate climate change adaptation into development planning.
4. Generation and application of technologies.
5. Innovative financing instruments

Additionally, the strategy provides a summary of the most significant climate risks and the required resilience actions across fifteen (15) key sectors, as the basis to design any new intervention and/or project (GoG, 2015).

1.3 Vulnerability Assessment in Guyana

The vulnerability assessment of the SNC for Guyana concluded that, climate change and extreme weather events, due to their severity and frequency will exacerbate the country's vulnerability. In addition, a number of studies conducted over the years concluded that Guyana is exposed to the following five (5) disaster hazards/threats (i) flooding as a result of excessive rainfall, (ii) coastal flooding as a result of breached levees and over-topping of the seawall, (iii) drought from reduced rainfall over an extended period, (iv) intense storms and high wind-speeds affecting people and property, and (v) risks of wild fires (due to excessive dry periods) (GLSC, 2010 & Cummings (not dated).

These hazards can be classified into two (2) categories of events, (i) ongoing and rapid/sudden- onset threats and (ii) slow-onset or creeping threats. Flooding can be categorised as a sudden- onset threat and drought as a slow-onset threat where, the latter occurs over a longer-term due to cumulative environmental changes which are not easily detected (Grasso, V, 2012). Therefore, the warning time for each threat varies significantly from 'now-casting' (immediate) to 'forecasting' (months in advance).

The country's vulnerability profile was computed using a number of climate scenarios with the following projected results (GoG, 2012):

- Sea level will rise more than 1 m by the year 2100 as a result of increased melting of the ice sheets;
- Mean annual air temperature in the 2060's is projected to increase between 0.9 °C to 3.3°C; and
- Projections of mean annual rainfall will vary between a reduction of 34% to an increase of 20% by 2090.

The assessment noted that rainfall patterns would vary significantly across the country and Guyana may experience intense water shortages in the months of October and November, based on a projection for the period 2040 – 2060. Guyana will experience the largest decrease in rainfall during the mid-year months (May, June, July- MJJ) by -68mm to +21mm per month. Relative changes in rainfall indicates strongest decreases (-82% to +68%) in the dry season (August, September, October) and the end of year wet season (November, December, January) (GoG,2012). Projections relating to future changes in the spatial changes of rainfall show that, generally, annual and seasonal rainfall would decrease slightly (approximately 10 %), especially in the 2090s, and that these decreases in rainfall would mainly affect the northern half of Guyana, including the critical coastal zone. The assessments further specified that there may be an increase in the maximum and minimum temperature, thereby, resulting in decreased precipitation. It is expected that such increases in temperature will lead to increases in evapotranspiration, leading to significant water deficits in the agriculture, domestic and industrial sectors and sub-sectors (GoG,2012).

With the above mentioned projections, the coastal region was found to be the most vulnerable since it houses over 90% of the population, along with the country's major infrastructure and economic zones (GoG, 2012). Guyana is already experiencing the impacts of extreme weather events, such as, floods due to increased and intense precipitation and, low annual and seasonal rainfall resulting in drought-like conditions. Flooding events in recent years occurred in 2005, 2006, 2008, 2010, 2011, 2013, 2014, 2015 and drought-like events occurred through the period 1997-1998, 2009-2010, 2015-2016 (GoG, 2015). The major flooding of 2005 affected approximately 275,000 people and resulted in approximately US$ 465,100 million in costs to the country (ECLAC, 2005; Cummings, not dated). The major drought of 1997 affected approximately 607,200 people and caused losses to the estimated sum of US$29 million (Cummings, not dated).

1.4 Sector and Technology Selection

1.4.1 An Overview of Expected Climate Change and its Impacts in the Prioritised Sectors Vulnerable to Climate Change

1.4.1.1 Coastal Zone

Guyana's coastal zone is extremely vulnerable to climatic changes because of its geophysical and socio-economic characteristics. The coastal zone, constitutes about 5% of the country's territory and is located on the northern boundary with the Atlantic Ocean at 1.4m below mean high-tide level. It is flat and narrow, approximately 430 km long and varies in width from 26 km to 77 km. Approximately 90% of the population of Guyana reside within this floodplain, alongside the main urban centers, industrial and commercial activities. Coastal assets include major infrastructure, such as, drainage and irrigation systems and mangrove ecosystems which add stability and protection to the coast, agriculture lands, roads and communication networks. According to assessments completed to date, 43% of Guyana's GDP is produced in regions exposed to significant flood risk (GoG, 2009).

About 45% of the coastline is currently subjected to erosion (Maurice, 2011 as cited by GoG, 2012); hence, sea-level rise may lead to increased erosion which would cause damage to the foundation of houses, while salt-water intrusion would affect the soil and can make lumber rot faster. A rise in sea-level of 0.6m can also inundate, weaken, and erode coastal roads (GoG, 2012). Thus, it can increase bridge structural load, as well as, scour bridge foundations. Indirect impacts on industry include those resulting from delays and cancellations due to climate impacts on transportation, communications and power infrastructure. Similarly, retail and commercial services are vulnerable because of the threat to supply chain network and transportation.

Historically, the coastal zone is protected by an elaborate system of sea defence structures and drainage network (canals and sluices) which are in dire need of rehabilitation and replacement. This is extremely costly. Approximately US$6.4 million is required to construct one kilometer of concrete sea defence, and the country needs to fortify an estimated 360 km of sea defence (GoG, 2012). Past events indicate that all resources and activities performed on the coastal plain are extremely sensitive to climate change. According to ECLAC Assessment (2005), floods have proven to be very costly for Guyana and largely affect human settlements. During the 2005 floods, the GoG provided emergency transfers to affected households and farmers (US$250 and US$500 respectively). Apart from the income support to the affected households, the Government also provided an estimated US$100,000 to the Civil Defence Commission for emergency relief and operating shelters (ECLAC 2005).

In the event of sea-level rise; inundation, erosion, and saline intrusion into surface and groundwater sources would very likely occur. According to **Table 1,** sea level rise for Guyana under maximum and minimum scenarios, as projected by two General Circulation Models (GCM), show significant increases over the next 50 years. The three scenarios a, b and c represented are: a) sea-level rise without storm surges; b) sea-level rise with a storm surge of 2m; and c) sea-level rise with a storm surge of 5m. Scenario ‘a’ represents the most conservative condition with just sea-level rise occurring. In the worst case scenario, (c), sea level rise range from 5.82m to 6.19m by the year 2071. With Guyana’s coastland already below mean high-tide level, this significant increase in sea level, can have devastating impacts.

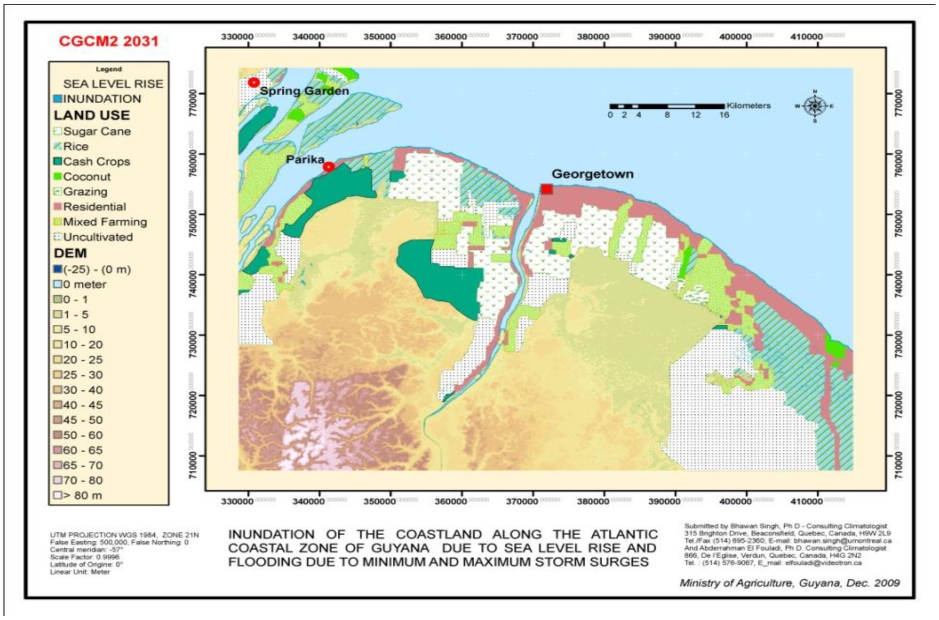
Table 1: Sea-level rises for 2031, 2051 and 2071 under three different scenarios (a, b and c) according to HadCM3[2] and CGCM2 [3]scenarios.

Year	Scenario	HadCM3	CGCM2e
2031	a. Sea-level (m)	0.14	0.26
	b. Minimum (m)	2.82	2.94
	c. Maximum (m)	5.82	5.94
2051	a. Sea-level (m)	0.21	0.34
	b. Minimum (m)	2.89	3.02
	c. Maximum (m)	5.89	6.02
2071	a. Sea-level (m)	0.25	0.51
	b. Minimum (m)	2.93	3.19
	c. Maximum (m)	5.93	6.19

Source: GoG, 2012

Map 2 below shows coastal likely coastal inundation caused by scenario (a) which projects a sea level rise of 0.26m by 2031.

[2] Hadley Circulation Model 3
[3] Canadian General Circulation Model 2



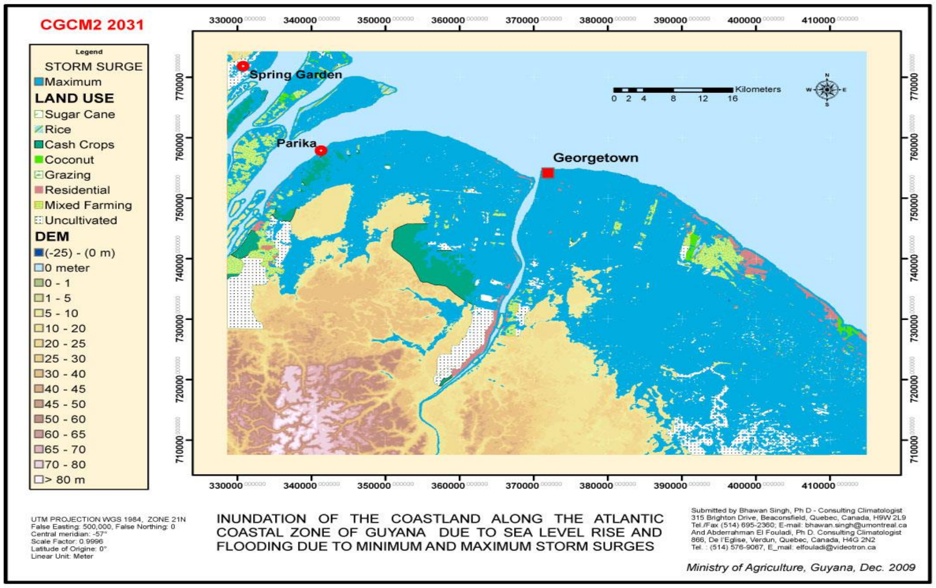
Map 2: **Coastal inundation for time slice 2031 due to projected sea level rise (a) according to CGCM2 scenario.**
Source: GoG, 2012

According to **Table 2** below, which considers storm surge scenarios b (minimum: 2m) and c (maximum: 5m), extensive areas of the coastal zone are likely to be inundated. In a worst case scenario, for the period 2031, a maximum storm surge will likely affect 140, 245 ha of coastal territory, as shown in **Map 3.** Though there is more than ample space in the inland Regions of Guyana, economic resources and poor soils make displacement to those areas difficult.

Table 2: Land area inundated on the coastal zone due to storm surges.

Model	Year	Land area in the coastal zone that is likely to be inundated (minimum-maximum)
CGCM2	2031	79,851- 140,245 hectares
	2051	82,881- 140,986 hectares
	2071	88,591- 142,480 hectares
HadCM3	2031	75,578- 139,123 hectares
	2051	78,038- 139,784 hectares
	2071	79,483- 140,152 hectares

Source: GoG, 2012



Map 3: **Coastal inundation for time slice 2031 during projected maximum storm surge (5m) according to CGCM2 scenario.**
Source: GoG, 2012

1.4.1.2 Agriculture

Agriculture is one of the sectors in Guyana which is expected to be significantly affected by climate change. Because of the sector's role in the national economy, food security and livelihood, any external shock to this sector can have cascading socio-economic consequences. Currently, agriculture contributes about twenty (20) percent of Guyana's GDP; forty (40) percent of export earnings and employs some thirty (30) percent of the country's labour force (MOA, 2013). Sugar and rice are the most important crops and main export commodities accounting for some seventy-four (74) percent of agriculture's GDP, as well as sixty-five (65) percent of Guyana's total agriculture exports. **Table 3** shows agriculture land loss from projected sea level rise and storm surge for three time slices. It is projected that inundation caused by minimum storm surge (2m) may inundate more than 25,000 ha of rice lands and 11,000 ha of residential areas, whereas maximum storm surge (5m) may affect over 29,000 ha of rice lands and an upper limit of 22,361 ha of residential lands for the periods 2031 to 2071 (GoG,2012).

Table 3: Land loss (hectares) according to land use categories due to projected sea-level rise and min/max (2m/5m) storm surges for the coastal zone of Guyana according to the CGCM2 and HadCM3 for three time slices, 2031, 2051 and 2071.

	Year	**2031**			**2051**			**2071**		
	Category	**Max Storm Surge**	**Min Storm Surge**	**Sea-level Rise**	**Max Storm Surge**	**Min Storm Surge**	**Sea-level Rise**	**Max Storm Surge**	**Min Storm Surge**	**Sea-level Rise**
	Unit (hectares)	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha
CGCM2	Rice	29,341	25,195	1,069	29,374	25,495	1,559	29,443	26,028	2,674
	Sugar-Cane	27,949	16,423	76	27,977	17,369	112	28,032	19,016	207
	Residential	22,067	11,325	1,347	22,166	11,872	1,537	22,361	12,947	1,854
	Cash Crops	7,542	1,240	53	7,647	1,387	65	7,848	1,739	83
	Coconut	1,446	621	74	1,472	644	83	1,521	690	95
	Mixed Farming	15,345	6,573	89	15,508	6,858	127	15,854	7,433	229
	Uncultivated	35,593	17,719	191	35,876	18,487	276	36,444	19,944	492
	Grazing	962	755	3	966	770	5	978	794	12
	Total	**140,245**	**79,851**	**2,902**	**140,986**	**82,882**	**3,765**	**142,481**	**88,591**	**5,646**
HadCM3	Rice	29,287	24,687	602	29,319	24,986	890	29,336	25,154	1,069
	Sugar-Cane	27,902	15,152	42	27,929	15,881	63	27,945	16,315	76
	Residential	21,915	10,595	1,066	22,005	11,008	1,256	22,056	11,258	1,347
	Cash Crops	7,391	1,063	38	7,479	1,163	48	7,529	1,224	53
	Coconut	1,415	587	59	1,432	608	69	1,443	619	74
	Mixed Farming	15,105	6,177	52	15,246	6,406	76	15,324	6,539	89
	Uncultivated	35,156	16,590	102	35,416	17,244	159	35,558	17,623	191
	Grazing	954	727	2	959	743	3	961	753	3
	Total	**139,123**	**75,578**	**1,962**	**139,785**	**78,039**	**2,563**	**140,152**	**79,484**	**2,902**

Source: GoG, 2012

About 70% of the population depend on agriculture and agriculture-related activities for their livelihood which amplifies the country's vulnerability to these extreme weather events. Most of the country's fertile lands are situated in the low-lying coastland, which is highly susceptible to salt water intrusion and which will exacerbate with sea level rise. The hinterland locations will also experience drought like conditions, and increased salinity. Guyanese have already started to note, with concern, the trend of above normal rainfall, the frequency with which longer, wetter spells occur, and the intense dry periods, as well as, the greater frequency of marine inundation due to rising sea-level.

1.4.1.3 Water

Guyana will confront challenges from extreme weather events, such as, intense rainfall and extensive dry periods and from sea-level rise, which can have significant impact on the country's water resources. Along coastal Guyana, most of the water for domestic and commercial purposes is extracted from ground water sources derived from three main aquifer systems. Water for industry and agriculture primarily originates from surface sources. Hinterland communities primarily utilise surface water supplied by a dense network of watersheds. There is limited knowledge of the aquifer systems along the coast and the increasing population size in this zone continue to raise questions of the possibility of water mining and salt-water intrusion. In interior locations, the major threat to surface water bodies originates from gold and diamond mining, and the accompanying erosion of soil.

Projections derived from GCM scenarios, show that Guyana will experience increases in temperature, increased rainfall in the rainy season and less precipitation in months where there are already water deficits. Mean annual air temperature in country has increased by 0.3°C since 1960, and projections of future climate indicate that this will have significant consequences for climate in future years, with temperature rising from 2°C to 4°C by the end of this century (GoG, 2012). It appears that the increase in temperature will be higher for the average monthly minimum temperatures, than for the average monthly maximum temperatures. The climate scenarios show that the country could experience decreases in mean annual rainfall. The rainfall patterns would experience considerable temporal and spatial change throughout the country and Guyana may suffer water deficits in October and November (GoG, 2012).

1.4.2 Process and results of Sector and Technology selection

1.4.2.1 Identification of Key Sectors:

Priority adaptation sectors were identified following a thorough review of national reports, strategies and plans addressing climate change in Guyana and a list of five (5) sectors was prepared. The five (5) sectors listed were derived from the assessments in the SNC and the adaptation sectors indicated in Guyana's INDC to the UNFCCC. These were represented in a decision matrix, as shown in **Table 4.** This list was presented to the NTC for their input into the prioritisation of the adaptation sectors to be further assessed. The NTC in their discussions agreed to select the sectors which were identified in both of the documents. Consequently. the adaptation priority sectors selected were (i) agriculture, (ii) water resources and (iii) coastal zone. However, the NTC recommended that the coastal zone sector be expanded to include 'low-lying communities'. The remaining sectors, buildings and health, while important for climate change adaptation, were viewed as lower priorities for technology transfer at this stage.

Following the sector identification, SWGs were established for each of the three priority sectors. The SWGs comprised experts from relevant fields/ institutions within the specific sector who participated in the prioritisation of technologies for each sector.

Table 4: Decision matrix of priority sectors for adaptation to climate change

Sectors	SNC (2012)	INDC (2015)
Agriculture	√	√
Building	√	
Coastal Zone	√	√
Water resources	√	√
Health		√

1.4.2.2 Criteria and Process of Technology Prioritisation

A criterion is a common standard by which something can be decided or judged. The development of criteria is critical in the TNA prioritisation process, due to its strong participatory characteristic. This prioritisation process helps to add robustness to the country-driven approach in the selection of technologies for transfer in the future.

The prioritisation process followed the guidelines recommended by UNEP-DTU for the TNA, summarised in the steps shown in **Figure 1.** Due to limited resources and time, the long lists of adaptation technologies were pre-screened through SWG meetings to derive short-lists of technologies for the sectors. During the pre-screening process, consultations were held with each SWG for the three (3) adaptation priority sectors. The objectives of the pre-screening process were to:

- Review the long list of technology options for adaptation;
- Identify additional technologies for the sectors, if necessary; and
- Prioritise technology options for each sector to derive a short list of adaptation technology options.

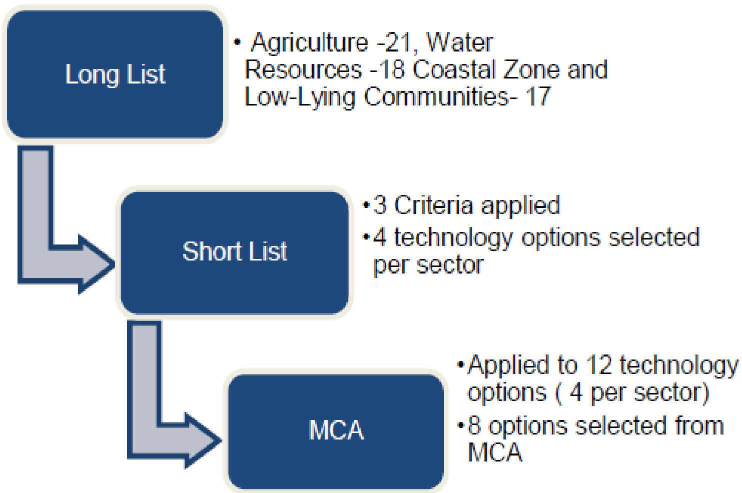


Figure 1: Sector and Technology Prioritisation Process

Experts from the respective sectors were engaged during the consultations and discussions were held on current and future climate impacts on the sector, existing programmes, assessments and gaps/needs/challenges. The final selection of priority adaptation technologies was made using three criteria as described in TNA Handbook:

- **Technical potential**: The applicability of the technology to the adaptation need, including the local skills and resources;
- **Climate Resilience**: The extent to which the technology will strengthen the capacity to withstand the impacts of climate change; and
- **National Development Priority**: The technology synergy with national development priorities/strategies.

During the SWG discussions, technologies were eliminated based on one or more of the following:

- The existing or planned programmes for that technology option;
- The technology did not satisfy the three pre-screening criteria above; and
- The technology did not satisfy the TNA definition for what is a technology.

Using a decision matrix format, twelve technologies were short listed for the next stage of the analysis and a report submitted to the NTC for review and approval of the short-listed technologies as shown in **Table 6**.

Table 5: Number of technologies in long & short list for each sector

Sectors	Long List	Short List
Agriculture	21	4
Water Resources	18	4
Coastal Zone & Low-Lying Communities	17	4

Table 6: Short-listed technology options for each priority sector

	SECTORS		
TECHNOLOGY OPTIONS	**Agriculture**	**Water Resources**	**Coastal Zone and Low-Lying Communities**
	Varietal development of saline tolerant crops	Rainwater harvesting (collection, storage and treatment)	Mapping and modelling of coastal processes for the construction of seawalls & groynes
	Freshwater harvesting for inland regions: Empoldering of water collection areas	Ground water mapping and modelling	Energy efficient mobile pumps for flood control
	Composting of agriculture solid waste (crops & livestock)	Surface water mapping and modelling	National Early Warning Systems (Flood & drought)
	Agro-meteorological system for forecasting and early warning	GIS modelling and mapping for water catchment protection	GIS technology to operationalise Land Use Plan

Following the approval by the NTC, factsheets were then prepared for the approved pre-screened technologies and a MCA was applied to determine a ranking of the short-listed technology options for the barrier analysis.

Multi-Criteria Analysis (MCA)

The MCA is a *"structured framework for comparing a number of adaptation technologies across multiple criteria"* (UNEP, 2015). It is a highly participatory process which allows for normative judgments and the incorporation of technical expertise. Thus, there is a strong emphasis on stakeholder representation. When applied to adaptation technologies, the MCA usually allows for quantitative, as well as, qualitative criteria. Criteria can be included which are quantifiable in monetary terms or quantity and for others it may not be possible apply a numerical measurement (UNEP-DTU).

The MCA was completed for each sector using the tool recommended by UNEP-DTU for TNAs. This is an excel based tool which allows for the application of scores and weights of criteria (qualitative or quantitative) for each technology. The scores and weights are normalised for comparison and a prioritised, ranked list of technologies is generated for each sector. With support provided by UNEP-DTU, the consultant used the excel model to perform the MCA. Chapters 3, 4 & 5 elaborate on the application of the MCA for each of the priority adaptation sector.

Chapter 2: Institutional Arrangement for the TNA and Stakeholder Involvement

The institutional arrangement for the execution of the TNA project in Guyana followed the general structure recommended for TNA processes as shown in **Figure 2**. As mentioned previously, it is a participatory, country driven process, whereby, institutional arrangements aim to maximise stakeholder participation at all levels or steps in the process.

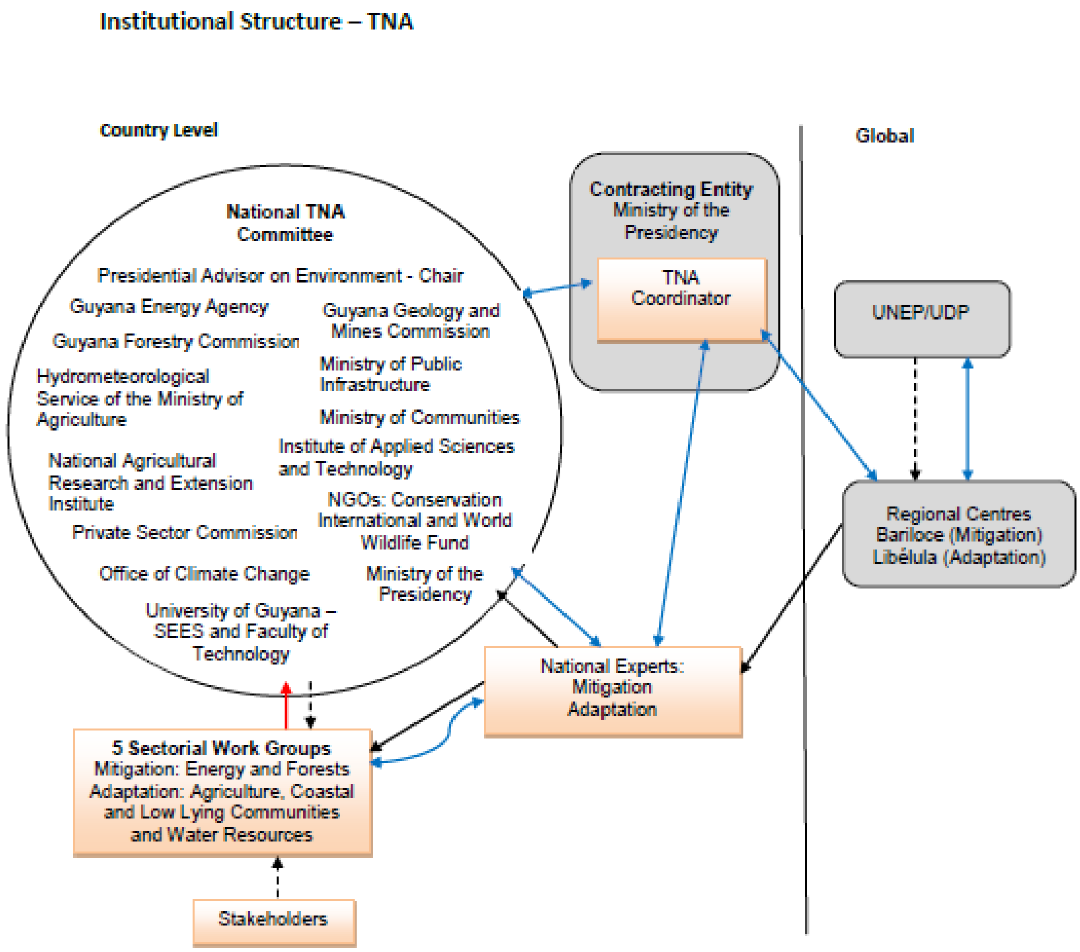


Figure 2: Institutional Arrangement for the TNA Project in Guyana

The national structure comprises the NTC, the TNA Coordinator, SWG for each of the priority adaptation technology sectors (agriculture, water resources and, coastal zone and low-lying communities), adaptation/mitigation consultants and other stakeholders such as, national sector experts and institutional representatives.

The TNA Project is implemented by the OCC which is located within the MOTP. This close proximity with the highest office of government compliment buy-in at the policy making level and the opportunity to integrate national concerns throughout the process. The TNA Coordinator facilitate all communication between the OCC, NTC, UNEP – DTU and the consultants.

2.1 National TNA Team

2.1.1 National TNA Committee

The NTC is the highest national decision-making tier of the project and comprises a core group of twenty-one (21) representatives from key national institutions. Refer to **Appendix 1** for details on the NTC membership. This Committee is chaired by the Presidential Adviser on Environment, Rear Admiral (Ret'd) Gary Best. The NTC provides guidance and overarching direction to the project, with responsibility for policy direction and the final approval of project outputs. There is no fixed schedule for meetings, thus, the Committee meet as a group when necessary. To date, three meetings were held to review and approve priority sectors and short-listed technologies and recommendations, feedback and follow-ups were forwarded to the Consultant through the TNA Coordinator. According to TNA guidance notes, specific responsibilities of the NTC include:

- Identifying national development priorities and priority sectors for technology needs;
- Deciding on the constitution of sectoral/ technological working groups;
- Approving technologies and strategies for mitigation and adaptation based on the recommendations of the sectoral groups; and
- Approving preliminary reports and the Technology Action Plan.

2.1.2 TNA Project Coordinator

The TNA Coordinator is a current staff of the implementing agency OCC and is responsible for the day to day activities of the project. The TNA Coordinator reports to the NTC and is the communication link between the consultants and the members of the national/global team. Initial review of draft and final reports is also performed by the TNA Coordinator.

2.1.3 Sector Working Groups

There are three SWGs, one for each adaptation priority sector: agriculture, water resources and, coastal zone and low-lying communities. The SWG is a stakeholder engagement process of the TNA, which includes representatives from the public and private sector, Non-Governmental Organisations (NGO), community groups, suppliers, end users of technologies and financial institutions. Some members, depending on their field of expertise, act as representative on two or all three SWG and may also be a member of the NTC. See **Appendix 2** for details on the representatives of the SWG. The consultant interacts directly with the SWG and other stakeholders through various media including, electronic mail, telephone and in face-to-face meetings. The meetings are arranged on a needs basis and in particular, when the SWG is required to deliver specific outputs in the TNA process.

2.1.4 National Adaptation Consultant

A National Adaptation Consultant (NAC) was recruited in collaboration with UNEP-DTU to undertake research, analysis and synthesis for technology transfer to strengthen climate resilience in Guyana. The NAC works in collaboration with the TNA Coordinator and the NTC, including other adaptation experts. The NAC's overall task is to coordinate and support the entire TNA process for the adaptation component ranging from engaging with stakeholders, identifying priority adaptation technology needs, prioritisation and assessment of technologies, to the development of a national TAP and formulation of concept notes for selected technologies. Specific tasks for the NAC are[4]:

1. Providing support to the identification and categorisation of the country's priority sectors, and identification and prioritisation of technologies for adaptation through a participatory process with a broad involvement of relevant stakeholders, including;
    a. identification and link-up with relevant stakeholders and facilitation of sectorial (adaptation) working groups,
    b. identification of institutions for data and expert support.
2. Leading the process of analysing with the stakeholder groups how the prioritised technologies can be implemented in the country and how implementation circumstances could be improved by addressing the barriers and developing an enabling framework based, *inter-alia*, undertaking of local market and other assessments, as may be required;
3. Preparing the TAP, which will outline essential elements of an enabling framework for technology transfer consisting of market development measures, institutional, regulatory and financial measures, and human and institutional capacity development requirements. It will also include a detailed plan of actions in order to implement the proposed policy measures and estimate the need for external assistance to cover additional implementation costs.
4. Conducting a techno-socio-economic appraisal and assist in the development of proposals for priority projects in the context of adaptation.
5. Preparing inputs and necessary assistance in the preparation and finalisation of the TNA and TAP reports and final report for the country, with inputs of stakeholders included.
6. Preparing working papers and other TNA-related documents as may be required to ease the consultative process and harnessing inputs from stakeholders during meetings, workshops, amongst others.
7. Providing any other inputs, as may be required, relevant to the adaptation part of the TNA process and output targeted as may be requested by the TNA Coordinator, the UNEP DTU Partnership, the Regional Centre (Libélula, Peru) and the NTC.

[4] Extracted from the NAC Terms of Reference

2.2 Stakeholder Engagement Process Followed in the TNA- Overall Assessment

Stakeholder engagement has been effected mainly through the NTC and SWGs. The project team considered this adequate at this stage in the TNA process, and several meetings were held with the SWGs and sub-committees of the NTC to review, discuss, recommend and approve the selection of sectors and identification of technologies for adaptation. This proved to be effective in expediting decisions by the NTC, particularly, where clarification is required on the process and technology options.

Stakeholders included senior level and technically competent representatives from government institutions, academia and non-governmental organisations. See **Appendices 1 & 2** for lists of members of the NTC and SWGs. Representatives from financial institutions, end users, private sector etc. have been identified to participate in the next stages of the TNA process.

The SWGs provided the critical technical and non-technical input throughout the technology prioritisation process. Six meetings with the SWGs, two per sector were completed. One-on-one meetings were pursued as needed and follow-up was done, mainly, via email. All meetings were facilitated by the consultant and supported by the project team.

All stakeholders involved to date have been provided with an orientation of the TNA Project and the tools to be used in the prioritisation of technology options. Specifically, the MCA excel tool was introduced to the SWG and effectively used to complete the prioritisation of the final technology options. Stakeholders were most engaged during the sessions and provided valuable input into the discussions.

Chapter 3: Technology Prioritisation for Agriculture Sector

3.1 Key Climate Change Vulnerabilities in the Agriculture Sector

3.1.1 Overview of the Agriculture Sector

Historically, agricultural activities have been concentrated along the coastal belt where the majority of Guyana's population resides and is a significant source of livelihood. The two main crops, rice and sugar, are the lead export earners. Approximately 31% of total exports were agriculture products and this excludes forest products. In 2013, rice exports totalled US$243M (14% of total exports); sugar totalled US$132.2M (9.5%); shrimp and fish US$63.9M (4.6%); timber US$39M (2.8%) and other crops (fruits & vegetables) US$4.7M (0.3%) (MOA, 2013).

Agriculture is more than a revenue earner for Guyana. It is a way of life for some 25,000 farm households, most of whom are located on the coastal plain covering some 400,000 ha of arable land across administrative regions 2, 3, 4, 5 and 6. The MOA has indicated that an estimated 1,740,000 ha of land are being used for agricultural purposes. However, only about 200,000 ha (500,000 acres) are used effectively with relatively adequate drainage and irrigation. About 100,000 ha additional agricultural lands are occupied with crops, but these have minimal or no drainage and irrigation. The National Land Use Plan (August 2013) indicates that 68% of Guyana's land area has soils which are deemed suitable for agriculture, while 32% were considered to have soil unsuitable for agriculture. It is estimated that about 3.3M ha (included in the 68% of suitable land) of additional agricultural land can potentially be brought into use (MOA, 2013). Some examples of land usage in the sector are: rice: 90,000 ha; sugar cane: 48,000 ha; non-traditional crops: 30,000-40,000 ha and livestock: 158,473 ha.

Crops and livestock production are characterised mainly by small scale farmers in Guyana, farming less than 15 ha of land. Apart from rice and sugar, Guyana has sizeable market in non-traditional crops. The largest share of agriculture production is made up of crops representing 24.5% of agriculture GDP and 4.8% of total GDP (MOA,2013). It is also the major source of income and employment for small scale farmers. Major non-traditional crops include, coconuts; ground provisions; vegetables such as, tomatoes, cabbage, pumpkin, bora, ochre, boulanger, squash, cucumber; herbs, spices and seasonings; fruits: banana, pineapple, pear, carambola and watermelon, and to a lesser extent, other crops: coffee, cocoa and cotton. Other types of cultivation practiced include, pasture/forage, ornamentals and floriculture. Livestock include, dairy and beef cattle, swine, poultry, sheep, goats, rabbits, bees and other wildlife. Guyana is "self-sufficient" in fresh meats, but not in milk (MOA, 2013). Some sub-sectors, such as swine and small ruminants, operate at subsistence level and livestock production is still well below potential capacity. The major producers in this sub-sector are poor rural households, many depending directly on the sub-sector for their livelihood, while others are supplementing their income from the output produced in this sub-sector.

Guyana has a thriving fishery industry, exporting over 21,000 tonnes of fish, prawns and fish products in 2013. The exports from this sector have consistently surpassed US$50 million since 2004 (GoG, 2013). Inland fishery, although not well developed is now growing. Aquaculture production occupies some 3,000 ha of land around the country (GoG, 2013) and with new markets, is expanding. In addition, the fisheries sector is a significant source of employment and affordable protein for many households. This sub-sector employs around thirteen thousand (13,000) people in the primary and secondary sector (FAO 2005). Others also benefit indirectly through fishing related industries such as boat building and gear supply and repair. The estimated per capita annual consumption of fish was 54kg in 2003, among the highest per capita consumption of fish and fish products within the Caribbean region (GoG, 2013).

Guyana is considered food secure, with much of its agriculture produce consumed in its domestic market. Most of the country's rice is produced by small scale farmers who will be severely affected by droughts and heavy rains. Many farmers practice an integrated type of system, combining crop production with some cattle rearing (GoG, 2013).

Finally, commercial agriculture is an imperative for many households on the coast. Many engage in small scale farming as their source of livelihood and to supplement income. Hinterland communities depend heavily on the sector to provide cassava, which is then converted into other products. Most of the farms are family owned small farms (under 5 ha) and any shock to the sector can have disastrous economic and social impacts, such as, loss of livelihood and threat to the wellbeing of households and communities.

3.1.2 Overview of Climate Change Vulnerability in the Sector

Climate change and sea-level rise are expected to result in greater risk of coastal erosion. Mangrove forests may be negatively affected by sea-level rise, threatening fertile agricultural lands protected by these defences. Assessments of the low-lying coastal plain concluded that a significant portion of land is expected to be inundated with large negative impacts to the rice sub-sector. Sugar cane and to a lesser extent mixed farming, cash crops, coconuts and grazing areas will also be affected. In an assessment using crop modelling technology to evaluate potential impacts of climate change on potential yields, such as, yields limited by soil water for rice and sugarcane crops, it was found that sugarcane would very likely be negatively affected by climate change through decreasing yields from increasing drought like conditions and rice production would be less impacted, since it relies heavily on irrigation (GoG, 2012).

Table 7 shows future (2040-2069) projections for sugarcane using two scenarios whereby, CO_2 fertilisation effect will likely reduce sugar cane yield losses for the future climate (GoG,2012).

Table 7: Sugarcane yields for Guyana under the future climate (2040-2069) according to the CGCM1 and HadCM3 scenarios, with and without CO_2 fertilization (t/ha).

Climate Scenario	CGCM1-with CO_2 (t/ha)	CGCM1-without CO_2 (t/ha)	HadCM3-with CO_2 (t/ha)	HadCM3-without CO_2 (t/ha)
Mean Yield (t/ha)	51.28	49.11	54.17	52.00
Yield Change (%)	-40.85	-47.06	-33.33	-38.89

Source: GoG, 2012.

Constraints on crop growth will affect yields and drive up production cost, particularly in areas experiencing water deficits and where irrigation may be needed. Since the bulk of agricultural activities are practiced on the coastal zone, there is the added threat from saline water incursions through inundation and intrusions. Already, these impacts are being experienced at varying degrees across the country (GoG, 2012).

To date no comprehensive assessment has been undertaken on the impact of climate change on livestock and fisheries in Guyana, even though these are sub-sectors which will be hard hit by drought and extreme flood events. Some of the direct effects of climate change expected are an increased spread of existing vector-borne diseases and macro parasites of animals, as well as, the emergence and spread of new diseases. Temperature changes can cause a shift in the range of fish species and a disruption to fish reproductive patterns. Also, rising sea-levels could affect important fishery nursery areas. Warming, can increase disease transmission and have an influence on marine pathogens (IFAD, not dated).

3.2 Decision Context

The focus of the TNA for the agriculture sector is to identify the technologies which will enhance the sector's capability to adapt to the impacts of climate change, as well as, complement existing technologies. The technologies identified are intended to address the needs relating to crop management, water conservation, waste management and planning for the sector. Experts and policy makers have recognised the need for a more modern and resilient agriculture sector, which can be achieved through the adoption of new farming techniques and planning tools. The National Strategy for Agriculture 2013-2020 provide a detailed roadmap of the sector's needs and plans, based on twenty-five (25) priority areas which include, focus on farming systems, water security and weather forecasting (GoG, 2013).

Over the years, Guyana has rolled out key initiatives in the agriculture sector to strengthen food security and enhance productivity as it prepares to combat the effects of climate change:

- Food and Nutrition Security Strategy (2011-2020) which focuses on rural small holder farmers aim to enhance agriculture production/ productivity and promote the consumption of a healthy nutritious diet;
- The 'Grow More' food campaign which introduced the implementation of a five-step plan, a US$21.9 million agricultural export diversification programme, a US$6 million rural enterprise and agricultural development programme, investment in drainage and irrigation, and training farmers to manage the maintenance of rehabilitated structures;
- Guyana's LCDS which identified key areas related directly to nurturing investment in high potential, low carbon sectors such as fruits, vegetables, aquaculture and, investment and development by the indigenous population in areas such as, cattle rearing and value-added production; and
- Development of a NASAP for the agriculture sector in Guyana by the Caribbean Community Climate Change Centre (CCCCC).

Additionally, with enhanced drainage and irrigation infrastructure, and improved extension services, there is ongoing research by National Agricultural Research and Extension Institute (NAREI) to introduce new varieties of crops, cultivation techniques and the establishment of a seed storage facility and gene bank. Rural diversification programmes and the use of alternative energy (hydropower and biofuels) are also being implemented.

3.3 Overview of the Main Existing Technologies in the Agriculture Sector

This section provides an overview of the main existing technologies found in the agriculture sector while Section 3.4 provides an overview of the technologies selected during the TNA process for prioritisation.

3.3.1 Crop Diversification and Introduction of New Varieties

Crop diversification and new varieties are highly promoted in the sector to build resilience to environmental stresses, introduce more crop variety for local and export markets and, contribute to health and nutritional value. Guyana has traditionally practiced large scale monoculture of a few crops, rice, sugar, coconuts, cassava, long beans etc. However, in recent years, agriculture diversification has become a sector policy with some success. Commodity species and production systems diversification are encouraged in the sector. Production systems are being developed as adaptation measures to combat the effects of climate change. Such systems include protected seedling production, shaded cultivation (inclusive of hydroponics) and the use of drip irrigation systems, combined with fertigation (GoG, 2013).

Generally, farmers need to be more informed and supported in adopting this type of technology for larger scale success. Globally, agriculture research has shown that wider crop variety and improved cultivars can help to reduce the risk associated with crop losses, low yields and income insecurity. Although the risk cannot be entirely eliminated, crop diversification and the planting of varieties more appropriate to the changed environment help farmers to reduce the risks caused by climate change.

3.3.2 Shade House Cultivation

Cultivation under shade (using mesh or plastic) is a technique that is currently being adopted as a climate smart agriculture practice by farmers, who have recognised the numerous benefits from this system. There are different combinations that could be used and raised beds are best practice. With the increase in the frequency of high precipitation events in Guyana, which can be worsened by climate change, causing more field flooding, problems will be created for field operations such as more soil compaction; possible crop losses due to lack of oxygen for roots and disease problems associated with wet conditions. Thus, this is an adaptation technique which can help strengthen resilience in the sector.

3.3.3 Aquaculture

Aquaculture farming has been recognised as an emerging sub-sector and is being promoted as an alternative technology to supplement the traditional inland and marine fisheries sectors. Current production in Guyana occupies an estimated 3,000 ha of aquaculture space. The main species farmed include, Tilapia, Mullet, Querriman, Bashaw, Black Shrimp, Tambaqui and Hassar. According to the Fisheries Department, MOA, the total aquaculture production for 2013 was estimated at over 218,000 kilograms. It has been noted that over the years the production of fingerlings has increased at the Mon Repos Aquaculture Station from 20,000 in 2008 to 93,180 in 2013 and distributed to farmers countrywide (GoG, 2013).

3.3.4 Drip and Sprinkler Irrigation

Increased temperature will tend to increase crop water demand and evapotranspiration. Many crops in the hinterland such as cassava and spices are not irrigated and depend on seasonal rainfall, which will be affected by climate change. In recent years, this technology has gained momentum in Guyana and is being widely promoted in the sector (NAREI, 2013). Through the project 'Improving the Nutrition and Health of CARICOM Populations under the Canadian International Food Security Research Fund, vegetable farmers were provided with scientific information on irrigation water application rates, as well as, the timing of application for year-round sustainable food production. Experiments were conducted on farmers' fields in two major vegetable growing regions (Black Bush Polder and Parika) and the initial results showed potential yields of the crops were attained with the use of drip irrigation (NAREI, 2013).

3.4 Adaptation Technology Options for the Agriculture Sector and their main Adaptation Benefits

This section of the report presents an overview of the technology options identified and prioritised through the TNA process for the Agriculture Sector. To avoid overlaps with technology options mentioned in Section 3.3, reference to specific technology options are made, where appropriate. The information in this section refer primarily to the details provided in the Fact Sheets.

3.4.1 Varietal Development of Saline Tolerant Crops

Salinity can have significant effect on crop quality and yield. Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change (Haggar A and Torres, 2011). Strategies for enhancing salinity stress tolerance in crop species include traditional breeding with selection for yield, mutation breeding, screening within phenotype, and introducing germplasm from wild species into the crop species". Rejuvenation of germplasm lines and maintaining genetic purity of commercial varieties and production of sufficient quantity of seeds of high genetic purity is also a priority, as well as, hybridization to create variability for increased yield potential, salt tolerance, aroma, and submergence tolerance.

Traditionally, research has focused on rice and sugar crops to improve variety, quality and yields. In recent years, varietal development of vegetable crops has gathered momentum, encouraged by the need to promote crop diversification and build resilience to climate change. The rice and sugar sub-sectors have been self-contained in terms of technology development and transfer by the Guyana Rice Development Board (GRDB) and the Guyana Sugar Corporation (GuySuCo) respectively (GoG, 2012, 2013). Currently, the GRDB is engaged in work on saline tolerant, drought and flood resistant rice varieties. One of the key objectives is to develop high-yielding varieties of rice with tolerance to lodging, salinity, acidity and resistance to blast, among other desirable characteristics. This technology will contribute to reduction in crop loss, improved food security, stock of germplasms and enhance research capacity.

3.4.2 Freshwater Harvesting

Damming or empoldering of water collection areas is a technology classified in the broad context of macro-catchment water harvesting. This is a method of harvesting water from a natural catchment (Mekdaschi Studer *et al.*,2013) and the water is used for agriculture (crop and livestock production) and domestic purposes. The runoff is stored in a dammed catchment area that captures the overflow of excess water. Aside from open surface water storage in dams and or ponds, other Macro-catchment water harvesting technologies are hillside runoff / conduit systems; large semi-circular or trapezoidal bunds (earth or stone); road runoff systems; groundwater dams (sub-surface, sand and percolation dams); above- or below-ground tanks (cisterns); horizontal and injection wells (Mekdaschi Studer *et al.*,2013).

Guyana's agriculture sector is highly dependent on water availability and it is important that adaptation strategies ensure the continuous supply of freshwater. One such option is the harvesting of freshwater through empolderment of catchment or water augmentation to collect and store surface water for use during the dry periods. This method ensures water is stored and available locally, especially the outlying or inland regions to prevent food insecurity and displacement of population as a result of drought. The deployment of the technology in the agriculture sector contributes to climate change adaptation by providing a source of water for crops in dry conditions. Having a stable source and supply of irrigated water increases the resilience of the sector to increasing temperatures and dry conditions. The catchment also allows for the storage of excess water during periods of extreme rainfall and as a result reduces the impacts of flooding on communities.

3.4.3 Agro-meteorology

Agro-meteorology deals with all the weather-sensitive elements of agriculture production. As a discipline, it includes the monitoring of pollination, animal migration, trafficability, transport of pathogens by wind, irrigation, climate manipulation and artificial climates, weather risk assessments, the use of weather forecasts in farming, crop yield and phenology forecasts, and providing advice to farmer, as well, as the required data and methods (FAO, 2005).

As a technology for forecasting and Early Warning System (EWS), agro-meteorological systems can range from a few observation units to highly sophisticated and complex network of Automatic Weather Stations (AWS) and/or agro-meteorological stations. A typical agro-meteorological system consists of several AWS and/or agro-met stations installed at strategic locations, which collects/store localised weather data for as much as twelve (12) parameters, including, wind speed and direction; precipitation; humidity; temperature; solar radiation; sunshine durations and soil moisture/temperature (WB, 2016).

An AWS typically consists of a perimeter fence, box enclosure containing the data logger, rechargeable battery, telemetry and the meteorological sensors with an attached solar panel. Data from the AWS are transmitted in real time to a central server which can be viewed from a web-based system through internet. The instruments are equipped with data storage system, thus, data downloading can also be done on a daily, weekly or monthly basis. The frequency of data collection can also be programmed according to the needs and use of such information. In addition, a telemetry system allows for remote access through mobile short message service (SMS) or other form of messages in real time.

This capacity is currently limited in Guyana and will be extremely beneficial to all stakeholders, especially farmers since it will provide advance information on weather conditions and projections. Agro-climatic data can help to determine the exact water requirement of crops in a specific area and enable farmers to better plan their cropping pattern. For instance, using the information obtained from the stations, farmers can be guided on the degree of soil moisture and can decide when their crops would need irrigation, or data on the forecasted timing and amount of impending rain can help determine what measures farmers should take (WB, 2016). The adaptive capacity of the sector and country to respond to weather related emergencies through improved networking and communication channels at the institutional and grassroots levels will be bolstered. Better forecasting can also help with risk assessments and planning for the sector's investments. Generally, with a strengthened capacity in early warning, farmers and local communities are better able to manage their resources and reduce their vulnerability.

3.4.4 Composting

Changes in temperature and rainfall, flooding from sea-level rise and storm surges, droughts which eventually lead to reduced soil water retention capacity and increased erosion, exert significant impact on overall crop production and yield. Successful adaptation to climate change requires healthy soils for farming and improved soil conditions through organic agricultural practice, such as, composting. In simple terms, it includes the accumulation, sorting, screening, curing and mixing of various feedstocks such as animal waste, crop residue, weeds and municipal household organic wastes to allow for decomposition by fungi and bacteria. Other adaptation benefits include the reduction of the quantity of inorganic (nitrogenous) fertilisers used by farmers in agriculture, thus indirectly preventing the pollution of water ways through run-off. Composting also has a mitigation co-benefit where it allows for the reduction of nitrous oxide and methane. Nitrogenous fertiliser is replaced with organic (compost) materials and methane emissions are reduced through improved management of livestock waste where it is used as a source material for composting.

3.5 Criteria and Process of Technology Prioritisation

3.5.1 Criteria, Weighting & Scoring

A list of criteria was developed as shown in the decision matrix with the long-list of technologies in **Table 8.** This was circulated to the SWG prior to the prioritisation of the technologies meeting held on December 01, 2015. Eleven(11) stakeholders, comprising government, academia and technical experts from the MOTP; MOA and its sub-sectors – NAREI, Guyana Livestock Development Authority, GuySuCo and the GRDB; Institute of Applied Science and Technology; University of Guyana – Faculty of Agriculture; Guyana School of Agriculture and the Environment Protection Agency (EPA), participated in the meetings of the SWG. The objectives of the meeting were to:

- Review the long list of technologies for the sector;
- Identify additional technologies for the sector, as necessary;
- Prioritise technologies using the three recommended pre-screening criteria listed below.

Pre-screening criteria for short-listing:

- The technical potential of the technology;
- How will the technology promote climate resilience; and
- Synergy with national development strategy and policies.

Table 8: Prioritisation of Technologies from long list for the Agriculture Sector

No.	Technology Category	Specific Technology					Notes
		Long List	**TP**	**CR**	**NDP**	**Short List**	
1	*Crop management*	Integrated Pest Management				N	Practiced informally. Not considered an urgent priority.
2		Crop diversification				N	Overlap with #4
3		Flood resistant crops				N	Overlap with #4
4		Varietal development (flood, drought, salinity)	X	X	X	**Y**	Subsequently revised for more targeted focus to "Varietal development of saline tolerant crops"
5		Seed and grain storage				N	National facility under construction. Plans ongoing
6	*Fisheries management*	Aquaculture				N	Fairly developed in country and included in sector strategies
7	*Livestock management*	Selective livestock breeding				N	Breeding programme exist. Can be included in 'varietal development'
8		Pasture restoration				N	Limited technical potential and not a national priority.
9	*Farming Systems*	Agro-forestry				N	Not an immediate priority
10		Integrated Mixed farming				N	Not an immediate priority
11		Shadehouse/Greenhouse				N	Introduced in country and gaining momentum in practice.
12		Aquaponics				N	Low technical potential and interest
13		Hydroponics				N	Low technical potential and interest
14	*Sustainable water use*	Micro-irrigations (drip/sprinkler)				N	Technology introduced and available
15		Freshwater Harvesting for inland regions: *Empoldering of water collection areas* *Drip & sprinkler irrigation*	X	X	X	Y	Mostly hardware. Focused on Empoldering
16		Rainwater harvesting				N	Good potential. Exist already
17	*Sustainable Waste Management*	Composting of agriculture solid waste (livestock & crop)	X	X	X	Y	Hardware and orgware
18		Integrated nutrient management (organic and inorganic)				N	Not an urgent need.
19	*Planning for climate variability*	Agro-meteorological system for forecasting and early warning	X	X	X	Y	Hardware, software, orgware
20		Extension system to promote green technologies in agriculture				N	Not a current need
21		Agriculture insurance				N	Environment not conducive

TP- Technical Potential; CL- Climate Resilience; NDP- National Development Priorities; Y- Yes; N- No; X – Satisfy criteria

The consultant facilitated the discussion and participation was highly satisfactory. Due to the small size of the group, it was easier to complete the discussions and selection as a single group. It was emphasized that technologies be targeted and as specific to the market as possible. Caution was made against trying to address too many needs through a specific technology, which can result in a wide focus. In the long list of technology, twenty-one (21) options were identified based on the country's priorities, the impacts in the sector, the type of technology and its application to the local context. New and emerging technologies were also considered for possible introduction. From this list, four (4) technologies were shortlisted as priorities for the sector and was approved by the NTC to advance to the next stage of the assessment, that is, the preparation of fact sheets and completion of a MCA. Some of the reasons considered in the non-selection of technology options were:

- The technology was not considered as an urgent priority;
- The technology was available locally and have some level of maturity;
- National programme/s exists and measures are underway for strengthening;
- There was some overlap with other technologies, for example, crop diversification and new varieties, and flood resistant crops were considered as adequately addressed under 'varietal development for flood, drought and salinity', which included crops and livestock; and
- The technology has limited technical potential.

In the final short list, technologies were selected based on how strongly it satisfied the criteria for short - listing. Others were rejected based on one or more of the following:

- Whether there were existing/planned programs for the technology already;
- The technology did not satisfy the three pre-screening criteria above; and
- The technology did not satisfy the TNA definition of hardware, software or orgware.

Applying UNEP-DTU guidelines for TNA assessments, three criteria categories – adaptation benefits, development benefits and cost, and a list of twelve (12) criteria as shown in **Table 9**, were identified for the MCA.

Table 9: Criteria Category and Criteria applied in the MCA for the Agriculture Sector

Criteria Category	Criteria
Cost	Implementation Cost
	Operation & Maintenance Cost
Adaptation Benefits	Promote food and nutrition security
	Reduce loss of crops & livestock
	Improve response to weather variability
	Improve farm management (soil fertility, pesticide)
	Increase crop and livestock yields
	Promote agrobiodiversity
Development Benefits	Promote livelihood security
	Reduce agriculture production
	Stimulate investment
	Increase income

The list of criteria was presented to the SWG at a meeting on April 04, 2016 for review and selection, followed by the assigning of weights and scores. The selection process followed a simple format, whereby, each criterion was discussed thoroughly, modified where necessary and approved via consensus by the group. A Yes/No/Somewhat value judgment, based on expert views and experience in the agriculture sector, was then assigned to the criteria. From the list of twelve (12) criteria, ten (10) were finally selected for use in the MCA. Following the selection of the criteria, weights were assigned to each criterion based on a value preference of importance. Weights were applied using the 'budget allocation' method, where, the sum of all weights equaled 100. The scale and value preference of the weights and scores applied were:

Weights: 5 – Less important; 10 – average/medium important and 15 – more important

Score: 20 – Very Low; 40 – Low; 60 – Moderate; 80 – High; 100 – Very High

A qualitative approach was applied using the Likert scale (due to the lack of appropriate quantitative data) to determine the scores for each technology option. Technologies were scored against each criterion using the information provided in the fact sheets, as well as, expert opinion. The fact sheets elaborated on each of the short-listed technologies, providing general information on the type of technology, cost (where available), scale of application, adaptation benefits and acceptability to stakeholders etc. Refer to **Appendix 3** for factsheets on the agriculture sector. Table **10** shows scores and weights of the technologies, including scores for sensitivity analysis.

Table 10: **Scoring matrix of short-listed Prioritised Technology Options for the Agriculture Sector**

CRITERIA CATEGORY	COST		ADAPTATION BENEFITS					DEVELOPMENT BENEFITS			TOTAL WEIGHTED SCORE	SENSITIVITY ANALYSIS TOTAL SCORE
CRITERION	Implementation cost	Operational/Maintenance	Promote food and nutrition security	Reduce loss of crops/livestock	Improve response to weather variability	Increase crop and livestock yields	Promote agro-biodiversity	Promote livelihood security	Reduce agriculture production cost	Stimulate investment		
WEIGHT	10	10	15	5	10	10	10	15	5	10	100	
TECHNOLOGY OPTIONS	**SCORES**											
Freshwater Harvesting	100	60	100	100	100	80	80	80	60	80	**85.0**	**70.0**
Agro-meteorology for forecasting and EWS	100	100	80	60	80	80	60	80	60	60	**73.3**	**50.0**
Composting	20	20	60	40	40	80	60	60	60	60	**20.0**	**35.0**
Varietal Development for Saline Tolerant Crops	60	40	80	80	100	100	60	80	60	80	**30.8**	**11.7**
Adjusted Scores for Composting	NA	NA	80	60	NA	60	NA	80	80	80	**NA**	

3.6 Results of Technology Prioritisation

The four (4) shortlisted priority technologies for the agriculture sector were presented to members of the SWG on April 04, 2016 to complete the MCA. It should be noted that prior to this step in the process and based on a recommendation from the NTC, one of the shortlisted technology was found to be too ambiguous. It was therefore suggested that the SWG revise this technology to specific terms. The following three options were proposed and circulated via email to the SWG members for their vote and comments:

- Varietal development of drought tolerant crops;
- Varietal development of saline tolerant crops; and
- Varietal development of flood resistant crops.

Feedback was limited from the SWG and a decision was taken to proceed with the recommendation received: *Varietal development of saline tolerant crops.* However, at the SWG MCA meeting on April 04, 2016, an objection was raised regarding the focus of this technology. One member opined that technologies to combat salinity has limited application and there were other national priorities, such as, the development of varieties to promote resilience to flood and pests. Following discussions on this matter, it was agreed that the MCA should proceed with the current technologies as listed.

Final short-list of technologies:

- Varietal development of saline tolerant crops;
- Freshwater harvesting: Empoldering of water collection areas;
- Composting; and
- Agro-meteorology for forecasting and early warning.

The MCA was completed and a ranking was obtained for the four technologies. A sensitivity analysis was also performed. Although there was no major disagreement, the sensitivity analysis addressed the technology and/or criteria of concern. The technology on composting scores were revised upwards for specific criterion. This reversed the initial ranking between 3 & 4 as can be seen in the **Table 11**. The scores were adjusted for criterion within the adaptation and development benefits categories. Stakeholders took into consideration that composting, on a commercial scale can have increased benefits within the two categories and therefore, should have higher scores to reflect those benefits. During this process, all opinions were considered and consensus achieved for each weight and score. **Table 11** shows final results, ranking and selection from the MCA.

Table 11: Summary of MCA results for the Agriculture Sector

Rank	Technology	Weighted Score/Rank	Sensitivity Analysis Score	Selected for Barrier Analysis
1	Freshwater Harvesting	85.0	70.0	Yes
2	Agro-meteorology for forecasting and EWS	73.3	50.0	Yes
3	Varietal Development for saline tolerant crops	30.8	11.7	No
4	Composting	20.0	35.0	No

At the conclusion, consensus was achieved among the SWG on the results. Stakeholders agreed that the ranking derived from the original analysis be used and the top two (2) technology options listed below should proceed to next stage of the TNA process:

1. Freshwater Harvesting; and
2. Agro-meteorology for forecasting and early warning

Chapter 4: Technology Prioritisation for Water Sector

4.1 Key Climate Change Vulnerabilities in the Water Sector

The water sector is critical for Guyana's socioeconomic development; however, it is one of the sectors projected to experience significant impacts from the effects of climate change. The sector's vulnerability, the availability and quality of water resources, therein, is determined by the two climate-induced threats, (i) extreme precipitation, where, the excess leads to flooding and lack of rainfall, resulting in water deficit and (ii) flooding as a result of sea-level rise and storm surges (GoG, 2012).

Key sectors in Guyana such as agriculture, fisheries, forestry, mining, manufacturing and settlements are highly dependent on water resources. Therefore, water availability in general, is critical for the sustainability of these sectors. While the sectors may have already contributed to water stress conditions, climate-induced impacts will likely exacerbate the effects. Water scarcity may become more severe in already stressed areas. Based on projections in the SNC, precipitation is expected to decrease and will therefore become more variable over time. Higher temperatures and decreases in rainfall will increase drought-like conditions, leading to significant water deficits for domestic, industrial and commercial purposes (GoG, 2012). Water deficits can contribute to saline intrusion into aquifers and soils, and as a result, introduce salt water further upstream of rivers. Projections relating to future changes in the spatial changes of rainfall, show that generally, annual and seasonal rainfall would decrease slightly (~ 10 %), especially in the 2090s, and that these decreases in rainfall would mainly affect the northern half of Guyana, including the critical coastal zone (GoG, 2012).

Currently, Guyana is experiencing one of its worst droughts in many years as a result of prevailing El Niño weather pattern since the last quarter of 2015. Region Nine (Upper Essequibo-Upper Takutu) has been one of the worst hit areas. Other affected Regions include Regions One (Barima-Waini); Two (Pomeroon-Supenaam); Five (Mahaica-Berbice); Seven(Cuyuni-Mazaruni) and Eight (Potaro-Siparuni). Farmers reported losing more than 7,000 acres (2,830 ha) of rice fields and hundreds of acres of cassava and peanut fields (Daily Mail, 2016).

With climate change and an expected consequent rise in sea level, salt water intrusion into rivers and possible adverse effects on aquifers is a major concern, according to a study by Narayan, 2006. The study also indicated that most of the settlements on coastal rivers located within a few tens of kilometers from the coast and within a few hundreds of metres from the edges of the rivers, including the vast agricultural areas of the country are expected to be affected by salt/brackish water intrusion. Water for domestic and agricultural requirements is extracted from the rivers. With salt/brackish water penetration getting further inland, the adverse effects expected can be summarised as follows:

- The concentration of salt content will be increased. This will be detrimental to agriculture, as there will be further penetration of salt water into the land; and
- Water tables will rise and because of the higher salt content, prime agricultural lands now under cultivation will become useless.

In terms of water use, the highest population density is within the coastal area, and with the exception of Georgetown, all residents on the coast depend on groundwater supply to meet their domestic needs. Estimates show that total water withdrawal in 2010 was 1444.7 million cubic metres per year, of which approximately 94.4 percent was for agricultural purposes, 4.2 percent for municipal and 1.4 percent for industrial purposes. See **Table 12 and Figure 3.**

Table 12: Estimated values of withdrawal of water

Water Withdrawal	Year	Quantity	Unit
Total Withdrawal	2010	1444.7	Million m^3/year
-Agriculture (irrigation + livestock + aquaculture)	2010	1363	Million m^3/year
-Municipalities	2005	61.3	Million m^3/year
-Industry	2005	20.4	Million m^3/year
Per habitant	2010	1838	M^3/year
Surface water and groundwater withdrawal (Primary & secondary)	2010	144.7	Million m^3/year
As % of total renewable water resources	2010	0.5	%

Source: FAO, AQUASTAT

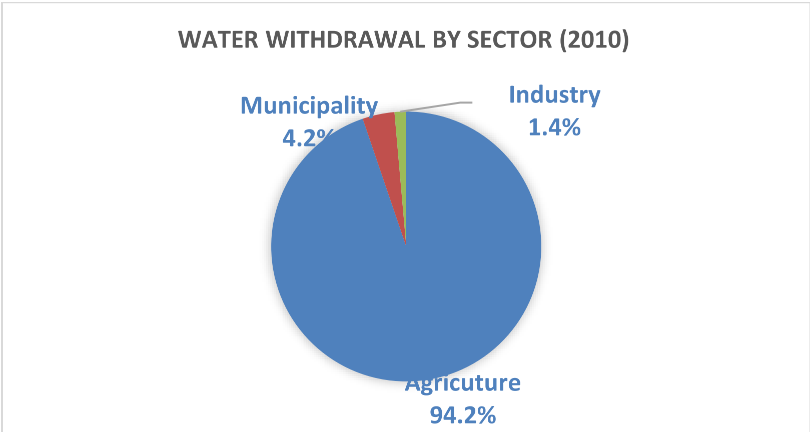


Figure 3: Percentage of water withdrawal per sector (2010)
Source: FAO, AQUASTAT.

Updated and reliable data on water sources, quantity and uses is limited. The Guyana Water Incorporated (GWI) collects data on water quality from wells along the coast. However, no data is available specifically on salinity. This may be deduced from the electrical conductivity levels.

Despite having well established national institutions and agencies overseeing water-related matters, there is a lack of monitoring data to make informed decisions on efficient use and management of water resources. Data is a vital input to water management and investment in water related infrastructure projects, such as, hydropower and sea/river defences. New and updated technologies are needed to coordinate data collection, collation, analysis and dissemination. As a result, Guyana needs to strengthen the capacity of institutions through the acquisition of appropriate technology and training.

4.2 Decision Context

Water resources in Guyana provide a range of existing and potential services such as, irrigation for its vast agriculture sector, domestic and commercial supply, ecotourism and hydropower. Projections show that these services will be severely affected with increased flood events and drought conditions. In the water sector, capacity exist at varying degrees. Generally, hydrological data and technical capacity is limited. There is also lack of an integrated water management system. The technologies identified for the sector were guided by the existing and future threats to water availability, downstream impacts, available capacity and the need to strengthen the adaptive capacity of all water users.

To date, limited studies have been completed for the sector. In 1998, a water resource assessment was completed by the United States Army Corps on the status of water resources in the country. Scenarios were also developed using climate models showing water deficits, evapotranspiration and precipitation along the coast where estimates show that Guyana will be confronted by a general drying trend (GoG, 2012).

Currently, the management of water resources in Guyana is dispersed between two key agencies with specific responsibilities, namely, MOA and the GWI. Other aspects of water management, such as, drainage and irrigation are shared with other agencies/mechanisms such as, MoPI, the National Drainage and Irrigation Authority (NDIA), Mahaica, Mahaicony, Abary/Agriculture Development Authority (MMA/ADA) and Water Users Associations (WUA). The WUAs assist with the maintenance of the secondary drainage and irrigation systems in the agriculture sector. Plans are also underway to resuscitate the National Water Council (NWC).

4.3 Overview of Existing Technologies in the Water Sector

This section provides an overview of the main existing technologies found in the water sector while Section 4.4 provides an overview of the technologies selected during the TNA process for prioritisation.

4.3.1 Rainwater Harvesting

Rainwater harvesting (RWH) in Guyana is widely practiced mainly for domestic purposes, particularly, along the Coast. It is collected from roof tops into large, plastic storage tanks. According to a study by Intven 2009, almost 15% of the population depend on rainwater harvesting as their primary source of drinking water. In urban areas, some 16% of the population use rainwater as a drinking water source and, in rural areas, the percentage is even higher at about 27%. Domestic use of rainwater suggest that, the Guyanese population view rainwater as high quality water and it is harvested specifically for drinking purposes (Intven,L, 2009). Rainwater harvesting for agriculture purpose is not common in Guyana. In hinterland areas, with increasing dry conditions, there is a need for more storage of water in large quantities. However, the cost to implement a large scale storage system can be high for individual households in hinterland communities.

4.3.2 Conservancy Management

Conservancies are shallow reservoirs, fed by streams and canals, offering a consistent supply of water year-round and some flood control (GoG, 2012). Along the coastal plain and part of the interior highlands, there is a system of drainage and irrigation canals that feed into the conservancies, designed to provide primarily irrigation water and secondarily, other water needs. In Guyana, water conservancies are located in Regions 2, 3, 4 and 5, including, the Essequibo Coast, Tapakuma Conservancy, the Boerasirie – West Demerara, the East Demerara Water Conservancy (EDWC) and the Mahaica/Mahaicony/Abary (MMA). Located in Region 4, the EWDC is one of the major conservancy, with an impoundment area of some 550 ha. Changes in sea level rise and severe rainfall events pose serious threats to the EWDC system, which has weakened over the years from severe weather events. According to estimates, repairing the EWDC can cost between US$200- US$300 million (GoG, 2012).

4.3.3 Drainage and Irrigation

Assessments have indicated that Guyana's D&I System (over 100 years old) is under stress and sea level rise will exacerbate this condition, due to the shrinking of the "discharge window" from low tide to mean tide (GoG, 2012). On the coast, where the land surface is below sea level and there is the threat from tidal flooding, excess water is a major concern. These lowlands are drained of water through a series of canals and a system of sluices/ gates which allow the water to drain via gravity flow into adjacent rivers or into the Atlantic Ocean (GoG, 2012). The country's D&I systems, once adequate, have deteriorated over the years because of a lack of maintenance.

At the institutional level, the NDIA is the primary institution responsible for addressing the management, improvement, extension and provision of drainage, irrigation and flood control infrastructure and services in ‘declared’ areas of the country (MOA, 2013). In the interest of sugar cane cultivation, GuySuCo also maintains a network of drainage system.

4.4 Adaptation Technology Options for the Water Sector and their main Adaptation Benefits

This section of the report presents an overview of the technology options identified and prioritised through the TNA process for the water sector. In order to avoid overlaps with technology options mentioned in Section 4.3, reference to specific technology options are made, where necessary.

4.4.1 Groundwater Mapping and Modelling

There is limited hydrologic data for the country, particularly since the late 1960’s when data collection decreased dramatically. To understand how ground water works and the risks posed by increased extraction, hydropower generation and climate change, there is a need to monitor and determine the long-term viability of ground water resources (US Army Corps of Engineers, 1998). There is a need to generate/update data on well inventory and characteristics, such as, pumping rates and piezometric heads.

Groundwater mapping and modelling is a highly technical and resource intensive process. Observation wells are created or existing wells are equipped with data logging instruments. Modern data loggers are battery/solar powered and can store water quality data, which can be then be downloaded and used in mapping and models. Groundwater mathematical simulation models, such as MODFLOW exist in several versions, are open sourced and can run on Microsoft systems. Groundwater modelling technology is extremely useful in predicting the effects of hydrological changes on the behavior of aquifers and has advanced significantly in the past two decades. It is now being used many aspects of water management, for example, groundwater models are now used to inform the development of water management plans in urban planning (USGS).

Guyana will experience increasing risks associated with drought and change in seasonal temperatures. According to climate projections using two downscaled climate scenarios, Guyana will experience increases in temperature, increased rainfall in the rainy season and less precipitation in months where there are already water deficits. Severe water deficits will lead to droughts, particularly in the south of the country, as experienced in 1997-1998 during the warm El Nino phase (GoG, 2012). Drier conditions will have an impact on ground water recharge and water quality.

The coastal aquifer system, a series of three separate but hydro-geologically connected aquifers, supply water for some 90% of the population that reside on the coastal lowlands. The rest is supplied by surface water sources. The three aquifers are: The Upper Sands, the A Sand, and the B Sand, with each capable of yielding large amounts of water. However, in 1913 withdrawals from the Upper Sands ceased. Water from this aquifer was found to be high in iron content, brackish and more saline towards the coast (US Army Corps of Engineers, 1998). The *A sand aquifer* which was first developed in 1913, is now considered the principal water source for Georgetown and the coastal lowlands region. This aquifer yields between 4,000 and 40,000 liters per minute year-round. The quality of water withdrawn from this aquifer is good, has low chloride content, high carbon dioxide and iron content, thus, it requires treatment for excessive iron (US Army Corps of Engineers, 1998). The *B sand aquifer* lies below the Upper Sands and the A sand aquifer and is not exploited to the extent of the A Sand aquifer, but has yields of 4,000 to 40,000 liters per minute year-round. The water is fresh with no elevated levels of iron or chloride, however, it has a trace of hydrogen sulfide. This aquifer was first used for domestic water in 1962. Due to the lack of data, no recharge area has been definitively determined for the B sand, but studies indicate that the B Sand may be recharged by infiltration of precipitation in the white sands formation (US Army Corps of Engineers, 1998).

Some examples of other aquifers include, the white sands formation, located in the southern coastal lowlands region and northern interior plains region. This formation is centered around the town of Linden; the Takatu sandstone formation, which is located farther inland in the northern savannahs of the Rupununi; and the Roraima Group, in the western part of the country in the vicinity of the Merume mountains. These aquifers yield small to moderate quantities of fresh water (US Army Corps of Engineers, 1998).

With a growing demand on surface water for agricultural and industrial needs, the monitoring and management of ground water is becoming an increasingly important issue. According to estimates by the Food and Agriculture Organisation (FAO), the internal renewable water resource is estimated at 241 km^3/year with groundwater resource at 103 km^3/year. Aquifers are very convenient sources of water because they are natural underground reservoirs and can have an enormous storage capacity, much greater than even the largest man-made reservoirs. Many aquifers are also able to offer natural protection from contamination, so untreated groundwater is usually cleaner and safer than its untreated surface water equivalent.

4.4.2 Surface Water Mapping and Modelling

To explore options for the future, simulation models are needed to predict future water cycles that can explore the impact of future trends and possible ways for sustainable adaptation (Huo,A, *et al*., 2016). Mapping of water is a prerequisite for water availability, accessibility, fair utilisation and management. According to research, effective data regarding surface water availability for watershed management demands application of geospatial techniques such as remote sensing, image processing techniques and GIS (Huo, A *et al*., 2016; Eshtawi,T *et al*., 2016 ;Bourdin,D, *et al*., 2012). Computer based models can provide a spatially and temporally detailed description of basin-scale hydrologic cycle, and simulate a variety of state and flux variables. For example, various types of software provide tools for the prediction and quantification of water from catchments to the end of a river system by integrating continuous rainfall-runoff and river system models (Eshtawi,T *et al*., 2016). There are also tools for the prediction and quantification of associated constituents, such as, salinity, suspended sediment and nutrient from catchments to a river system and propagation along the river system (Eshtwai, T *et al*., 2016; Huo,A *et al*., 2016).

These type of technologies require significant investment in hardware, software and a supportive orgware framework. Typical data requirements can include digital elevation model, soil, land use, meteorological data and others used for model setup, as well as, models for streamflow, calibration and validation (Huo, A *et al*., 2016; Eshtawi,T *et al*., 2016 ;Bourdin,D, *et al*., 2012). Efficient and informative graphic displays of the large amount of modeling data are highly desired to aid process interpretation and management decision making (Huo, A, *et al*., 2016). For example, specific model simulations may be processed for GIS analysis for floodplain mapping, flood damage computations, ecosystem restoration, and flood warning response and preparedness (US Army Corps of Engineers, 2016).

In Guyana, in addition to the significant decrease in hydrologic data collection over the years, measuring equipment, such as, stream gauges need to be repaired or replaced and efforts are underway to install modern telemetric gauges throughout the country (US Army Corps of Engineers, 1998). Currently, hydrographic surveys are done by the Geodetic Section of the Guyana Lands and Surveys Commission (GLSC) to determine the topography/bathometry of conservancy bed, river bed and ocean bed.

Guyana has an extensive network of rivers and streams that have many rapids and waterfalls, with an absence of naturally occurring lakes. Surface water (which is extracted from shallow reservoirs, streams, or drainage canals) is primarily used for agricultural and industrial purposes. Only about 10 percent of the country's drinking water comes from surface water (GoG, 2012). Guyana faces the typical water pollution problems of developing countries in tropical regions. Biological and chemical contamination of surface water vary in magnitude according to location, but is increasing with population growth and land use demands.

In Georgetown and in populated areas of the coastal lowlands, surface water contamination occurs from inadequate waste disposal and from chemicals used in the production of rice and sugarcane (GoG, 2012). Chemical contamination of surface water also occurs primarily near manufacturing areas, especially along major rivers within mining districts. According to an assessment by the US Army Corps of Engineers (1998), "surface water is laden with sewage, particularly in heavily, populated coastal areas". Another concern cited is, the improper disposal of sawmill waste which raises biological oxygen demand levels and endanger aquatic life in rivers.

Studies have shown that mapping and modelling of surface water has significant benefits as a central and indispensable tool in decision-making processes of policy makers and stakeholders. It is felt that policy makers need reliable simulation models so that decisions can be made on realistic predictions (Huo, A, *et al*., 2016). This technology will reduce vulnerability risks caused by climate change, increased economic activities and population growth. Given the multiple used of surface water (irrigation, livestock, fisheries, hydropower, manufacturing, mining and transport), it is important to assess and reduce water-related risks and vulnerabilities in sectors such as agriculture, energy, health, environment, and urban water utilities as part of overall development planning (UNESCO, 2011).

4.4.3 GIS for Water Catchment Protection

The benefit of water catchment mapping and modelling is to achieve an integrated approach to natural resource management, through a comprehensive view of water and land uses within the catchment areas. The use of Geographic Information Systems (GIS) and remote sensing technology can provide pertinent information on surface and groundwater flows, run off rates, delivery of flows and constituents into river systems. When used in hydrological models, remote sensed data can be converted to the type of information useful to water resource systems operators. With such information on water catchment, areas can be demarcated, micro-catchment areas identified, buffer zones established and water safety plans developed (FAO,2011). GIS technologies can enhance Guyana's capacity to improve overall water management for all water users.

This technology is readily available in North America. The US Geological Survey (USGS)) has been providing leading services in the development of hydrologic simulation models since the 1960's. The models are widely used to predict responses of hydrologic systems to changing stress.

4.4.4 Rainwater Harvesting

Domestic rainwater harvesting can be regarded as a mature technology in Guyana. Refer to section 4.3.1 for details on RWH in Guyana. Recognising the high dependence of the country on ground water sources, projected increase expansion in the housing sector, and vulnerability due to variability of precipitation leading to projected water deficits, it is paramount that adaptation strategies be implemented in the water sector. One such option is through the application of water conservation techniques by diversifying the water supply as in the adoption of technologies such as RWH.

RWH is a low cost practice that is easy to implement and is being promoted by the GWI for application at the individual household level. RWH can also be pursued at the community level, allowing for collection in small concrete reservoirs. Considering the water demand on ground water sources and surface water by coastal and riverine communities, the deployment of this technology contribute greatly to climate change adaptation, through diversification of water supply at the household, industry and community levels. It allows for water conservation by reducing pressure and dependence on the traditional water sources through decreased demand.

4.5 Criteria and Process of Technology Prioritisation

4.5.1 Criteria, Weighting & Scoring

A list of criteria was compiled as shown in the decision matrix with the long-list of technologies in **Table 13.** This was circulated to the SWG prior to the prioritisation of the technologies meeting held on December 01, 2015. Stakeholders, comprising government, academia and technical experts from the MOTP, MOA, NDIA, IAST, University of Guyana – Faculty of Technology, GWI and the EPA, participated in the meetings of the SWG. See **Appendix 2(b)** for list of members. The objectives of this session were to:

- Review the long list of technologies for the sector;
- Identify additional technologies for the sector, as necessary; and
- Prioritise technologies using the three recommended pre-screening criteria listed below.

The following pre-screening criteria were applied:

- Technical potential of the technology;
- How will the technology promote climate resilience; and
- Synergy with national development priorities/strategy.

In the long list of technologies, eighteen (18) technology options were identified based on the country's priorities, the impacts on the sector, the type of technology and its application to local context. New and emerging technologies were also considered for possible introduction. From this list, four (4) technologies were shortlisted as priority for the water sector and approved to advance to the next stage where fact sheets were prepared and the MCA completed. Some of the reasons considered in the non-selection of technology options were:

- The technology was not considered as an urgent priority;
- The technology was available locally and have some level of maturity;
- National programme/s exists and measures are underway for strengthening; and
- The technology has limited technical potential.

In the final short list, technologies were selected based on how strongly it satisfied the criteria for short - listing. Others were rejected based on one or more of the following:

- Whether there were existing/planned programmes for the technology;
- The technology did not satisfy the three pre-screening criteria above; and
- The technology did not satisfy the TNA definition of hardware, software or orgware.

Table 13: Prioritisation Matrix of Technologies in the Water Sector

No.	Technology Category	Specific Technology					
		Long List	**TP**	**CR**	**NDP**	**Short List**	**Notes**
1	*Water conservation*	Rainwater harvesting (collection, storage, treatment)	X	X	X	Y	Mostly hardware. A mature technology on the coast but much needed for inland areas due to increasing dry conditions.
2		Efficient water fixtures and appliances				N	Not a priority. More private sector driven.
3		Water reclamation and reuse (recycling)				N	Possible overlap with # 9.
4		Shade balls				N	Low technical potential.
		Lysimeter (installation)				N	Unsure about need
5	*Groundwater recharge*	Infiltration basins to increase ground water recharge				N	Need scientific studies on ground water first.
6		Water catchment protection				N	Overlap with # 18.
7	*Water quality protection*	Structural barriers to saltwater intrusion				N	Not a priority.
8		Encasement and retrofitting of wells to protect from flood and contamination				N	Not a priority.
9		Domestic and industrial waste water treatment				N	Not an immediate priority. Longer term and private sector driven.
10	*Planning*	Borehole mapping				N	Overlap with # 15.
11		System of water resources monitoring				N	More of an orgware. Prefer hardware.
12		Observation wells				N	Costly. Existing wells can be used where possible.
13		Water safety plans				N	Other programmes addressing water safety.
14		Remote sensing				N	Some capacity exists.
15		Ground water mapping and modelling	X	X	X	Y	Hardware, software, orgware.
16		Surface water mapping and modelling	X	X	X	Y	Hardware, software, orgware.
17		Training/capacity building hydrology, meteorology, climatology				N	Very much needed. Can be included in #15 & 16.
18		Mapping and modelling for water catchment protection	X	X	X	Y	Hardware, software, orgware.

TP- Technical Potential; CL- Climate Resilience; NDP- National Development Priorities; Y- Yes; N- No; X – Satisfy criteria

Based on the UNEP-DTU guidelines for TNA assessments, three criteria categories – adaptation benefits, development benefits and cost, and a list of twelve (12) criteria shown in **Table 14** were identified to be used in the MCA for the water sector. This list was presented to the SWG on March 31, 2016 for stakeholders' review, selection and prioritisation. Each criterion was discussed thoroughly and consensus achieved on the decision to accept or reject the criteria. This was indicated by a yes/no/somewhat judgment based on expert views and knowledge of the sector. Generally, criteria dealing with costs were retained. Discussions centered on selecting/adding the appropriate adaptation and development benefits criteria to be used in the measurement. Finally, eight (8) criteria were selected with some amendments to complete the MCA. See **Table 15**.

Table 14: Criteria Category and Criteria applied in the MCA for the Water Sector

Criteria Category	Criteria
Cost	Implementation
	Operation and maintenance
Adaptation benefit	Diversification of water supply
	Improved access to water quality
	Promoted water conservation
	Improved monitoring of water resources
	Improve water quality
Development benefit	Promote livelihood security
	Promote ecosystem health
	Increase income
	Improve health of households
	Generate employment

Following the selection of the criteria, weights were assigned to each criterion based on a value preference of importance. Weights were applied using the 'budget allocation' method, where the sum of all weights equaled 100. A sensitivity analysis was performed to address differing views from the discussions. A qualitative approach was undertaken using the Likert scale (due to the lack of appropriate quantitative data) to determine the scores for each technology option in the water sector.
The scale and value preference of the weights and scores applied were:
Weights: 5 – Less important; 10 – average/medium important and 15 – more important
Score: 20 – Very Low; 40 – Low; 60 – Moderate; 80 – High; 100 – Very High

The technologies were scored against each criterion using the information provided in the fact sheets, as well as, expert opinion. The fact sheets elaborated on each of the short-listed technologies, providing information on the type of technology, cost (where available), scale of application, adaptation benefits and acceptability to stakeholders etc. Refer to **Appendix 4** for factsheets on the water sector. The scoring matrix of the short-listed prioritised technology options for the water sector is presented in **Table 15** along with the sensitivity analysis.

Table 15: Scoring matrix of short-listed Prioritised Technology Options for the Water Sector and Sensitivity Analysis

CRITERIA CATEGORY	COST		ADAPTATION BENEFITS				DEVELOPMENT BENEFITS		TOTAL WEIGHTED SCORE	SENSITIVTY ANALYSIS TOTAL SCORE
CRITERION	Implementation	Operation & Maintenance	Diversification of water supply	Contribute to improved access to water quality	Promote water conservation	Strengthen monitoring of water resources	Promote livelihood security	Promote ecosystem health		
WEIGHT	10	15	10	15	10	15	10	15		
TECHNOLOGY OPTIONS	SCORES									
Rainwater Harvesting	60	40	60	60	80	40	80	60	**35.5**	**35.0**
GIS Mapping and modelling for water catchment protection	100	60	80	80	80	80	40	80	**37.50**	**45.0**
Ground water mapping and modelling	100	60	100	100	80	100	60	80	**60.0**	**60.0**
Surface water mapping and modelling	80	60	80	80	80	80	60	80	**47.50**	**42.5**

Sensitivity Analysis: Adjusted scores for selected criteria

Technology Option	Criterion	Adjusted Score
Rainwater Harvesting	Operation and maintenance cost	20
Ground water mapping and modelling	Promote livelihood security	40
Surface water mapping and modelling	Strengthen monitoring of water resources	60

4.6 Results of Technology Prioritisation

In the long list of adaptation technologies for the water sector, eighteen (18) options were identified based on the country's priorities, the impacts in the sector, the type of technology and its application to local context. New and emerging technologies were also considered for possible introduction, including, a list of areas (needs) provided by the GWI.

Three (3) technologies were initially identified in the short list by the SWG, however, a fourth technology "*GIS for Water Catchment Protection"* was added by the TNA Committee, based on the technology potential to promote climate resilience and reduce vulnerability. National experts felt that there was a need to have some focus on 'source protection', rather than 'end-of-pipe treatment' of water resources. The following final shortlist of adaptation technologies were approved by the TNA Committee, for which fact sheets were prepared and the MCA completed:

1. Groundwater mapping and modelling
2. Surface water mapping and modelling
3. GIS for water catchment protection
4. Rainwater harvesting

Members of the SWG, facilitated by the consultant, completed the MCA for the four technologies using the excel tool provided by UNEP-DTU. On completion, a ranking was obtained and a sensitivity analysis was performed, where scores for technologies and specific criteria were adjusted based on any concern/uncertainty expressed by stakeholders. In the sensitivity analysis, scores were revised downwards for three technologies, against specific criterion:

- *Rainwater Harvesting*: The score was revised for the criteria on 'operation and maintenance cost', since stakeholders agreed that in the local context, this cost would be very low.
- *Groundwater mapping and modelling:* The score for the criteria 'promote livelihood security' was lowered because of the limited scale this technology would have in promoting this adaptation benefit. Livelihood security was interpreted in terms of the jobs which will be created through the diffusion of this technology.
- *Surface water mapping and modelling*: The criteria 'strengthen monitoring of water resources' was adjusted from a 'high' benefit to a 'moderate' benefit. Stakeholders were of the view that, surface water monitoring will require more resources, which is outside the scope of this technology.

There was general consensus among members of the SWG with the results of the MCA, summarised in **Table 16**. In the final results, the SWG recommended the ranking derived from original scores and the top three technologies to proceed to the next stage of the TNA process, which is, the barrier analysis.

The technologies are (i) Ground water mapping and Modelling, (ii) Surface water mapping and Modelling, and (iii) GIS for water catchment protection.

Table 16: Summary of MCA results for the Water Sector

Rank	Technology	Weighted Score	Sensitivity Analysis Score	Selected for Barrier Analysis
1	Ground water mapping and modelling	60.0	60.0	Yes
2	Surface water mapping and modelling	47.5	42.5	Yes
3	GIS for water catchment protection	37.5	45.0	Yes
4	Rainwater harvesting	35.5	35.0	No

Chapter 5: Technology Prioritisation for Coastal Zone and Low-Lying Communities Sector

5.1 Key Climate Change Vulnerabilities in the Coastal Zone and Low-Lying Communities Sector

Projected sea level rise as a result of climate change will have significant impacts on Guyana's low-lying coastal zone. As a consequence, the vulnerability of economic activities, infrastructure, and the natural ecosystems found within this natural region increases significantly. According to a Coastal Vulnerability and Risk Assessment study conducted for Guyana in 2002 under the Caribbean Planning for Adaptation to Climate Change Project (CPACC), the country is identified as being in a "high risk" situation as it relates to sea level rise. The CPACC study considered three (3) scenarios for the vulnerability assessment and concluded that inundation and flooding are expected to be the major impacts of sea level rise on the coastal zone and low-lying communities. In essence, coastal and low-lying population, agricultural activities, industries and manufacturing and water resources were found to be highly vulnerable to even slight increases in sea level rise and by extension, salt water intrusion.

Moreover, the vulnerability and adaptation assessment conducted for the SNC focused on the coastal zone as a critical area. The vulnerability of the coastal region was assessed by (i) examining the weakness of the coastal zone to physical and ecological changes as a result of sea level rise, (ii) likely potential impacts due to the changes of the system on the socio-economic structure, and (iii) the ability of the coastal zone to cope with the changes, refer to **Section 1.4.1.1** of this report for additional information.

All natural and man-made streams in Guyana drain into the Atlantic Ocean and as a result, saline water tends to spread into the river mouth, resulting in contamination of the river in its lower reaches. This saltwater intrusion can be found upstream of many rivers and creeks, and under extreme dry conditions, the reach of the river affected can extend for more than two hundred kilometers (CCCCC, 2014). Contamination of the aquifer systems can also occur due to sea level rise, possibly from two directions: (1) water penetration from the outlets of the aquifers to the ocean and (2) intrusion from rivers and above land surface (CPACC, 2002).

The drainage network, with its supporting network of seawalls and dams, dykes and polders work to maintain the integrity of the low-lying coast and to allow for distribution and drainage of the natural region. While some channels drain by gravity flow, others require direct pumped action and based on the CPACC assessment, it was found that the pressure of the water flowing from the Ocean to the coast exceeds the water being drained out of the coast.

5.2 Decision Context

Guyana's coastal zone and low-lying communities are flood prone areas which require significant resources to protect from the sea and excess water during heavy rainfall. Many of the country's coastal sea defence are over 100 years old and in urgent need of maintenance or replacement. The protection of Guyana's coastal zone is a matter of national priority and this has been reflected in the numerous initiatives, such as, vulnerability and risk assessments, the preparation of action plans and programs/projects for shoring up sea defences and strengthening capacity for early warnings. The technologies in this sector draws heavily on the needs identified through the numerous assessments, current experiences and national development plans.

To date many initiatives have been completed towards a more integrated approach in coastal zone protection and management. These include, the preparation of an Integrated Coastal Zone Management Plan (ICZM)(2008); a Climate Change Adaptation Strategy and Implementation Strategy for Coastal and Low-lying Areas (Khan, M,2002); Guyana's First and Second National Communications to the UNFCCC (2002/2012), Capacity Development and Mainstreaming for Sustainable Land Management Project (2008-2011) UNEP/GEF; Disaster Risk Management Policy (CDC, 2013) ; Integrated Disaster Risk Management Plan (CDC, 2009-2011); Early Warning System Framework (GoG/UNDP, 2013); Japan International Cooperation Agency (JICA) to implement an EWS for flooding pilot project in Mahaica -Mahaicony (2015); the Conservancy Adaptation Project (CAP) World Bank (2007-2011)and the Cunha Canal Rehabilitation Project (LCDS 2013).

5.3 Overview of Existing Technologies in the Coastal Zone and Low-Lying Communities Sector

This section provides an overview of the main existing technologies found in the Coastal Zone and Low-lying Communities while Section 5.4 provides an overview of the technologies selected during the TNA process for prioritisation.

5.3.1 Seawalls and Groynes

Approximately 110 km of Guyana's coastline is protected by concrete sea defences, 250 km by a mangrove belt, backed by earthen embankment and 70km by natural sandbanks (GoG, 2012). Guyana's sea wall structures are over 100 years old and have suffered significant damage/weakening over time. Over the years, new structures and reinforcement have been used, namely, 'rip-rap' construction and gabion baskets. The introduction of other barriers, such as, the HESCO barrier (modern bastion made of collapsible wire mesh container and heavy duty fabric liner) were also tested.

The cost of constructing and maintenance of Guyana's sea defence is astronomical. As a result, rehabilitation programmes have been supported by international donor agencies, such as, the European Union and the Inter-American Development Bank. Upgrading infrastructure to protect against flooding has been identified as 'urgent near-term' measures in Guyana's LCDS, which has committed funds (US$30M) for the maintenance and reinforcement of the sea walls.

5.3.2 Stationary and Mobile Pumps

Flood control and irrigation are critical areas in water management in Guyana. Between 1988 and 2010, flood events resulted in more than US$634m in economic damage affecting up to 42% of the population (CDB,2013). In January 2005 alone, catastrophic floods in the coastal zone affected 25% of the population resulting in a near breach of the EDWC dam. The effects included total economic losses equivalent to 60% of GDP for that year. The SNC noted that the recent flooding events *"demonstrate Guyana's vulnerability to climate driven events and its short-comings in the current drainage infrastructure which is insufficient to discharge excess water from heavy rainfall" (G*oG, 2012).

The NDIA is the institution responsible for the drainage and irrigation services in the country and it is located within the MOA. Over the years, the NDIA has been building its capacity, resulting in a significant number of equipment being acquired, inclusive of mobile and fixed pumps, long reach excavators, bulldozers and other machinery. The NDIA has adopted a policy of constructing and rehabilitating sluices that are found to be functional through suitable foreshore conditions along the coast and riverine areas, aimed at upgrading and expanding the drainage system. These works allow for expanded acreage of agricultural activities and to better cope with extreme rainfall events associated with climate change. All improved and rehabilitated sluices are now serving areas to withstand in excess of 2.5" of rainfall in 24 hours as compared to 1.5" in 24 hours previously (NDIA, 2016). While stationary pumps allow primarily for drainage, mobile pumps are also used for irrigation purposes during the dry weather.

The NDIA's upgrading and rehabilitation of drainage and irrigation infrastructure to ensure optimum capacity is ongoing. Rehabilitation of drainage structures have been undertaken in Regions 2 to 10. Through its Community Drainage and Irrigation Project (CDIP), the Authority has been supporting vulnerable residential areas by clearing critical drains and canals. Over the last five years, over 1448km of drains and canals were maintained yearly in Regions 2, 3,4,5,6 and 10 by the NDIA. The WUA has also assisted with the maintenance of the secondary drainage and irrigation systems in key farming areas.

5.4 Adaptation Technology Options for Coastal Zone & Low-Lying Communities Sector and their main Adaptation Benefits

This section of the report presents an overview of the technology options identified and prioritised through the TNA process for the coastal zone and low-lying communities. In order to avoid overlaps with technology options mentioned in Section 5.3, reference to specific technology options are made, where necessary.

5.4.1 Early Warning System

Early Warning System (EWS) goes beyond the use of technology for monitoring, prediction and dissemination of information. It is an established system that provide advance information of possible hazards and encompasses components to manage risks and mitigate losses through planned measures and response actions (CDC, 2013). Guyana has no fully functional, integrated EWS to date. Many of the technologies for EWS in Guyana have focused on the building of institutional capacity to mainstream early warning into planning and are primarily orgware/software types. Hardware type technologies are more or less limited to information transmission equipment/ infrastructure and logistics in response systems.

A number of studies were conducted by the Civil Defence Commission (CDC) and the GLSC to understand Guyana's context and requirements for the establishment of EWS in the country and its functionality as part of a national disaster risk reduction approach. Elements of EWS such as, meteorological observations, forecasting and to some extent, dissemination of information, exist. However, there is limited capacity to make future projections. The use of GIS and remote sensing, satellite images, flood forecasting system to adequately monitor and predict hazard events, are not yet in use (CDC, 2013 & GLSC, 2010). The following is a list of existing initiatives completed for early warning in Guyana:

- Early Warning Study – Situation Report (2009)
- National Adaptation Strategy and Action Plan for the Agriculture sector (2009)
- Early Warning System Framework (2013)
- A Multi-Hazard Preparedness and Response Plan (2013)
- National Integrated Disaster Risk Management Plan and Implementation Strategy (2013)
- Draft Early Warning Protocol for Drought (2015)
- National Emergency Monitoring System (2015)

A fully functional EWS would be able to forecast a number of climatic and weather related events across different temporal scales, and contribute to reduction of vulnerability to climate change and extreme weather events, as well as, increase climate resilience of the country through the provision of timely information to critical stakeholders. It further allows for a reduction of impacts on the environment associated with flooding.

5.4.2 GIS for the Operationalisation of Guyana's National Land Use Plan

With support from the European Union, Guyana completed its National Land Use Plan (NLUP) in 2013. There is no Land Use policy at the moment, thus, the NLUP is used to guide land use decisions. According to the NLUP *"the primary objective is to provide a strategic framework to guide land development in Guyana"*. The plan builds upon a number of national policies and strategies that have a direct relevance for land use and land management and to enable financial resources to be targeted at optimal land uses at the regional level (NLUP, 2013). These include the National Development Strategy (NDS 1996), the Poverty Reduction Strategy (PRS 2000, 2004, 2011), the Land Use Baseline Document (1996) which led to the Draft Land Use Policy (2004, 2007), the Manual for Regional Land Use Planning in Guyana (2003), the National Competitiveness Strategy (NCS 2006) and the Low Carbon Development Strategy (LCDS 2010).

The need to make land-use decisions on a national and regional scale in a single system, makes GIS an excellent tool for integrating planning processes. In Guyana, the vast majority of data which can be mapped and used in a plan is at the national level, i.e. small scale of 1:1 million or smaller. The output maps for the NLUP will be at 1:2.5m and 1:1m scales. Spatial mapping/modelling makes it possible to estimate the widest range of impacts of existing trends of population, and of economic and environmental change. For example, a range of environmental scenarios can be investigated through the projection of future demand for land resources from population and economic activities. GIS for operationalisation the land use plan has a number of adaptation benefits and these are:

- Contribute to the reduction of impacts due natural disaster such as flood, forest fires etc;
- Improve understanding of natural resources and map changes over time;
- Provide data for the protection of vulnerable habitats and ecosystems;
- Guide the sustainable harvesting of natural resources; and
- Contribute to effective urban and rural planning.

5.4.3 Energy Efficient Mobile Pumps for Flood Control

Guyana's drainage system is natural, gravity flow, augmented by pumps and depends on the main rivers, which extend beyond the coast. Pumps are critical to moving large quantities of water over land, given inability of the coastal drainage infrastructure to drain the land effectively, particularly during high intensity rainfall. However, mobile pumps have high capital and operational costs. Based on recent expenditure for 120 cubic feet per second discharge capacity mobile pump at US$250,000 plus fuel and maintenance costs, the estimated cost for mobile pumps would be high, but significantly lower than the cost for fixed pumps. Owing to high operational cost, mainly from fuel purchases, energy efficient pumps have been recommended. According to the NDIA, there are currently thirty-three (33) mobile pumps throughout the country, with discharge capacity between 20 – 120 cubic feet per second. Most have a discharge capacity of 40 cubic feet per second.

The adaptation benefits from this technology will be significant, especially in the agriculture and health sectors. Mobile pumps will enable the draining of accumulated water in otherwise, hard to reach areas. The ability to drain the land faster will bring relief to flooded farms and households, reducing the loss of crops and livestock, and proliferation of water borne diseases. Mobile pumps are also used to irrigate farming areas during the extremely dry periods.

5.4.4 Mapping and Modelling of Coastal Processes

Modelling helps us to better understand the risks of flooding and of coastal erosion, and to use the information to develop a risk based approach to address problems of flooding and coastal management. It also allows for preparation through flood forecasting and warnings. It is an important aspect of communicating information for better risk management. Modelling simulates real life situation through physical or computer models and explore different ways a situation can develop, based on differing influencing factors. For example, a model can be developed of how the sea responds to tides and the weather to assess how coastal erosion may develop. In the analysis of coastal hydrodynamic processes, modelling (physical, numerical and composite) is often employed to simulate the main phenomena in the coastal region.

This technology involves extensive use of data such as, hydrology, flood defence conditions and or ground surface information. These are computed in the mathematical models, providing a scientific basis for planning. With the advancement of technology, a variety of coastal models have become available and the techniques have become quite mature. Physical models refer to the use of laboratory models at an appropriate scale (micro, small, medium and large scale models) for investigating the relevant process, numerical models refer to the use of computer codes (commercial & open source) and composite models refer to the integrated and balanced use of physical and numerical models (CoastalWiki, 2016).

Guyana's coastline with the Atlantic Ocean lies at elevations between 0.5 m and 0.7 m above mean sea level, but it is threatened by tides which rise to 1.6 m above mean sea level. Several major rivers also run through the coastal zone, including the Demerara and Essequibo rivers (Van Ledden et al, 2009). As a result, the entire coast is protected by a system of concrete walls, boulders, groynes and mangroves. The coastland of Guyana is extremely vulnerable to sea level rise and storm surge, refer to **Map 3** on coastal inundation as a result of projected sea level rise. This vulnerability highlights the country's need to construct and maintain a reliable system of protection from extreme climatic events. In 2005, Guyana experienced a major flood, which damaged approximately 1520m of sea defence structures along the coastline. Most of the structures damaged were constructed during the period 1945-1959 (Van Ledden et al, 2009). Estimates show that by 2030, the annual loss due to flooding in Guyana is projected to be US$150 million (LCDS, 2010).

Guyana has significant experience in the construction of sea wall, groynes and mangrove restoration. However, there is a need for better application of tools (design) based on the knowledge of coastal hydrodynamics, such as, movement of mud shoals and sediment, wave propagation/properties etc. In January 2016, the Government of Guyana emphasised the importance a strong sea defence structure, and committed to making adequate investments for the protection of the country's coastal zone infrastructure and systems. The main adaptation benefits identified are:

- Overall adaptation costs, which is estimated at US$1billion per annum will be reduced;
- Robust infrastructure as a result of improved designs and planning;
- Will have updated baseline data to better understand coastal dynamics and guide intervention efforts;
- Strengthen prevention planning to protect coastal infrastructure and habitat; and
- Reduce flooding and subsequent losses.

More recently, in April 2016, the Caribbean Development Bank and the GoG launched a sea and river defence project to the sum of US$30.9M for the reconstruction and improvement of approximately 5.4km of sea and river defenses, benefiting over 45,000 residents about 9000 households in Regions 2, 3 4 & 6 (CARICOM, 2016).

5.5 Criteria and Process of Technology Prioritisation

5.5.1 Criteria, Weighting & Scoring

The compilation of a long list and short-listing of technologies followed the same process as in the agriculture and water sectors, see **Table 17.** Nine (9) stakeholders, comprising of technical experts and institutional representatives from the CDC, NDIA, GLSC, Caribbean – Terrestrial Solutions, MoPI, IAST and the MOTP participated in the SWG meeting held on December 2, 2015. See **Appendix 2(c)** for list of members. The objectives of the meeting were to:

- Review the long list of technologies for the sector;
- Identify additional technologies for the sector, as necessary; and
- Prioritise technologies using the three recommended pre-screening criteria listed below.

The following pre-screening criteria were applied:

- Technical potential of the technology;
- How will the technology promote climate resilience and
- Synergy with national development priorities/strategy.

In the long list of technologies, seventeen (17) technology options were identified based on the country's priorities, the impacts in the sector, the type of technology and its application to local context.

Table 17: Prioritisation from long list of Technologies for Coastal Zone and Low-Lying Communities Sector

No.	Technology Category	Specific Technology					
		Long List	TP	CR	NDP	Shortlist	Notes
1	*Sea and river defence*	Construct/upgrade Sea walls and groynes	X	X	X	N	Technology initially shortlisted but was not approved by the TNA Committee and was recommended for review. Meeting with the sector expert confirmed that the technology already exists and is being addressed through other national programmes.
2		Storm surge barriers and closure dams				N	Priority to upgrade current infrastructure.
3		Beach nourishment (realignment)				N	No technical potential.
4	*Flood Proofing*	Construct storm water drains				N	Priority to upgrade current drainage system.
5		Enforcement of building codes				N	Not clearly defined as a technology.
6		Energy efficient drainage pumps	X	X	X	N	Was initially identified but subsequently reviewed. Not considered a priority since retro-fitting existing pumps can deploy this technology easily.
7		Energy efficient mobile drainage pumps for flood control	X	X	X	Y	Hardware. There is limited diffusion of this technology. The focus of this technology was revised to include energy efficiency following the review of the draft report.
8		Deepening of canals				N	Some capacity exists in country.
9	*Planning*	Hazard mapping				N	Capacity exist.
10		National Early Warning Systems (Flood and drought)	X	X	X	Y	Need for an integrated system.
11		Technology to operationalize Land Use Plans (GIS)	X	X	X	Y	Can build upon capacity within institution and make planning more efficient. Include hardware and software components.
12		National Land Information System (orgware)				N	Exist at the Guyana Lands Commission.
13		Community EWS				N	Low priority compared to national system.
14		ICZM monitoring				N	Some aspects covered through various institutions.
15		Monitoring of coastal processes for the construction of sea wall and groynes	x	x	X	Y	Need to generate scientific data on coastal dynamics. Has wide range of potential benefits.
16	*Ecosystem-Based adaptation*	Mangrove restoration (LIDAR and drones)				N	Activities being implemented through the Mangrove Restoration Project.
17		Wetland protection and restoration				N	Covered under other national programmes.

TP- Technical Potential; CL- Climate Resilience; NDP- National Development Priorities; Y- Yes; N- No; X – Satisfy criteria

From this list, four (4) technologies were shortlisted based on the satisfaction to the criteria and approved by the NTC to advance to the next stage for the preparation of fact sheets and completion of a MCA. Some of the reasons considered in the non-selection of technology options were:

- Whether there were existing/planned programmess for the technology;
- The technology did not satisfy the three pre-screening criteria above; and
- The technology did not satisfy the TNA definition of hardware, software or orgware.

Using the recommended UNEP-DTU guidelines, a list of twelve (12) criteria were identified for the MCA as shown in **Table 18** below. This list was presented to the SWG on March 29, 2016 for stakeholders' review, selection and prioritisation of 7-10 criteria. Each criterion was discussed and the selection made by a yes/no/somewhat value judgment based on expert views and experience in the sector. Discussions centered on selecting/adding the appropriate adaptation and development benefits criteria to be used in the measurement. Finally, eight (8) criteria were selected with some amendments to be applied in the MCA for the technologies. See **Table 19**.

Table 18: Criteria Category and Criteria applied in the MCA for Coastal Zone & Low-Lying Communities Sector

Criteria Category	Criteria
Cost	Implementation
	Operation and maintenance
Adaptation benefit	Improve flood management
	Strengthen sea defence planning
	Improve land use management
	Reduce risk from weather related disaster
	Reduce land use conflicts
	Reduce losses from flooding
Development benefit	Improved security for economic sectors
	Promote livelihood security
	Increase income
	Improve health & safety of households

Following the selection of the criteria, weights were assigned to each criterion based on a value preference of importance. Weights were applied using the 'budget allocation' method, where the sum of all weights equaled 100. A sensitivity analysis was performed in the end to address any concern/uncertainty about the parameters.

The Likert scale was used (due to the lack of appropriate quantitative data) to determine the scores for each technology option. Using the same scoring method as in the previous sectors, technologies were scored against each criterion using the fact sheets information, expert opinions and experience. The fact sheets provided specific technological information on the type of technology, cost (where available), scale of application, adaptation benefits and acceptability to stakeholders etc. Refer to **Appendix 5** for copies of the factsheets pertaining to technology options for the coastal zone sector.

The following scale and value preference of the weights and scores applied were:

Weights: 5 – Less important; 10 – average/medium important and 15 – more important

Score: 20 – Very Low; 40 – Low; 60 – Moderate; 80 – High; 100 – Very High

The scoring matrix of the short-listed prioritised technology options for the sector is presented in **Table 19**, including scores for sensitivity analysis.

Table 19: Scoring matrix of short-listed Prioritised Technology Options for the Coastal Zone and Low-Lying Communities Sector

CRITERIA CATEGORY	COST		ADAPTATION BENEFITS				DEVELOPMENT BENEFITS		TOTAL WEIGHTED SCORE	SENSITIVITY ANALYSIS TOTAL SCORE
CRITERION	Implementation	Operation & Maintenance	Improve Flood Management	Strengthen Sea Defence Planning	Improve Land Use Management	Reduce risk from weather related disaster	Improve security for economic sectors	Promote livelihood security		
WEIGHT	15	15	15	10	10	15	10	10		
TECHNOLOGY OPTIONS										
Early Warning System	80	60	100	80	40	100	80	80	**81.7**	**79.2**
GIS for Operationalisation of land use plan	80	60	60	40	100	60	60	60	**40.0**	**30.0**
Mapping and modelling of coastal processes	80	80	100	100	80	80	100	80	**81.7**	**84.2**
Energy efficient mobile pumps for flood control	100	100	100	40	60	80	80	60	**30.8**	**33.3**
Weights adjusted for sensitivity analysis	10	10	NA	NA	NA	NA	15	15		

5.6 Results of Technology Prioritisation

In the long list of adaptation technologies, seventeen (17) options were identified for Coastal Zone and Low-Lying Communities using similar criteria as applied in the Agriculture and Water sectors. New and emerging technologies were also considered for possible introduction. Most of the long list technologies were accepted by stakeholders, with the following modifications through meetings with members of the SWG and institutional sector experts:

1. *GIS for the implementation of Land Use Plan;*
2. *Monitoring of coastal processes for construction of sea walls and groynes;*
   Based on further discussions with the MoPI, this technology was included to reflect the sector's gap in the design and construction of sea defence infrastructure. It was considered vital in the planning of sea defence of Guyana's coast and includes hardware, software and orgware components.
3. *Energy efficient mobile pumps for flood control;*
   This technology was added to the long list following discussions with the NDIA. Initially, this technology was proposed as 'energy efficient pumps'. However, after some deliberation with the NDIA, it was subsequently modified and assessed as 'Mobile pumps for flood control'. Following subsequent discussions by the NTC, it was finally recommended that the initial view of energy efficient drainage pumps be incorporated thus, the technology currently recommended is 'Energy efficient mobile pumps for flood control'. Given Guyana's challenges with flood events, mobile pumps will be very effective due to its ease of transport, operation and can be located in previously, inaccessible areas. There is some availability locally; however, wide scale deployment has been slow. One of the key challenges mentioned was, high fuel consumption and operational cost and therefore, energy efficient pumps would be more acceptable.

Of the seventeen (17) technology options for coastal zone and low-lying communities, four (4) were shortlisted by the SWG. The following is the final short list of adaptation technologies for factsheet preparation and completion of a MCA:

1. Mapping and modelling of coastal processes;
2. Early Warning System;
3. GIS for implementation of National Land Use Plan; and
4. Energy efficient mobile pumps for flood control.

The MCA was completed on March 29, 2016 by the SWG for the four (4) shortlisted technologies. A ranking was obtained and a sensitivity analysis was performed to address any concern/ uncertainty. In the sensitivity analysis, noting the wide variation in the results from the weighted scores, stakeholders decided to revisit the weights and made some adjustments for criteria categories on cost and development benefits. The weight for cost was lowered and weights for development benefits was increased to the maximum value. The SWG felt that, while cost was an important consideration, the development benefits from the technologies should have higher priority.

In the final results, the SWG recommended the ranking from the sensitivity analysis and approved the top three technologies to proceed to next stage of the TNA process. The technologies are (i) Mapping and modelling of coastal process, (ii) Early Warning System, and (iii) Energy efficient mobile pumps for flood control. **Table 20** provide a summary of the results of the MCA for coastal zone and low-lying communities sector.

Table 20: Summary MCA results for the Coastal Zone and Low Lying Communities Sector

Rank	Technology	Weighted Score	Sensitivity Analysis Score	Selected for Barrier Analysis
1	Mapping and modelling of coastal processes	81.7	84.2	Yes
2	Early Warning System	81.7	79.2	Yes
3	Energy efficient mobile pumps for flood control	30.8	33.3	Yes
4	GIS for implementation of Land Use Plan	40.0	30.0	No

Chapter 6: Summary and Conclusions

The TNA for Guyana was conducted with a robust participatory process. The assessment involved two main steps, sector selection and prioritisation of adaptation technology in the selected sectors. This was informed by literature reviews of key sector and national documents, expert judgment, use of a pre-screening process, multi-criteria analysis, including application of sensitivity analyses. Throughout the process, guidance and support were provided by the UNEP-DTU team directly and via training and resources at the TNA website www.tech-action.org.

The sector selection was derived from a review of the country's vulnerability assessments and national development strategies/plans by the national project team. Prioritising of technologies for selected sectors was completed according to the TNA methodology, in highly engaged sector working group meetings and with consensus.

From the assessments, three priority sectors were identified for adaptation technologies: Agriculture, Water and, Coastal Zone & Low-Lying Communities. In the final results, a total of eight technologies were identified:

Agriculture Sector: (1) Freshwater harvesting: Empoldering of water collection areas (2) Agro-meteorology for forecasting and early warning

Water Resources*:* (1) Groundwater mapping and modelling (2) Surface water mapping and modelling (3) GIS for water catchment protection

Coastal Zone and Low-Lying Communities: (1) Mapping and modelling of coastal processes (2) Early Warning Systems (3) Energy efficient mobile pumps for flood control.

The eight prioritised technologies have been reviewed by the NTC and will now be subjected to the barrier analysis which aim to identify the key technological, financial, social, environmental, policy and other barriers likely to affect the transfer of those technologies. This will be followed by the preparation of a Technology Action Plan (TAP).

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Appendix 3: Fact Sheets for the Agriculture Sector

Sector	**Agriculture**
Subsector/ Category	Diversification of water supply/sources
Technology	Freshwater Harvesting for inland regions: Empoldering of water collection areas
Scale of Application	Community scale (collection in small reservoirs) to large scale (macro-catchment)
Availability	Water harvesting is a mature technology and available in Guyana. This technology is applied mainly on the coast in the agriculture sector but is limited in inland regions, due to reasons such as, uneven terrain, accessibility, cost & supply of materials and technical support.
Technology Characteristics	
Introduction Recognizing the high dependence of Guyana on agriculture and the sector's vulnerability, it is paramount that adaptation strategies be implemented to ensure the continuous supply of freshwater. One such option is the harvesting of freshwater through empoldering of catchment or water augmentation to collect and store surface water for use during the dry periods. This method ensures water is stored and available locally, especially the outlying or inland regions to prevent food insecurity and displacement of population as a result of drought. Water harvesting (WH) is often described as *"the collection and management of flood water or rainwater runoff to increase water availability for domestic and agricultural use, as well as, ecosystem sustenance"* (Mekdaschi Studer *et al.* (2013) and it is an essential component of sustainable land and water management. Its basic application is, to collect water in an area and transfer it to other areas (where it is most needed) in order to increase the availability, and, volume of water in that area. The fundamental components of a WH system are (i) catchment or collection area, (ii) runoff conveyance system, (iii) storage component, and (iv) application area. The WH technique in use determines whether the components are next to each other or connected using the conveyance system. There are a number of water harvesting technologies depending on their application but the most common are (i) flood water harvesting (ii) macro-catchment water harvesting (iii) micro-catchment water harvesting, and (iv) rooftop and courtyard water harvesting.	
Institutional /Organizational	At the national and regional level, the Ministry of Agriculture, National Drainage and Irrigation Authority, Ministry of Public Infrastructure and the Regional Democratic Council all have roles and responsibilities in the construction and operation of empoldering infrastructure. In deploying the technology in-land it may be necessary to involve representatives from the surrounding communities in the process of construction, operation and maintenance.
Adequacy for Current Climate	This technology application is highly suitable to Guyana's climatic conditions since the country benefits from two (2) wet seasons and two (2) dry seasons annually. Moreover, increased water deficits are projected for the country due to increased rainfall variability and increases in temperature and evapo-transpiration. As a result, the country needs to find solutions to reduce the impact on the population and agriculture sector.
Size of Potential Beneficiary	The direct beneficiaries are the agricultural communities in the hinterland or in-land regions.
Disadvantages	• Not reliable during extensive dry periods or periods of prolong drought due to limited or variability of precipitation; • The volume of water stored depends on the type and size of the storage medium or catchment area;

	• The larger the storage medium, the higher the cost and evaporation losses; • The construction of artificial reservoirs and catchment requires feasibility assessments, proper siting, and skilled design to ensure dam safety; • The sustainability of the investment can only be assured if it is able to satisfy a socio-economic need of the local area.
Endorsement by experts	Damming or empoldering of water collection areas is a technology classified in the broad context of macro-catchment water harvesting (MacroWH). MacroWH is a method of harvesting water from a natural catchment (Mekdaschi Studer *et al.* (2013)) and the water is used for agriculture (crop and livestock production) and domestic purposes. The runoff is stored in a dammed catchment area that captures the overflow of excess water. Aside from open surface water storage in dams and or ponds, other MacroWH technologies are hillside runoff / conduit systems; large semi-circular or trapezoidal bunds (earth or stone); road runoff systems; groundwater dams (subsurface, sand and perculation dams); above- or below-ground tanks (cisterns); horizontal and injection wells Mekdaschi Studer *et al.* (2013).
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation*: National estimates for this technology are not available. However, this is recognised as a moderate to high cost techology by experts. Lininger and Critchley (2007) as sourced by Mekdaschi Studer *et al.* (2013) note that the construction of a 10,000m^3 earth dam could cost about US$ 5 per m^3, with adjustments for national situations. There is also the additional cost of materials to construct concrete empolderment. Much of the cost include, expenses for hardware and labour. Since this technology targets inland regions, costs are likely to be even higher due to the logistics of acquring materials from the coastal areas. *Operational /Maintenance:* Once this technology is deployed, given the robust infrastructure, operational and maintenance costs are likley to be minimal over time. This would include maintenance of conveyance lines, pumps, fuel, impoundment barriers etc. Also, capacity building needs to be a critical component of the institutional arrangement especially to ensure the security and effectiveness of the system.
Development Benefits – direct/indirect benefits	
Adaptation benefits	The deployment of the technology in the agriculture sector contributes to climate change adaptation by providing a source of water for crops in dry conditions. Having a stable source and supply of irrigated water increases the resilience of the sector to increasing temperatures and dry conditions. The catchment also allows for the storage of excess water during periods of extreme rainfall and as a result reduces the impacts of flooding on communities.
Economic benefits	• Freshwater harvesting reduces the need and cost associated with deep well drilling or other costly investments in piped water supplies; • Creates employment opportunities for inland regions; • Increase agriculture productivity, particularly during dry periods.
Social benefits	• Increase/improve livelihood ventures; • Stable and sustained access to potable water to communities with limited or no access, especially, during dry periods;

	• Diversified sources and increase volume of water available to inland communities; • Maintains and improve food security; • Promote health benefits that comes with improve access to water.
Environmental benefits	• Promote water conservation; • Reduce pressure on ground water supply; and • Prevent land degradation and erosion.
Local Context	
Status of Technology	Using earthen dams to empolder water is not new in Guyana. This system, serviced by a network of reservoirs, irrigation and drainage canals, has been in use for decades particularly on the coast of the country. For example, there are eight man-made conservancies which harvest and store rainwater runoff, to provide a reliable supply of water to agricultural lands, as well as, to act as a flood control measure.
Market potential	This technology is proven in Guyana's context already although its application is concentrated on the coastal regions. However, the experience and lessons learnt could provide a good basis to examine its in-land application. It will require detailed assessments regarding the technical application based on soil characteristics and structure, as well as, any downstream impacts. The market success of the technology and its sustainability depends also on socio-economic context of the area or region it will service.
Acceptability to stakeholders	WH is easily accepted by stakeholders especially in the agriculture sector and by communities with limited access to ground water.
Opportunities and Barriers	*Opportunity:* • Diversification and provision of a continuous supply of water for agriculture and reduce dependency on rain-fed agriculture; and • Macro-catchment WH using a system of empoldered dams and could help to capture surface runoff and river overflow to reduce the impact of flooding on the communities. *Barriers* : • Low interest at decision making and community levels; • Limited information pertaining to WH at community scale; • The cost for large capacity storage could increase overall investment cost; and • MacroWH structures require high investment costs.
Time Frame	Medium to Long-Tem

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Sector	Agriculture
Sub-sector/Category	Planning for Climate Variability
Technology	Agro-meteorology for forecasting and early warning
Scale of Application	This technology will be applied to provide coverage on a national scale. It will take into account the Government's drive to develop inland agriculture. Pilot sites in priority areas may include, Ebini, Manari and the coastal locations.
Availability	This technology is rapidly evolving and gaining traction around the world. As an agriculture based economy, Guyana needs to advance its agro-meteorological capability, which is currently very limited. Presently, the Caribbean Climate Outlook Program provides seasonal forecast using a regional model. Also, the Caribbean Institute for Meteorology and Hydrology (CIMH) provides training and studies in forecasting and modelling for the region.
Technology Characteristics	
Introduction	Agrometeorology deals with all the weather-sensitive elements of agriculture production. It includes pollination, animal migration, trafficability, transport of pathogens by wind, irrigation, climate manipulation and artificial climates, weather risk assessments, the use of weather forecasts in farming, crop yield and phenology forecasts, and particularly advice to farmer, as well as the required data and methods (FAO). As a technology for forecasting and EWS, agro-meteorological systems can range from a few observation units to highly sophisticated and complex network of Automatic Weather Stations (AWS) and/or agro-meteorological stations. A typical agro-meteorological system consists of several AWS and/or agro-met stations installed at strategic locations, which collects/store localized weather data for as much as 12 parameters, including, wind speed & direction; precipitation; humidity; temperature; solar radiation; sunshine durations and soil moisture/temperature (World Bank, 2016). An AWS typically consists of a perimeter fence, box enclosure containing the data logger, rechargeable battery, telemetry and the meteorological sensors with an attached solar panel. Data from the AWS are transmitted in real time to a central server which can be viewed from a web-based system through internet. The instruments are equipped with data storage system, thus, data downloading can also be done on a daily, weekly or monthly basis. The frequency of data collection can also be programmed according to the needs and use of such information. In addition, a telemetry system allows for remote access through mobile SMS or other form of messages in real time. Agro-climatic data can help to determine the exact water requirement of crops in a specific area and enable farmers to better plan their cropping pattern. For instance, using the information obtained from the stations, farmers would be guided on the degree of soil moisture and could decide when their crops would need irrigation, or data on the forecasted timing and amount of impending rain could help determine what measures farmers should take (World Bank, 2016).

	  Example of AgroMet Weather Station available and a AWS installed in Guyana.
Institutional /Organizational	This technology will be implemented by the Agromet division of the Hydro-meteorological Service, which is located within the Ministry of Agriculture. Currently, the service is working towards addressing the specific personnel needs of the division. Staff capacity includes, an agronomist and four technicians, who are graduates of the Guyana School of Agriculture. Collaborative institutions include the Guyana Rice Development Board Research Station, Guyana Sugar Coorporation, National Agricultural Research & Extension Institute, Guyana School of Agriculture and the University of Guyana. Regional institutions include, Caribbean Rice Development Institute, Caribbean Institute for Meteorology and Hydrology and the Caribbean Community Climate Change Center.
Adequacy for Current Climate	Driven by the risks posed to agriculture and food security as a result of climate change, there is a growing need for a more science based approach to planning adaptation strategies. According to climate projections for Guyana, risks from extreme weather events such as prolonged drought and flash floods are likely to increase. Dry conditions exacerbate saline conditions, which have resulted in significant losses in the sector. Major climate related events such as, the 1998 El Nino droughts, the 2004/5 flood and the current El Nino further amplifies the case for an effective forecasting and warning system.
Size of Potential Beneficiary	This technology will benefit decision makers, researchers, extension workers and farmers. It will have a significant impact on women farmers, a commonly under-represented group, particularly where women are not only involved in marketing, but also, in cultivation and agro-processing. According to the FAO, the economically active population in agriculture in Guyana is 51,000 (14% of the total active population), of which 8% are women.
Disadvantages	• Recurring cost for maintenance and field work; • Access to appropriate training and attraction/retention of technical skills; • Keeping updated with changing methods and technology; and • Need to be highly efficient to attract the interest and confidence of stakeholders.
Endorsement by experts	Agro-meteorology is a mature technology worldwide, for example, in countries with advanced remote sensing and forecast technologies. In some countries (i.e. France) Early warning systems is developed along with plant protection and extension services to deliver information to farmers. Currently, such systems are of higher potential among the technologies that are promoted for adaptation (URC/UNEP, UNDP, University of Manchester, World Bank, FAO) under specific conditions and for many weather aspects (TNA,Fact Sheet). Its application can range from the advanced system of ‘modern agro-meterology’ which includes numerical models and data analysis, to less complex systems using basic climat

<table>
<tr><td></td><td>data. The application in countries depend largely on the needs and resources, including skills. Two key initiatives implemented in the region are:

2010 - Caribbean Agrometeorological Initiative (CAMI Project) which is a partnership between the Caribbean institute for hydrology and meteorology, World Meteorological Institute, Carribean Agriculture Research and Development Institute and 10 meteorological services, including Guyana;and
Caribbean Drought and Precipitation Monitoring network implemented Jointly by McGill University, CIMH and three countries, Grenada, Jamaica and Guyana.
</td></tr>
<tr><td colspan="2">Capital Costs</td></tr>
<tr><td>Cost to implement/Operate/Maintain</td><td>Implementation:

Modern agromet systems are costly and require consistent maintenance. An agromet system for Guyana should build on the capacity that already exists, such as, historical data, AWS and EWS. Considering the promotion of hinterland agriculture, there will be a need to install stations in targeted areas, such as, Ebini and Manari. Costs for climate/agromet stations can range from US$2500-US$30,000. A rough estimate to implement a system in three pilot areas would be US$ 160,000. Generally, capital costs will include, preparation of sites, Automatic Weather Stations (AWS) and computers, mapping & modelling software/ licensed fees, and training of staff in applied meteorology and forecasting of outputs

The modernization of agrometeorology have introduced new tools which include data acquisition techniques (ground observation, aircraft and satellite), data transmission techniques (including the Internet) and data analysis (models and other software). There is a range of sources of data and techniques of analysis, such crop models, Geographic Information Systems, Random Weather Generators and spatial interpolation techniques. In addition, the transmission of crop and weather data from the rural areas to the national agrometeorological services is now easier than in the past due to telecommunication and improved transport systems.

Operational/Maintenance:

The Hydrometeorological Service has indicated that the operational and maintenance cost of this technology will be a part of the operational budget of the Service. There is already an orgware and some hardware capacity, however, a more extensive, modern system will entail higher O&M costs for training, repairs, security and logistical support.</td></tr>
<tr><td colspan="2">Development Impacts – direct/indirect benefits</td></tr>
<tr><td>Adaptation benefits</td><td>This technology will be of tremendous benefit to all stakeholders and the country, since it will provide advance information on weather conditions and projections. It can help with risk assessment and the planning of programs and project investments according to the eventual risk occurrence. When EWS is properly provided to farmers and local community, it enables them to manage their farm and water resources in a manner to adapt to climate change and reduce vulnerability. Direct adaptation benefits include:

Strengthened decision making for the sector as a whole, due to improved data collection/analysis and real-time experience;
Increase the adaptive capacity of the sector and country to respond to weather related emergencies through improved networking and communication channels at the institutional and grassroot levels; and
</td></tr>
</table>

	• Farmers will receive more precise information and advice on weather conditions in advance. This will enable better planning for cropping schedule and protect crops/livestock from potential threats.
Economic Impacts	• Reduction in the loss of income due to improved farm management; • Increased productivity due to returns on yields and less product loss; and • Increased market competitiveness;
Social Impacts	• Stimulate employment/entrepreneurial activities within communities; • Strengthen food security and promote livelihood opportunities; • Increased awareness and education using the available channels of communication such as, farmers weather bulletin, websites, radio, TV programs and text messaging. Farming community will become more informed and better equipped to participate planning. • Instill confidence in local farmers and encourage new agriculture ventures when successfully deployed; and • Encourage women's participation in problem solving for the sector through their involvement in public awareness, field studies and farm management.
Environmental Impacts	• Improved water and soil management; • Improved fertilizer and pesticide applications; • Reduction of new pests and diseases due to rapid detection and intervention; • Promote ecosystem resilience through enhanced knowledge of micro and macro climatic conditions and its interactions; • Reduce environmental degradation through long term observations and appropriate action; and • Promote farming techniques based on sound scientific assessments and experiential learning.
Local Context	
Status of Technology	The agromet unit of the Hydromet Service in Guyana was resuscitated a few years ago and is in its infancy. As a result, the unit works closely with the climatology division to meet some of its objectives. Currently, three automatic agro-met stations have been installed at the LBI and Albion sugar estates, and the GRDB research station at Burma. Also, in a few areas, some stations have been double classified and function as climate/agromet stations e.g Ebini station. A national 24-hr Weatherwatch service is operated out of the National Weather Watch Centre at Timehri. As part of the service the public can call in to request forecasts and a text service is activated during extreme weather events.
Market potential	The market potential for this technology is high. There is a significant gap in the knowledge and understanding of bio-physical interactions with agriculture at the local and regional levels. There is even more urgency now, than before, due to a rapidly changing climate and the threats/opportunities to food security/livelihood. Currently there is heightened interest and efforts towards developing agromet capability in Guyana.
Acceptability to stakeholders	Many national stakeholders are aware of the need for this technology. However, the challenge of technical capacity has to be overcome. Agriculture extension workers and farmers are eager to receive weather related information which they can use to make decisions on the type of crops, planting cycles, pest/fertilizer applications and water management.

Opportunities and Barriers	*Opportunities:* • Capacity building in 'modern agro-meteorology' and knowledge of new farming techniques/models, such as, response farming, flex cropping; and • With local downscaled models and real-time data, Guyana can become less reliant on regional models and make better climate projections. *Barriers:* • High investment and maintenance costs; • Retention of skills -data analysis and numerical modelling require specialized skills, which may be a challenge to attract and retain; and • The cost of equipment, training and personnel can limit the scale and rapid deployment of this technology.
Time Frame	Medium to long term.

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Sector	Agriculture
Sub-sector/Category	Crop Management
Technology	Varietal development of saline tolerant crops
Scale of Application	National
Availability	In recent years, varietal development of vegetable crops has gathered momentum, encouraged by the need to promote crop diversification and build resilience to climate change. However, globally, this technology has had limited success in the other crops group for various reasons. According to a study at Michigan State University, "the lack of success of breeding programs in developing commercially successful salt-tolerant crops is also often the result of breeders' preference for evaluating their genetic material under idealized conditions" (Loescher,W et al, 2011). In Guyana, the National Agricultural Research and Extension Institute (NAREI) has been developing new strains and conducting field trials aimed at introducing new varieties and strengthening germ plasm of existing varieties. Rice and sugar sub-sectors have been self-contained in terms of technology development and transfer by the Guyana Rice Development Board (GRDB) and the Guyana Sugar Corporation (GuySuCo) respectively (FAO, Not dated).
Technology Characteristics	
Introduction	Salinity can have significant effect on crop quality and yield. Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change (Haggar A and Torres, 2011). Breeding salt-tolerant crops requires consideration of (1) the technical aspects of genetic manipulations, (2) the interactions between salt tolerance and management of soil and water, and (3) the effects of salt on food and feed quality. According to Loescher et al (2011) "salt tolerance is quite complex, and perhaps not amenable to simple approaches to breeding problems, both classical and non-traditional (''biotechnological'') approaches are now common. Strategies for enhancing salinity stress tolerance in crop species include traditional breeding with selection for yield, mutation breeding, screening within phenotype, and introducing germplasm from wild species into the crop species". While approaches differ according to the special characteristics of the environment, crop type and resources, according to the USDA, the salt tolerance of a crop may be appraised according to three general criteria: • Ability of the crop to survive on saline soils; • Yield of the crop on saline soils; and • Relative yield of the crop on a saline soil as compared with its yield on a non-saline soil under similar growing conditions. Rejuvenation of germplasm lines and maintaining genetic purity of commercial varieties and production of sufficient quantity of seeds of high genetic purity is also a priority, as well as, hybridization to create variability for increased yield potential, salt tolerance, aroma, and submergence tolerance. In Guyana, sixty-one (61) crosses of rice to create variability were produced during the year 2014 (27 in the first crop and 34 in the second crop). The crosses made in the first crop were successfully raised in the second crop of 2014 (GRDB, 2014). In the sugar sector, although some new varieties have been identified, decisions related to development and implementation of those varieties typically require between 15 to 20 years. In direct response to climate change, and based on planned utilization of new, more climate change -resistant varieties, it is recommended that replanting of new varieties be implemented as soon as feasible.

Institutional /Organizational	Ministry of Agriculture is the leading institution for technology generation and transfer in the agriculture sector in Guyana. This is done through NAREI, which has research stations in Georgetown and Ebini. These, together with the Caribbean Agricultural Research and Development Institute (CARDI), the National Dairy Development Programme (NDDP), the Inter-American Institute for Cooperation on Agriculture (IICA), the Guyana School of Agriculture (GSA) and the Faculty of Agriculture of the University of Guyana (UG/FA), provide a variety of services to the sector. The GRDB (Burma Research Station) and GuySuCo have research programs/facilities with specific focus on rice and sugar crops.
Adequacy for Current Climate	The agriculture sector in Guyana is extremely vulnerable to the impacts of climate change, particularly from flooding, drought and salt water intrusion. Most of the country's fertile lands are situated on the low-lying coastline, which is highly susceptible to salt water intrusion, which will exacerbate with sea level rise. The hinterland locations also experience drought like conditions, a condition which contributes to increased salinity. Climate projections show that Guyana is likely to experience drier conditions and is at increased risk from sea level rise. Hence, there is a need to diversify crop cultivation, through the development of more resilient varieties which will boost Guyana's adaptive capacity in a changing climate.
Size of Potential Beneficiary	This technology is likely to have direct benefits to the general population, where successfully diffused. There are about 25,000 farm households in Guyana of which over 90 percent are located on the more fertile soils of the coastal plain covering some 400,000 ha of arable land and comprising administrative regions 2, 3, 4, 5 and 6. Rice and sugarcane are grown on small farms, as well as large estates. Most farmers practice mixed farming on farms of 2-5 ha. Ninety percent of farms is under 10 ha (on 40 % of farmland); 25 percent is under 1 ha (2 % of farmland); 38 percent is between 1- 4 ha (12 % of farmland); and 5 percent on more than 20 ha (47 % of cropland) (NAREI).
Disadvantages	• High input cost; • Using only native varieties can limit the range of benefits and response; • Slow uptake by farmers; • Unforeseen risks in yield and market conditions; • Risk of introduced varieties becoming pests.
Endorsement by experts	Research into the development of crop varieties is quite advanced globally. However, success in salt tolerant cultivars has been slow. In Guyana, there has been significant research in the rice and sugarcane sub-sectors to develop varieties which are resilient to changing weather conditions. NAREI is actively involved in identifying and researching selected varieties of crops which are tolerant to various climatic stresses, including high temperature, intensive precipitation, flooding, drought, increases in soil and water salinity and pest/disease infestation. At the Rice Research Station (RRS), new varieties are developed to enable farmers' access to plants that are more conducive to providing a better quality and higher volume of grain, as well as greater resistance to pests, diseases and weather fluctuations. Research at the station is done in the plant breeding, entomology, agronomy and plant pathology departments.
Capital Costs	
Cost to implement/Operate/ Maintain	*Implementation:* • A conservative estimate of varietal development in the rice sector over a 5-year period is approximately US$4.2M (GRDB). Estimates take into account costs for laboratory services, equipment/infrastructure seed storage/preservation, breeding (field experiments), purchase of new seed varieties, extension services and training & capacity building.

	• The cost of developing new crop varieties depends on many factors, such as, the type of crop, scale of research and the method employed. *Operation/Maintenance:* • O&M costs would include expenses for maintaining seed stock, demonstration plots, equipment, extension services and training. • Major crop variety development has been taken up by government institutions and with a budget line covering such costs.
Development Impacts – direct/indirect benefits	
Adaptation benefits	• Reduction in crop loss; • Improved food security; • Repository of saline tolerant germplasms; • Strengthen research capacity in crop development; and • Increase awareness of climate stress on crops.
Economic Impacts	It is expected that there will be a significant economic impact from the successful implementation of this technology. Direct benefits include: • Increased farmer's income due to reduced crop loss; • Decreased cost of production; • Increase in productivity per acreage; and • Enhanced market competitiveness.
Social Impacts	• Promote employment in the research sector, as well as communities; • Improve livelihood and strengthen resilience; • Improve household health and wellbeing; and • Increase awareness of climate change.
Environmental Impacts	• Reduce use of chemical neutralizers; • Improve crop quality and yields; • Strengthen crop diversity and resilient cropping system; • Promote ecosystem resilience; and • Secure low land cultivation
Local Context	
Status of Technology	This technology is currently limited in Guyana. The generation and transfer of crop variety has traditionally focused on the rice and sugar sub-sectors. Currently, the GRDB is engaged in work on saline tolerant, drought and flood resistant rice varieties. One of the key objective is to develop high-yielding varieties of rice with tolerance to lodging, salinity, acidity and resistance to blast, among other desirable characteristics (GRDB, 2014). In the sugar industry, GuySuCo has been involved in developing different sugar varieties for decades, but the focus has typically been on disease-resistant cultivars, as opposed to those which tolerate climate change effects. In recent years, research has been directed to the development of flood resistant varieties. One variety of sugarcane, which has already been introduced in response to climate change is sugar 93409 (GoG, 2013).
Market potential	The market potential for this technology is certain for the rice and sugar sectors. However, the success of this technology in the market for other crops would depend on the economic value of the crop. High yields may not necessarily translate into a positive cash flow if the product is not marketable. Globally, there are not many crops that are both tolerant to salinity and have a high

	economic value. Asparagus is tolerant to salinity and has a high economic value, but harvesting is labor-intensive and costly.
Acceptability to stakeholders	Already the impacts of climate change are being felt and policy makers have recognized the need for improved technologies in the sector, such as, crop diversification and germplasms. Transfer of this technologhy will build the capacity of extension workers and research capacity of the country. However, farmers' perception of the economic value of new varieties can slow down the diffusion of this technology among those stakeholders.
Opportunities and Barriers	*Opportunities:* • Market demand may encourage monoculture which can increase vulnerability; • Access to new markets and promote value added products; • Potential for increased profitability and competitiveness; and • Develop/strengthen partnerships with research facilities and farmers/producers. *Barriers:* • High initial investment cost; • Limited knowlege/skill of the techology (not much research globally); and • Willingness to absorb the technolgy due to other priorities.
Time Frame	Medium to long term

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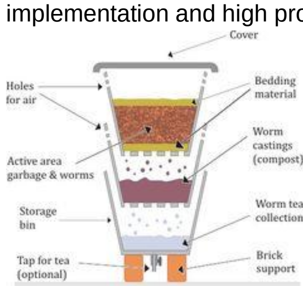
<table>
<tr><td>Sector</td><td>Agriculture</td></tr>
<tr><td>Subsector/ Category</td><td>Soil and nutrient management</td></tr>
<tr><td>Technology</td><td>Composting of agriculture solid waste (crops & livestock)</td></tr>
<tr><td>Scale of Application</td><td>National, particularly farmers.</td></tr>
<tr><td>Availability</td><td>This technology has been introduced in Guyana.Vermicomposting is used to breakdown fresh cow manure at National Agriculture Research Institute (NAREI). However, its application remains limited among farmers and practically non-existent among households. There is also no commercial composting enterprise. Generally, there is a wide range of composting systems/techniques available in the international market, from simple homemade bins to industrial scale, aerated static pile systems. A typical vermi compost bin at NAREI has an approximate area of 6.0 $m^{2.}$ An average 400 kg of vermi compost is produced every 2-3 months when the bins are harvested.</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td colspan="2">Introduction

The agriculture sector is an important contributor to Guyana's economy and is one of the sectors highly impacted by the effects of climate change and extreme weather events. Threats to the sector result from changes in temperature and rainfall, flooding from sea-level rise and storm surges, droughts which eventually lead to reduced soil water retention capacity and increased erosion impacting overall crop production and yield. The sector's vulnerability is further compounded by the fact that the main crops are grown on the already vulnerable coastal plain (the coast is about 1m below mean sea level) (GoG, 2012). Successful adaptation to climate change requires healthy soils for framing and improved soil conditions through organic agricultural practice, such as, composting.
Composting is an important tool for adaptation to climate change and a key organic practice in agriculture. It is best applied to source separated fractions and to dry feedstock. In simple terms, it includes the accumulation, sorting, screening, curing and mixing of various feedstocks such as animal waste, crop residue, weeds and municipal household organic wastes to allow for decomposition by fungi and bacteria. There are several composting methods or techniques and the three (3) main aerobic composting techniques are (i) Aerated (Turned) Windrow (ii) In-vessel composting, and (iii) Aerated Static Pile composting[5]. The selection or application of one or more of these methods depend on a number of factors such as land availability, space, material feedstock, waste volume, ease of diffusion and associated implementation costs. Aerated static pile is the method of choice for Guyana's context based on its ease of diffusion, relative low costs associated with implementation and high production rate – it takes approximately 3 to 6 months to produce compost.




</td></tr>
<tr><td>Institutional /Organizational</td><td>This technology will be implemented through NAREI, Ministry of Agriculture.</td></tr>
<tr><td>Adequacy for Current Climate</td><td>Moisture control is important for successful composting. This technology is not climate dependent when covered designs/systems are used. Open air systems may not be suitable during the wet seasons, unless flood proofed and covered.</td></tr>
<tr><td>Size of Potential Beneficiary</td><td>The primary beneficiaries are farmers, in particular, and the agriculture sector in general. Urban households with limited space are more likely to adopt vermicomposting (worm composting).</td></tr>
</table>

[5] http://www.climatetechwiki.org/technology/jiqweb-abt-0

Disadvantages	• Inadequate aeration of compost could potentially release methane emissions from the process if manure is used as an input material[6]; • Cost of the operation would potentially increase if composing is done off-site away from the source or feedstock, type of waste stream and method of composting; and • Aerated Static Pile covers could slow the process through restriction of airflow.
Endorsement by experts	This practice is endorsed by local and international experts. It is highly recommended by the National Agricultural Research Extension Institute as a low cost and environmentally safe method to improve soil fertility.
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation Cost:* This would vary based on the scale of the technology, household/ small farm size to commercial scale. Typically, include expenses for land space, fencing/partitioning (mesh, wooden, concrete, equipment for shovelling & mixing, bins/bags for storage & transport and labour. The use of existing facilities, such as, land space/sheds and equipment (used containers, cages, wooden boxes) would reduce initial investment costs. This would increase incrementally based on the volume of materials to be composted, as in commercial scale operations. *Operation and maintenance*: Include recurring cost of equipment replacement, labour and overall day-to-day management.
Development Benefits – direct/indirect benefits	
Adaptation benefits	This practice will reduce the quantity of inorganic (nitrogenous) fertilizers used by farmers in agriculture, thus indirectly preventing the pollution of water ways through run-off. The application of the technology also has a mitigation co-benefit where it allows for the reduction of nitrous oxide and methane. Nitrogenous fertilizer is replaced with organic (compost) materials and methane emissions are reduced through improved management of livestock waste where it is used as a source material for composting.
Economic benefits	• Stimulate investment/business enterprise: The composting product, mulch, could be produced for resale locally as an income generating venture; • Reduced operational costs associated with rural livestock farming since animal waste (cow manure) is a suitable feedstock for composting; and • Reduce cost of agriculture input, such as, fertilizer.
Social benefits	• Increase yields and income; • Generate employment – significant in large scale operations; and • Promote livelihood security.
Environmental benefits	• Reduce dependency on artificial fertilizer and herbicides; • Helps to repair degraded and enhance nutrient poos soils; and • Contribute to water conservation due to moisture retention properties; • Divert agriculture/organic solid waste from the landfill; • Helps in weed control.
Local Context	
Status of Technology	Applied on a limited scale locally. Benefits and know-how still not widely known.
Market potential	Composting is a proven technology and can be applied from the individual household garden level to large scale agricultural farms. There is local potential to significantly reduce organic municipal solid waste and agricultural crop residues through composting where the mulch produced can be used in private and commercial gardens and large scale farming.
Acceptability to stakeholders	Will become acceptable to beneficiaries once the benefits are proven. Composting is yet to be fully accepted on a large scale by stakeholders.

[6] http://www.climatetechwiki.org/technology/manure-management

Opportunities and Barriers	*Opportunities*: • Will reduce inorganic fertilizer imports and dependence; • Promote reuse agricultural residue and organic solid waste; • Reduce wastage and waste disposal costs; and • Can promote entrepreneurship, especially in rural areas. *Barriers* : • Limited understanding of the process and technique at local levels; • Limited recognition placed on the benefits from the use of compost; • High maintenance cost for large scale operation; and • May be more acceptable in rural communities
Time Frame	Short to medium term.

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Appendix 4: Factsheets for the Water Sector

Sector	**Water Resources**
Subsector/ Category	Planning
Technology	Ground water mapping and modelling
Scale of Application	National
Availability	This technology has matured in the global marketplace. The US Geological Survey(USGS)is a major developer of hydrological models since the 1960's and provides a wide range of models depending on the degree of sophistication required. For example, MODFLOW was built in the 1980's by the USGS and it continues to evolve as one of the most widely used ground water simulation models. NASA also provides a Global Change Master Directory (GCMD)on a wide range of models.
Technology Characteristics	
Introduction In Guyana, hydrologic data are lacking throughout the country, particularly since the late 1960's when data collection decreased dramatically. Drier conditions will have an impact on ground water recharge and water quality. Already, saline intrusion is a problem in some aquifers. With a growing demand on surface water for agricultural and industrial needs, the monitoring and management of ground water is becoming an increasingly important issue. According to estimates by the FAO, the internal renewable water resources (IRWR) are estimated at 241 km^3/year with groundwater resources at 103 km^3/year. According to AQUASTAT data, roughly 90 percent of the population is concentrated within the coastal area and thus all residents of the coastal area depend wholly on groundwater supply to meet their domestic needs, with the exception of Georgetown, which utilizes about 10 percent of surface water from the EDWC conservancy. Because of the abundant surface water resources, sparse population, and lack of suitable aquifer-forming rock types, interior locations have only a limited number of wells. Overall, water supply sources for the entire country are about 178 ground water wells and 8 surface water sources (WRA, 1998). The Intermediate savannahs and hinterland used a mixture of surface and groundwater. In Guyana many businesses that use large quantities of water have their own wells to meet their needs. These include the bottling of beverages, water, other manufacturing and food processing industries (FAO, 2015). To understand how ground water works and the risks posed by increased extraction, hydropower generation and climate change, there is a need to monitor and determine the long-term viability of ground water resources (WRA,2009). There is a need to generate/update data on well inventory and characteristics, such as, pumping rates and piezometric heads. Groundwater mapping and modelling is a highly technical and intensive process. Observation wells are created or existing wells are equipped with data logging instruments. Modern data loggers are battery/solar powered and can store water quality data, which can be then be downloaded and used in mapping and models. Groundwater mathematical simulation models, such as MODFLOW exist in several versions, are open sourced and can run on Microsoft systems.	
Institutional /Organizational	The Ministry of Agriculture, Hydro-meteorological Services is the institutional authority for ground water resources. The Hydromet also collaborates with the Guyana Water Inc.
Adequacy for Current Climate	This technology is not climate dependent. However, it is a useful tool that will provide significant benefits for ground water management. The climate parameters such as rainfall and temperature are basic inputs to the program of groundwater modelling. Climatological data must be adequate and reliable. The results of groundwater flow predictions obtained with the computer model is a very important source of information for decision makers.
Size of Potential Beneficiary	The general public will benefit from this technology directly and indirectly, including, water managers, lecturers, researchers, householders, industries and farmers.
Disadvantages	• Require specialized skills in GIS technology and modelling; • Need to keep updated with models and training; • Lack/inadequate training may cause loss of interest in the technology; • High operating cost at the beginning; and • May diffuse slowly.
Endorsement by experts	The USGS (USA) is a leading provider of hydrologic and geochemical simulation models since the 1960's. USGS models are widely used to predict responses of hydrologic systems to changing stresses, such as, increases in precipitation or

	ground-water pumping rates, as well as to predict the fate and movement of solutes and contaminants in water (TNA FS). In the Caribbean Region, through the CARIWIN project, three pilot countries have benefited from training and capacity building in Integrated Water Resource Management, which include the testing, developing and disseminating new tools and information products including, hydrological data and measurements, flood analysis, climate change, watershed and groundwater modelling, GIS and water resources, hydrometeorology and water quality.
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • High investment cost, which would include, preparation of observation wells, data logging equipment, computers, open source or software license, procurement of expert/consultancy services for training; and • Many of the software developed by the USGS for ground, surface and water quality modelling, for example, MODFLOW are available for free download. *Operation/Maintenance:* • Training, ongoing data collection, security for observation wells/ equipment, procurement of software updates
Development Benefits – direct/indirect benefits	
Adaptation benefits	• Groundwater modelling technology application is actually derived from existing water scarcity as a result of climate change impact. Therefore, it is very important to have this projection model on water resource in order to better manage the available water; • Will build capacity to make recommendations on, risks, well locations, rates of extraction etc. based on scientific assessments; • Protection of aquifers: Aquifers are very convenient sources of water because they are natural underground reservoirs and can have an enormous storage capacity, much greater than even the largest man-made reservoirs. Many aquifers are also able to offer natural protection from contamination, so untreated groundwater is usually cleaner and safer than its untreated surface water equivalent;
Economic benefits	• Employment opportunities for technical experts and community support workers; • May spur investment in ground water assessment and protection services; and • Generate investment in enterprises such as small-scale hydropower, domestic water supply, food production etc.
Social benefits	• Increased awareness of the status of ground water resources and the impact of a changing climate on water resources; • Communities can use data to plan for water management; • Improve water access and supply; and • Reduce hardship on vulnerable groups of water carriers, such as, women, children and the elderly.
Environmental benefits	• Promote water security; • Strengthen capacity to monitor ground water resources; • Prevent ground water contamination and excessive extraction; • Reduce subsidence and salinization; and • Promote ecosystem health.
Local Context	
Status of Technology	This technology is non-existent in Guyana.
Market potential	Modelling technology has become a very important tool in natural resource assessments. This technology is advanced and is widely used by governments,

	universities, scientific institutions and service providers. It has significant market potential in the provision of expertise and services. Can inspire more extensive research in in the future.
Acceptability to stakeholders	Has high acceptability among all water users as a result of its potential to provide quick and efficient results. Considering the gap in hydrologic data, this technology will provide much needed updated information on the status of ground water in the country, which can be used to make informed decisions for water management in the future.
Opportunities and Barriers	*Opportunities:* • Can contribute to the establishment of a water resource information system; • Strengthen capacity to monitor ground water and make predictions; and • Significantly strengthen planning for water resource management and development programs. *Barriers*: • Lack of institutional skills to deploy the technology; • High initial investment cost; and • Cost to retain technical staff and sustain this technology.
Time Frame	Medium to long term.

References

1. Elliott, M., Armstrong, A., Lobuglio, J., and X Bartram, J. (2011): Technologies for Climate Change Adaptation – The Water Sector. TNA Guidebook Series. UNEP.
2. Food & Agriculture Organisation (FAO) http://www.fao.org/nr/water/aquastat/countries_regions/guy/index.stm
3. Government of Guyana, (2012): Guyana Second National Communication to the United Nations Framework Convention on Climate Change.
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5. US Army Corps Engineers, (1998): Water Resources Assessment of Guyana.
6. United States Geological Survey (USGS) http://water.usgs.gov/software/

Sector	**Water Resources**
Subsector/ Category	Planning
Technology	Surface water mapping and modelling
Scale of Application	National
Availability	The US Geological Survey (USGS) is a major developer of hydrological models since the 1960's, providing a wide range of models, depending on the degree of sophistication required. NASA also provides a Global Change Master Directory (GCMD)of a wide range of models, for example, the Surface Water Modelling System (SMS) is a comprehensive environment for one-, two-, and three-dimensional hydrodynamic modelling provided by the US Army Corps of Engineers (NASA, 2013).
Technology Characteristics	
Introduction Mapping of water is a prerequisite for water availability, accessibility, fair utilisation and management. Services for digitizing and mapping exist locally and can be procured. Effective data regarding surface water availability for watershed management demands application of geospatial techniques such as remote sensing, image processing techniques and GIS. It involves a range of data sets, sophisticated equipment and skills such as, digital terrain model, soil, stream flow, field staff and water engineers, software etc. Surface water includes streams, rivers, ponds, lakes and other exposed inland water bodies. In Guyana, numerous rivers flow into the Atlantic Ocean, generally in a northward direction. There are fourteen major river basin: Waini, Pomeroon, Essequibo, Potaro (tributary of Essequibo), Mazaruni, Cuyuni, Supenaam, Demerara, Berbice, Canje (tributary of Berbice), Boerasirie, Mahaica, Mahaicony and Abary. The Essequibo, the country's major river, runs from the Brazilian border in the south to a wide delta west of Georgetown. Since the late 1960's, hydrologic data collection has decreased significantly. Measuring equipment, such as, stream gauges needed to be repaired or replaced and efforts are underway to install modern telemetric gauges throughout the country (WRA, 2009). Hydrographic surveys are done by the Geodetic Section of the GL&SC to determine the topography/bathometry of conservancy bed, river bed and ocean bed. This service has been halted due to the need for improving the current hydrographic stock of equipment (GL&SC). Guyana has an extensive network of rivers and streams that have many rapids and waterfalls, with an absence of naturally occurring lakes. Surface water (which is extracted from shallow reservoirs, streams, or drainage canals) is primarily used for agricultural and industrial purposes. Only about 10 percent of the country's drinking water comes from surface water. Guyana faces the typical water pollution problems of developing countries in tropical regions. Biological and chemical contamination of surface water varies in magnitude according to location but is increasing with population growth and land use demands.In Georgetown and in populated areas of the coastal lowlands, surface water contamination occurs from inadequate waste disposal and from chemicals used in the production of rice and sugarcane. Chemical contamination of surface water occurs primarily near manufacturing areas, especially along major rivers within mining districts (FAO, 2015). According to an assessment by the United States Army Corps of Engineers (1998), "surface water is laden with sewage, particularly in heavily, populated coastal areas". Another concern cited, is the improper disposal of sawmill waste which raises biological oxygen demand levels and endanger aquatic life in rivers. As a result, surface water, if not monitored properly, could develop into a major health hazard.	
Institutional /Organizational	The Hydro-meteorological Service, Ministry of Agriculture undertakes responsibility for the hydrological resources, including surface water. The Guyana Lands and Surveys Commission also has some responsibility in terms of executing hydrographic surveys. Other collaborating agencies are, the Environment Protection Agency, the Guyana Water Inc. and the National Drainage and Irrigation Authority.
Adequacy for Current Climate	Not climate dependent. Mapping of water resources is a useful tool that will improve water resource management, particularly in a fast changing climate.

Size of Potential Beneficiary	The general population will benefit from this technology, including, professionals, academics, research institutions, water managers and communities.
Disadvantages	• Require specialized skills in GIS technology and modelling; • Changing pace of models and the need to keep updated for compatibility with newer versions; and • Maintenance of equipment and operating cost will be high due to the higher risk of wear & tear, and loss.
Endorsement by experts	This is a mature technology applied in many countries and by research institutions. It is also a dynamic technology, constantly improving to address the changing needs and provide optimum results. The USGS is a leading resource for this technology. In addition, the Caribbean Region, through the CARIWIN project, three pilot countries have benefited from training and capacity building in Integrated Water Resource Management, which include the testing, developing and disseminating new tools and information products including, hydrological data and measurements, flood analysis, climate change, watershed and groundwater modeling, GIS and water resources, hydrometeorology and water quality.
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • The initial investment cost will be high, taking into account data logging equipment which may be needed, computers, open source or software license, establishment of a data management system, procurement of expert/consultancy services and training; and • Many of the software developed by the USGS for ground, surface and water quality modeling are available for free download. Other software can be accessed through the NASA- GCM directory surface water modeling. *Operation/Maintenance:* • Include ongoing training, data collection, repair and maintenance of equipment, software subscriptions and the procurement of technical services; • Maintenance of field equipment will be high due to the rapid wear and tear from the external environment and risk to malfunctions; and • Security field equipment and logistic costs for data collection.
Development Benefits – direct/indirect benefits	
Adaptation benefits	This technology will reduce vulnerability risks caused by climate change, increased economic activities and population growth. It is important to assess and reduce water-related risks and vulnerabilities in sectors such as agriculture, energy, health, environment, and urban water utilities as part of overall development planning. Because some of the most serious climate change impacts are the effects on water and its various uses, adaptation is a vital component of water policy. Some of the multiple uses of surface water include, irrigation, livestock, fisheries, hydropower, manufacturing, mining and transport. (UNESCO, 2011)
Economic benefits	• Employment opportunities for technical experts and community support workers;

	• May spur investment in surface water assessment and protection services; and • Stimulate investment in enterprises such as hydropower and agriculture.
Social benefits	• A more informed population as a result of the awareness of the status of water resources and the impact of a changing climate on these resources; • Decision makers and communities can use data to plan for better water management; • Improve access to/availability of water, particularly for household use; and • Promote overall health and wellbeing of communities.
Environmental benefits	• Provide data on the impact of economic activities on, and the status of surface water flow and quality; • Strengthen response to flooding and droughts; • Improve water quality/flow of rivers/creeks/falls/lakes; • Promote ecosystem health; and • Strengthen water security.
Local Context	
Status of Technology	Not available in Guyana.
Market potential	This technology is advanced and is widely used around the world by governments, universities, scientific institutions and service providers. It has significant market potential in the professional expertise services for the many impact sectors. There is also potential to provide capacity building services to institutions in the Caribbean Region.
Acceptability to stakeholders	Has high acceptability among water resource managers, researchers and users. It will be particularly useful in the scientific community and for IWRM programs.
Opportunities and Barriers	*Opportunities:* • Contribute to a database of a water resource information; • Build local technical capacity; and • Contribute to improved water management. *Barriers:* • Lack of institutional /technical skills to deploy the technology; • Retention of technical staff ; and • May be slow to implement due to the initial investment needs.
Time Frame	Medium to long term

References

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6. United States Geological Survey (USGS) http://water.usgs.gov/software/
7. UNESCO, (2011). Water and Climate Dialogue. Briefing Note. http://unesdoc.unesco.org/images/0021/002115/211591E.pdf

Sector	Water Resources
Subsector/ Category	Planning
Technology	GIS Mapping and modelling for water catchment protection
Scale of Application	National
Availability	This technology can be considered new for Guyana. To date, there is no known capacity for the modelling of water catchment in Guyana. However, there is national capacity in digitizing/ GIS mapping applied to water resources.

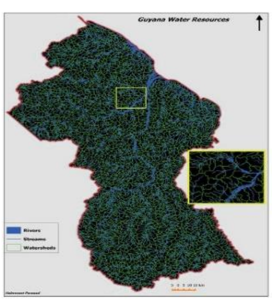
Technology Characteristics

Introduction

Guyana is regarded as the ‘land of many waters’. Numerous rivers flow into the Atlantic Ocean, generally in a northward direction. There are fourteen major river basins and eight man-made conservancies. The river basins, for example, Waini, Pomeroon, Potaro, Mazaruni, Cuyuni, Supenaam, Canje (tributary of Berbice), Boerasirie, Mahaica, Mahaicony, Abary, Demerara, Berbice and the Essequibo combine to provide large quantities of surface water. The Essequibo is the largest and has its source south to the border with Brazil. Many creeks also flow into the large, as well as smaller rivers. The Corentyne river is the border river with Suriname, from its source till the sea. It is considered that the entire flow of this river is generated both in Guyana (50 percent) and in Suriname (50 percent). The conservancies are located in the “backland” or upper stream catchment areas and comprise water-retaining embankments and structures (FAO, 2015).

Water catchment typically describes the area around a water source, where rainfall naturally collects and feeds into the source. Catchment areas can vary in size, from a few square meters, as in the case of small streams to thousands of square kilometers for rivers & lakes. These catchments are “functional geographical areas” that integrate a variety of environmental processes, such as climate variability and climate change, and human impacts on landscapes.

The benefit of water catchment mapping and modelling is to achieve an integrated approach to natural resource management through a comprehensive view of water and land uses within the catchment areas. Remote sensing technology can provide pertinent information on surface and groundwater flows, run off rates, delivery of flows and constituents into river systems. When used in hydrological models, remote sensed data can be converted to the type of information useful to water resource systems operators. With such information on water catchment, areas can be demarcated, micro-catchment areas identified, buffer zones established and water safety plans developed (FAO,2011).



Water Resources Map of Guyana. Watersheds generated from SRTM 30m with a minimum areas size of 40,000m2. Using Qgis and GRASS GIS.
Source: Geospatial Ideas, 2011

Institutional /Organizational	The Ministry of Natural Resources and the Environment Protection Agency are the institutions responsible for the protection of natural resources in Guyana. Other key stakeholder institutions are, the Guyana Lands and Surveys Commission, the Hydro-meteorological Department of the Ministry of Agriculture and the Guyana Water Inc.
Adequacy for Current Climate	Not climate dependent. Will build Guyana's capacity in water resource planning and management.
Size of Potential Beneficiary	The general public, including, water resource managers, natural resource managers, land use planners, researchers, households, farmers, fisheries, miners and manufacturers. Local water managers will be provided with updated information/ expertise/tools for a more scientific basis in water management.
Disadvantages	• Require specialized skills in GIS and modelling; • Changing pace/ cost of this technology and the limitations of off-the-shelf models; • Operating cost may be high initially due to the need for data collection and specialized training; and • Diffusion at community levels may be slower due to the lack of financial and human resources.
Endorsement by experts	This technology is readily available in North America. The US Geological Survey (USGS)) has been providing leading services in the development of hydrologic simulation models since the 1960's. The models are widely used to predict responses of hydrologic systems to changing stresses, such as increases in precipitation or ground-water pumping rates, as well as to predict the fate and movement of solutes and contaminants in water (TNA FS).
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • Will include costs for engineering hardware and software components, such as, computers (desktop & field notebooks), servers, data collection, GIS tools, numerical models and training/capacity building. Price for models vary with the level of complexity required and can range from USD1000 -10,000. Where there are existing resources available locally, such as, GIS expertise, this can be utilized. Software can be open-sourced or procure license; and • A conservative estimate for the implementation of this technology is USD 55,000. *Operation/Maintenance*: • This cost is likely to be moderate and will primarily include fees for software subscription (if purchased), equipment updating and ongoing capacity building.
Development Benefits – direct/indirect benefits	
Adaptation benefits	• Improve the overall capacity in water management for all categories of water users; and • Enhance Guyana's capacity to prepare/adapt to the impacts due to a changing climate.
Economic benefits	• Employment opportunities for technical core staff, as well as, persons in local communities and water user groups; and • Can stimulate investments due to improved water management, such as in agriculture and industry.

Social benefits	• Increased awareness and knowledge of ground water resources; • Community empowerment through participation in local water management programs; • Contribute to livelihood security due to reduced wastage; and • Improved health due to increased water availability and improved water safety.
Environmental benefits	• Promote water security in terms of clean and safe water sources; • Contribute to the health of water ways and ecosystems due to improved protection; • Strengthen capacity to manage forest/bush fires, control erosion and monitor biodiversity changes; and • Provide scientific data for decision making.
Local Context	
Status of Technology	This technology does not currently exist.
Market potential	Has potential for the development of a national network of water catchment monitoring. Can also be integrated with Regional framework for water catchment protection with basin states as in the Amazon basin.
Acceptability to stakeholders	Has high acceptability among water resource managers, researchers and users.
Opportunities and Barriers	*Opportunities:* • Can contribute to the development of local water management plans; and • Will promote more effective water management when applied efficiently. *Barriers:* • May be perceived as too complex, resulting in loss of interest; • Lack of/Low level of commitment to undertake responsibility; and • Difficulty in retaining trained staff
Time Frame	Medium to long term.

References

1. Elliott, M., Armstrong, A., Lobuglio, J., and X Bartram, J. (2011): Technologies for Climate Change Adaptation – The Water Sector. TNA Guidebook Series. UNEP.
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Sector	**Water Resources**
Subsector/ Category	Diversification of water supply/sources
Technology	Rainwater harvesting – Above ground (Collection, Storage & Treatment)
Scale of Application	Household level and community scale
Availability	Domestic rainwater harvesting (DRWH) can be regarded as a mature technology in Guyana. Approximately, 14.6% of the population depends on rainwater harvesting as their primary source for drinking water. Data from 2005 and 2006 show that in urban areas 12.8-16.4% of the population use rainwater collection as a drinking water source and in rural areas the percent is even higher at 25.6-27.2%. Domestic use of rainwater suggest that the Guyanese population views rainwater as high quality water and harvests it more specifically, for drinking purposes (Intven,L, 2009)

Technology Characteristics

Introduction

Guyana will be severely affected by climate change through changes in rainfall patterns including floods and droughts (SNC, 2012). The impact on the water sector will be felt not only at the points of water supply and distribution for domestic and commercial (industrial) sectors, but also in agriculture and health. According to the assessment for the water sector in the Guyana's Second National Communication, water availability due to projected rainfall patterns and evapotranspiration for the period 2040-2069 in Regions 5, 6, & 10 will decrease. Temperatures will increase, while precipitation is projected to decrease, thus, leading to overall water shortages for domestic, industrial and agricultural uses (SNC, 2012).

Recognizing the high dependence of the country on ground water sources, projected increase expansion in the housing sector, and vulnerability due to variability of precipitation leading to projected water deficits, it is paramount that adaptation strategies be implemented in the water sector. One such option is through the application of water conservation techniques by diversifying the water supply as in the adoption of technologies such as Rainwater Harvesting.

Rainwater harvesting (RWH) is a low cost practice that is easy to implement and is being promoted by the Guyana Water Inc. (GWI) for application at the individual household level. RWH can also be pursued at the community level, allowing for collection in small concrete reservoirs. Rooftop rainwater harvesting require primarily containers for collection and storage, and conveyance (gutters & pipes). The most common collection/storage containers used are the 450 gallons, tuff water tanks and to a lesser extent, 55 gallons, blue shipping barrels. Many households are equipped with rooftop harvesting , using 1 to 2 tuff storage tanks. Construction of new catchment area and reservoir increases the cost for RWH. This depends on the size of the catchment area and capacity of the reservoir.



Institutional /Organizational requirements	The GWI is the primary institution responsible for water supply in Guyana. However, there is no specific institution with core responsibility for RWH. The GWI partner with

	other institutions such as the Environmental Protection Agency, Ministry of Health and the Guyana Red Cross to promote and encourage RWH. The specific system will be designed for the household and/or the community levels. However, community systems will require more planning and resources.
Adequacy for Current Climate	This technology application is highly suitable to Guyana's climatic conditions since the country benefits from two (2) rainy seasons annually, April to August and November to January. Annual average rainfall totals between 1600-3000mm. Geographical influences, such as mountains and oceans, results in three major climate types: *Tropical savannahs*, which are very dry regions with annual rainfall of less than 1788mm; *very wet tropical forest climate,* with annual rainfall exceeding 2728mm, and the *wet-dry tropical forest*, which represent the rest of the country, with annual rainfall between 1778mm to 2800mm (SNC,2012).
Size of Potential Beneficiary	The entire population could benefit from its application, especially, the agriculture sector. Guyana is currently experiencing severe dry conditions, resulting in the loss of major crops, such as, rice and vegetable crops in Regions 2,3,5 and 6. Currently, approximately 90% of the population resides on the coastland of Guyana where agriculture is a dominant activity. With the development of inland agriculture as a high priority in the sector, RWH is becoming more important within those regions.
Disadvantages	• Not reliable during dry periods or periods of prolong drought due to limited or variability of precipitation; • The size of the storage devices can limit storage capacity and the harvesting potential; and • Larger storage capacity could lead to increase installation and operating cost making the technology less viable in the longer term.
Endorsement by experts	RWH is widely practiced in many countries worldwide. Over 60 million people were using RWH as their main source of drinking water in 2006 and that number is projected to increase to more than 75 million by 2020 (WHO and DFID, 2010). It is likely that hundreds of millions more collect rainwater as a supplementary source of water for potable and non-potable uses. RWH can aid climate change adaptation even in the most developed countries. If safe, reliable piped supplies are available, RWH for non-potable uses can partially offset the increase in household use. Simple rain barrels are commonly used to water landscapes without taxing the piped water supply. One-third of residential water in Europe is used for toilet flushing and 15% in washing machines and dishwashers (UNEP, 2004).
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • The cost of the RWH system depends on catchment area, conveyance system, storage devices and capacity. Quantity of rainwater from catchment is estimated using the following formula: *Water harvested= catchment area x amount of rainfall x conversion factor (differs for catchment type)* • Rooftop rainwater harvesting require primarily containers for collection and storage, and conveyance (gutters & pipes). The most common collection/storage containers used are the 450 gallons, tuff water tanks and to a lesser extent, 55 gallons, blue shipping barrels. Many households are equipped with rooftop harvesting , using 1 to 2 tuff storage tanks. The cost of the tanks can range from US$25 to US$100. A single household system is estimated at US$ 140; and

	• Construction of new catchment area and reservoir increases the cost for RWH. This depends on the size of the catchment area and capacity of the reservoir. *Operation/Maintenance:* • The system is designed to protect water quality through the installation of filters or screens and a 'first flush' system to discard the initial volume of precipitation; • Storage devices are usually covered to avoid the breeding of mosquitoes and to protect water quality. One such system is the rainwater harvesting model designed by the Global Water Partnership-Caribbean and promoted by GWI. Maintenance can be done every three (3) to four (4) months in preparation of the rainy season; and • Generally, has very low running cost and is not labor intensive.
Development Benefits – direct/indirect benefits	
Adaptation benefits	Considering the water demand on ground water sources and surface water by coastal and riverine communities, the deployment of this technology contributes greatly to climate change adaptation, through diversification of water supply at the household, industry and community levels. It allows for water conservation by reducing pressure and dependence on the traditional water sources through decreased demand.
Economic benefits	• Alternative or non-potable uses of rainwater can offset piped-water costs; • Employment opportunities as a result of construction of RWH systems and the supply of materials; and • Additional income due to the stimulation of commercial enterprises.
Social benefits	• Stable and sustained access to potable water especially to communities with limited or no access; • Diversified sources of potable water for coastal communities; • Reduced incidence of water-borne diseases caused by the dependence on surface water sources for domestic purposes in inland communities; and • Increases per capita water availability and sustainability of water resources. .
Environmental benefits	• Promote water savings; • Diversified water supply; • Reduced stress on ground and surface water sources; • Mitigate flooding by capturing runoff during rainstorms; and • Capture water that would have otherwise evaporated.
Local Context	
Status of Technology	RWH is a mature technology in Guyana. Its application has been mainly along the coastal regions of the country, to augment the tapped-water supply during periods of rationing and well maintenance. In land regions have traditionally used a combination of rain water and freshwater from rivers/streams. Over the years, wells have been dug and piped water is available in some communities. However, tapped water supplied through GWI's piped distribution network is inconsistent in some communities, whereby, water is supplied for a few hours during the day. In addition, there are still some communities which have limited or no access to potable sources of water. These communities depend on other sources of potable water. The GWI in partnership with the Global Water Partnership – Caribbean have been promoting

	rainwater harvesting as a water conservation and diversification technique within the framework of building climate resilience in the water sector.
Market potential	This technology is trans-generational, well-proven and extends to the entire population residing on the coast, as well as, communities in the inland regions. A significant market exists in the inland regions in Guyana once the technology is deployed to communities as methods of water conservation and diversification. The simplicity of this technology makes it easy to diffuse in the market. Materials are locally available for installation, operation and maintenance.
Acceptability to stakeholders	RWH is easily acceptable to all stakeholders. Individual household rainwater harvesting currently exists along coastal areas, to supplement tap and surface water sources with limited application in the inland regions.
Opportunities and Barriers	*Opportunities:* • Promote economic development and general wellbeing due to improved access and water quality; and • Increased savings due to less use of piped water; *Barriers :* • Vegetative roofing used by most inland communities may be inadequate or unsuitable for the application of RWH; • The cost of the rainwater storage devices is often seen as the costliest component and a notable barrier for deployment of the technology in poor households; • Adequate space for storage containers; and • Treatment options, such as, filters and filtration devices can increase overall operational/maintenance cost.
Time Frame	Short to medium term.

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Appendix 5: Factsheets for Coastal Zone and Low-Lying Communities Sector

Sector	Coastal Zone and Low-Lying Communities
Sub-sector/Category	Coastal Zone protection
Technology	Mapping and modelling of coastal processes for construction of seawalls and groynes
Scale of Application	Coastline of Guyana – Approximately 230 KM long.
Availability	Guyana's seawall structures are over 100 years old and in dire need of replacement or re-enforcements. In some areas along the coastline, there is a need to put in new structures. Mapping and modelling to inform the construction of this infrastructure is currently unavailable/limited in Guyana. It is proposed that numerical models be applied to better understand the causes and consequences of coastal dynamics. Recent research by Van Ledden et al (2009) used numerical model SWAN to study wave event along Guyana's shoreline in 2005. SWAN is a third-generation wave model, developed at Delft University of Technology, that computes random, short-crested wind-generated waves in coastal regions and inland waters (SWAN, 2016). It is available through open source.
Technology Characteristics	

Introduction

In the analysis of coastal hydrodynamic processes, modelling (physical, numerical and composite) is often employed to simulate the main phenomena in the coastal region. With the advancement of technology, a variety of coastal models have become available and the techniques have become quite mature. Physical models refer to the use of laboratory models at an appropriate scale (micro, small, medium and large scale models) for investigating the relevant process, numerical models refer to the use of computer codes (commercial & open source) and composite models refer to the integrated and balanced use of physical and numerical models (CoastalWiki, 2016).

By 2030, the annual loss due to flooding in Guyana is projected to be US$150 million (LCDS, 2010). Guyana's coastline with the Atlantic Ocean lies at elevations between 0.5 m and 0.7 m above mean sea level, but it is threatened by tides which rise to 1.6 m above mean sea level. Several major rivers also run through the coastal zone, including the Demerara and Essequibo rivers (Van Ledden et al, 2009). As a result, the entire coast is protected by a system of concrete walls, boulders, groynes and mangroves. The coastland of Guyana is extremely vulnerable to sea level rise and storm surge. There is a need to construct and maintain a reliable system of protection from these climatic events. In 2005, Guyana experienced a major flood, which damaged approximately 1520m of sea defence structures along the coastline. Most of the structures damaged were constructed during the period 1945-1959 (Van Ledden et al, 2009).

Seawalls and overtopping in Guyana

To date, Guyana has significant experience in the construction of sea wall and groynes. However, there is a need for better application of tools (design) based on the knowledge of coastal hydrodynamics, such as, movement of mud shoals and sediment, wave propagation/properties etc. A survey in 2014 of Guyana's sea defence structures, which covered 91.2% of the total length, shows that 2.28km (1%) is in critical condition, 20.53km (9%) is poor and 80.22km (34.4%) is in fair condition (Budget Presentation, 2016). Rehabilitation of the critical and poor sections of the sea defence structures are being executed on a phased basis. In 2015 a total sum of $1,274.084B was provided for Sea and River Defence and at the end of December 2015 the sum of $1,270.370B was expended. These works were done throughout Guyana, including at Wakenaam and Scottsburg, Corentyne, among others. In 2016, a sum of $1,383.786M has been provided for Sea and River Defence Works. Among some of the major projects identified are the construction of rip rap river defences in Wakenaam; Blenheim, Leguan; Islington, Berbice; and Waller Delight, West Coast Demerara, among others (MoPI, Budget 2016).	
Institutional /Organizational	The Ministry of Public Infrastructure (MoPI)is the primary institution responsible for the sea and river defence in Guyana. This technology will be implemented through the Sea and River Defence Division of the MoPI. There will be close collaboration with the Maritime Administration Department (MARAD), Lands & Surveys Commission and the Environment Protection Agency.
Adequacy for Current Climate	Not climate dependent. However, will contribute significantly to Guyana's capacity to adapt to the worst impacts from sea level rise and storm surge.
Size of Potential Beneficiary	The entire coastal population which accounts for approximately 90% of the country's total population.
Disadvantages	• Require reliable /historical data; • Slow to implement due to the lack of skills and may confront resistance to potentially increase work demands; and • High maintenance cost of equipment and salaries for technical expertise.
Endorsement by experts	The mapping and modeling of coastal processes have been endorsed by engineering experts globally. In recent decades, with the advancement of technology, various types models have been developed, such as, WAVEWATCH by National Oceanographic and Atmospheric Administration (NOAA), SWAN by Delft University of Technology, delft3D by Deltares – independent research institution in the Netherlands, etc. providing innovating advanced modelling techniques and applied in countries like the USA, Netherlands, Singapore, Hong Kong etc.
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • There is no available data of estimated costs for this type of technology in Guyana. Much of the cost estimates available are for the construction of the sea wall/ groynes. However, costs for mapping and modeling will be high due to the engineering hardware/software components, such as, computers, servers, data collection, GIS tools, numerical models and training/capacity building; and • Existing resources such as, data collection equipment and skills is expected to be utilized, which will offset some human resource cost.

	Operation/Maintenance: • Will likely be high due to the required field work; • Software/hardware update; and • Expenses to retain technical skills.
Development Impacts – direct/indirect benefits	
Adaptation benefits	• Updated baseline data for coastal protection; • Robust designs in sea defence infrastructure; • Avoidable damage to coastal infrastructure and habitat; and • Reduce overall adaptation costs, which is estimated at USD1billion per annum.
Economic Impacts	• Direct economic impact may result from employment through the implementation phase of the technology, as in the, recruitment of consultants, use of technical services and hiring of skilled personnel and labor; and • Other long term impacts occur on a macro scale through the improved protection of agriculture lands and coastal settlements.
Social Impacts	• Employment for technical and field staff; • Increased awareness of coastal characteristics and its impacts; and • Community involvement in coastal protection and management.
Environmental Impacts	• Improve coastal zone management; • Contribute to restoration of degraded coastal areas; • Reduce flooding of coastal lands; and • Protection of inland fisheries, agriculture and settlements.
Local Context	
Status of Technology	This is a much needed technology which is currently lacking/limited in Guyana. The current approach to the design & construction of sea defence use techniques such as, inspections, surveys (including aerial surveys) and assessment of vulnerable areas and deteriorating structures.
Market potential	Sea wall/groynes construction is widely applied and is a proven technology. However, mapping and modelling has had limited application. Will be easily diffused among groups such as, engineers, academics, providers of expert services for sea wall construction and financial donors for infrastructure development (CDB, IDB, EU).
Acceptability to stakeholders	The technology will have high level of acceptability among coastal protection engineers and decision makers. New and robust designs will be beneficial for overall coastal zone protection and management which include stakeholders at the institutional, as well as, community levels.
Opportunities and Barriers	*Opportunities:* • Can be implemented along with other technologies for coastal zone management and protection, such as, managed retreat and mangrove restoration; • Improved local technical capacity; and • Improved planning in sea defence intfrastructure design. *Barriers:* • A major barrier is the cost to implement and sustain; • Lack of technical skills and labour; and

	• Materials for construction can hamper the effectiveness of this technology.
Time Frame	Medium to long term

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Sector	Coastal Zone and Low-Lying Communities
Subsector/ Category	Extreme weather events (Flood & Drought Management)
Technology	National Early Warning Systems (EWS) (Flood & Drought)
Scale of Application	National scale
Availability	A fully functional and integrated formal system is not yet available or operational in Guyana. Response action to disasters is coordinated by the CDC. To date, much work has been completed to support the establishment of an integrated EWS in Guyana, such as, the preparation of the following: A EWS Framework (2013), a National Integrated Disaster Risk Management Plan & Implementation Strategy (2013), A Multi-Hazard Preparedness and Response Plan (2013), An EWS Study – Situation Report (2009), A Draft EWS Protocol for Drought (2015), A National Adaptation Strategy & Action Plan for the Agriculture sector (2009) and recently, in December 2015, the CDC launched a National Emergency Monitoring System. EWS can be formal with readily visible structures that are part of the national government bureaucracy or they can be informal aspects of local, cultural traditions. Currently, EWS in operation covers most types of natural hazards, conflict, ecological changes, health-related and complex humanitarian crises (CDC, 2013)
Technology Characteristics	

Introduction

Sea-level rise from climate change is projected by more than 1 m by 2100. The coastal region is most vulnerable from sea level rise and extreme weather events since it houses over 90% of the population, along with the country's major infrastructure and economic zones (SNC, 2012). Climate change and extreme weather events, due to their severity and frequency, will exacerbate the country's vulnerability. A number of studies were conducted over the years and these concluded Guyana is exposed to the following disaster risks/ hazards /treats (i) flooding as a result of excessive rainfall, (ii) coastal flooding as a result of breached levees and over-topping of the seawall, (iii) drought from reduced rainfall over an extended period, (iv) intense storms and high wind-speeds affecting people and property, and (v) risks of wild fires (due to excessive dry periods) (GLSC, 2010 & Cummings (not dated).

Already, the country is experiencing the impacts of extreme weather events such as floods due to increased and intense precipitation and low annual and seasonal rainfall resulting in drought-like conditions. The major flood of 2005 affected approximately 275,000 people, killed 34 and cost the country approximately USD 465M (ECLAC, 2005; Cummings, not dated). The major drought of 1997 affected approximately 607,200 people and caused the country USD 29M (Cummings, not dated). Findings showed that information was not disseminated to communities and general warning systems were inadequate to inform the public of the threat and the extent of the disaster and, as a result, the impacted population was caught off-guard (ECLAC, 2005).

Early warning system (EWS) is a critical component of a country's disaster risk reduction strategy and adaptation framework and allows for the provision of timely and reliable information in advance of the occurrence of a disaster to adequately plan and safeguard lives and livelihoods. EWS goes beyond the use of technology for monitoring, prediction and dissemination of information. It is an established system that provides advance information of possible hazards and encompasses components to manage risks and mitigate losses through planned measures and response actions (CDC, 2013).
This technology application in Guyana is focused on a national-scale EWS for flooding and drought as a component of the country's climate change adaptation strategy. It takes into consideration that a fully functional EWS must be able to

<table>
<tr><td colspan="2">forecast a number of climatic and weather related events across different temporal scales. The warning must be timely to allow for planning and response, reliable and simple to understand (Grasso,V, 2012).

The national studies conducted in Guyana to establish an early warning system present the four (4) elements as (GLSC, 2010):
(i) Monitoring & Warning – technical hazard monitoring and warning service;
(ii) Dissemination and Communication – communicate risk information and warnings timely and appropriately;
(iii) Preparedness and Response – national (and community) preparedness and response capabilities; and
(iv) Knowledge - understand the hazard, vulnerability and risks through assessments and data collection and information preparation.</td></tr>
<tr><td>Institutional/Organizational</td><td>The Civil Defence Commission (CDC) has the responsibility prepare, coordinate and respond to all types of disaster in Guyana. Other collaborating institutions are, National Drainage and Irrigation Authority, Sea and River Defence Division, Environmental Protection Agency, Hydrometeorological Service. As it relates to the elements of an EWS, a number of institutions have specific responsibilities and these are:
(i) Monitoring and warning - Hydrometeorological Service;
(ii) Communication and dissemination - Government Information Agency (GINA) in collaboration with other media houses;
(iii) Preparedness and response – CDC in collaboration with other agencies;
(iv) Knowledge of hazard, vulnerability & risks as well as data collection – Environmental Protection Agency, Guyana Lands and Surveys Commission, Bureau of Statistics, Guyana Red Cross, Hydrometeorological Service, Guyana Water Inc.</td></tr>
<tr><td>Adequacy for Current Climate</td><td>The national policy environment in Guyana favors the formal establishment of an EWS as new institutions are not required. A formal system enables effective planning, collaboration and coordination among the responsible institutions and build synergies for the optimization of resources to allow the country to effectively adapt to climate variability and future climate change.</td></tr>
<tr><td>Size of Potential Beneficiary</td><td>The direct beneficiaries are ‘at risk’ communities in the vulnerable areas, however, the entire country and all sectors would also benefit from the implementation of a national scale EWS.</td></tr>
<tr><td>Disadvantages</td><td>• Monitoring of slow-onset hazards such as droughts could be a challenge in the absence of advance technology and improved knowledge;
• High costs associated with implementation and maintenance of the system, especially to monitor drought conditions;
• Skills and capacity to analyze the information; and
• Public perception, behaviour and response to warnings could impact the functioning of the system.</td></tr>
<tr><td>Endorsement by experts</td><td>EWS is fully endorsed by national and international experts. EWS as defined by the United Nations states that “EWS is a set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm and loss[7]” (UN ISDR, 2009).</td></tr>
</table>

[7] http://www.preventionweb.net/english/professional/terminology/v.php?id=478

Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • There is no single institution to oversee and manage EWS. The Hydrometeorological Service provides all weather-related data to the CDC and other stakeholders. The CDC oversees disaster response and collaborates and coordinates with responsible institutions. The implementation of a national scale EWS will incur high costs, including, strengthening the capacity of the Hydromet Service, consultancy services, training in EWS response techniques, equipment for data collection, communication, networking and transport. *Operation/ Maintenance:* • Effective functioning of networking and communication systems; and • Ongoing training/capacity building in response measures.
Development Benefits – direct/indirect benefits	
Adaptation benefits	• Contributes to reduction of vulnerability to climate change and extreme weather events and increased climate resilience of the country through the provision of timely information to critical stakeholders.
Economic benefits	• Reduces overall national expenditure on climate related disasters; • Reduce impacts and economic losses at the household level due to early warning; • Allow for interventions to reduce the impact of flooding and droughts in advance of the event; and • Increase employment opportunities and provision of local skills in range of disciplines to support the operation and maintenance of EWS.
Social benefits	• Minimize risks to life and livelihoods and allows for early evacuation of vulnerable groups; • Timely dissemination of information through EWS to 'at risk' population and sectors enable stakeholders to plan activities to reduce losses and risks and safeguard income; and • Reduce impacts on health and the spread of diseases, especially during flooding.
Environmental benefits	• A fully functional EWS will provide information to contribute to environmentally sustainable development; and • Allows for a reduction of impacts on the environment associated with flooding.
Local Context	
Status of Technology	A formal early warning system is not yet operational in Guyana. To-date a number of studies were conducted by the CDC and the GLSC to understand Guyana's context and requirements for the establishment of EWS in the country, as well as, how the system could function as part of its national disaster risk reduction approach. Elements of EWS such as meteorological observations, forecasting and to some extent dissemination of information exist, albeit, there is limited capacity to make future projections. The use of geographic information system and remote sensing, satellite images, flood forecasting system to adequately monitor and predict hazard events are not yet in use (CDC, 2013; GLSC, 2010).

Market potential	This technology widely available and applied in many countries. A significant market exists locally for the provision and application of equipment for monitoring, mapping and modeling and dissemination of information.
Acceptability to stakeholders	All groups of stakeholders are affected greatly by natural disaster in Guyana, and view this technology as critically needed. Recognizing the impact on the agriculture sector can have a crippling effect on the economy, farmers will readily embrace the implementation of an EWS.
Opportunities and Barriers	*Opportunities:* • Promote institutional strengthening for roles and responsibilities of each component of the EWS; and • Generate wider national interest/involvement in disaster preparedness; *Barriers:* • Lack of specific legislation and legal framework to address disaster preparedness and response planning, in general, and specific to EWS; • The absence of a formal system of early warning leads to insufficient coordination, participation, investment and lack of clarity of roles and responsibilities (duplication of roles and responsibilities); and • Lack of adequately trained personnel to support the implementation of EWS and use of hardware/software.
Time Frame	Short to medium term

References:

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Sector	Coastal Zone and Low-Lying Communities
Sub-sector/Category	Flood Control
Technology	Energy efficient mobile pumps for flood control
Scale of Application	Coastal Zone
Availability	Mobile pumps for flood control has been introduced in Guyana and isused mainly to alleviate flood. However, it is also used for irrigation during extremely dry conditions. The capacities and model of the pumps differ depending on the quantity of discharge required. Due to the high fuel costs and the shift towards cleaner technologies, energy efficient pumps are recommended. The use of clean energy and more efficient motors for pumping solutions is already in the global market place, for example, Groundfos, a US based company is a major supplier providing pumping solutions in India.

Technology Characteristics

Introduction

Climate Change and variability will result in extreme weather conditions, from excessive high intensity rainfall and flooding to protracted droughts, which would have catastrophic effects on agriculture and livelihood (SNC, 2012). These climatic events will place additional stress on flood control and the country's drainage network.

Guyana's drainage system is natural, gravity flow, augmented by pumps and depends on the main rivers, which extend beyond the coast. Between 1988 and 2010, flood events resulted in more than $634m in economic damage affecting up to 42% of the population. In January 2005 alone, catastrophic floods in the coastal zone affected 25% of the population resulting in a near breach of the East Demerara Water Conservancy dam. The effects included total economic losses equivalent to 60% of GDP for that year. Flood hazard risks are further exacerbated as a result of CC and climate variability trends. According to the SNC,2012, the recent flooding events "demonstrates Guyana's vulnerability to climate driven events and its short-comings in the current drainage infrastructure which is insufficient to discharge excess water from heavy rainfall".

Hydra Flow Mobile pump used in Guyana

Discharge Capacity - Cusec	***Number of Pumps***
15	1
20	2
40	**16**
80	**5**
120	9

Number of Hydra Flow mobile pumps in Guyana. Source: NDIA, 2016.

Mobile hydra flow pump is a complete pump station on wheels. The Hydra flow is a submersible axial or mixed flow pump driven by a hydraulic pump and motor through flexible hydraulic lines, instead of a typical long, fixed shaft. The design allows great flexibility, cost savings and speed in the placement of the pump. Since little to no civil works are required to install the Hydra flow pump system, total project costs can be reduced by up to 70%, and its design allows the pumps to be mobile. The portability of the Mobile Hydra flow permits easy movement to various locations where large volumes of water need to be pumped. Everything needed for pumping is mounted on a spring/axle trailer. This includes: the diesel engine, water pump, fuel tank, hydraulic oil reservoir, rigid discharge pipe, flexible discharge hose, and a complete safety shutdown system (MWI Pumps).

Mobile pumps techlogy are constantly evolving for improved efficiency and durability. Energy efficient mobile pumps for Guyana aligns with the national development thrust for clean technologies and a green economy.	
Institutional /Organizational	The National Drainage and Irrigation Authority (NDIA) is responsible for the implementation of this type of technology.The Authority functions as Guyana's apex organization dealing with all public matters pertaining to management, improvement, extension and provision of drainage, irrigation and flood control infrastructure and services in declared areas of the country (MOA). There may be some collaboration with the Ministry of Public Infrastructure (MoPI).
Adequacy for Current Climate	Highly suitable for the current climate due to the high vulnerability of coastal areas and low lying areas to flooding. The GOG had undertaken to install drainage pumps throughout the coast of Guyana and replacing old and undersized pumps and to deploy additional pumps to meet the growing demand in drainage, due to increased farming acreage under cultivation and to cope with impacts caused by rising sea levels (Guyana Chronicle, 2015).
Size of Potential Beneficiary	The general population in coastal and low lying areas which is approximately 90% of the country's total population.
Disadvantages	• High initial capital cost; and • Need to have reliable maintenance service
Endorsement by experts	Mobile pumps for flood control has gained traction globally and has been introduced in Guyana for some time. However, there is a need for more energy efficient units.
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • Capital investment cost would depend on the brand, design and capacity of the pumps. Estimated cost for a 120 cubic feet per second discharge capacity mobile pump is US$250,000. Energy efficient pumps will have a higher cost. *Operation/Maintenance:* • Cost significantly lower than expenses for stationary /fixed pumps; • Include fuel, cleaning, spare parts, operator/s salary, transport to site/s and security; and • Costs will be higher during periods of flood and drought.
Development Impacts – direct/indirect benefits	
Adaptation benefits	• The adaptation benefits will be significant, especially in the agriculture and health sectors. Mobile pumps will enable the draining of accumulated water in otherwise, hard to reach areas. The ability to drain the land faster will bring relief to flooded farms and households, reducing the loss of crops and livestock, and proliferation of water borne diseases. •
Economic Impacts	• Direct economic benefits will be from cost savings by the NDIA when compared to the civil works required by stationary pumps; • Savings from better efficiency and renewable energy source • Stimulate investment/ enterprise in mobile pump technology and flood control; and • Reduce loss in income from damage to livelihood ventures.

Social Impacts	• Develop/strengthen awareness of climate change and Guyana's vulnerability; • Promote capacity building in communities through their involvement in the operation/maintenance of the pumps; and • Reduce risk from loss of income and livelihood.
Environmental Impacts	• Reduce flooding of coastal lands and salt water intrusion; • Reduce loss of crops and livestock; and • Prevent/minimize damage to buildings/assets.
Local Context	
Status of Technology	Mobile pump technology has been introduced in Guyana. According to the NDIA, there are currently 33 mobile pumps throughout the country, with discharge capacity between 20 – 120 cusec. Most have a discharge capacity of 40 cusec. However, there is a need for energy efficient pumps.
Market potential	The rapid deployment of this technology will build the capacity of the NDIA and other users in flood control. Investors and enterprises are also likely to cash in on providing equipment/materials/maintenance/transportation services
Acceptability to stakeholders	Floods affect many groups of stakeholders. Farmers in particular are a highly vulnerable stakeholder group and the wide dissemination of this technology will be most welcome alongside improved drainage networks.
Opportunities and Barriers	*Opportunities:* • Wider deployment of this technology would create more awareness about flood control and present opportunities for faster response action on flood events; and • Strengthen Regional and community bodies capacity to use technology. *Barriers:* • High capital cost; • Limited interest at decision-making levels; and • Lack of know-how about the technology can be a barrier to implementation.
Time Frame	Short to medium term

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Sector	Coastal Zone and Low-Lying Communities
Sub-sector/Category	Coastal Zone protection
Technology	GIS for operationalisation of land use plan
Scale of Application	National
Availability	GIS mapping/modelling are increasingly being used by planners around the world. With the increase in user friendliness and the number of functions of GIS software, and the marked decrease in the prices of GIS hardware, GIS is now an operational and affordable information system for planning. Recent advances in the integration of GIS with planning models, visualisation, and the Internet will make GIS more useful to urban planning (Chen, 2014). Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. GIS technology has been introduced in Guyana. Although not widely diffused throughout the country, it is being used by some key sectors and agencies, such as, the Forestry sector, EPA and the Guyana Lands and Surveys Department. There is also a handful of independent GIS services.
Technology Characteristics	
Introduction With support from the European Union, Guyana completed its National Land Use Plan (NLUP) in 2013. There is no Land Use policy at the moment, thus, the NLUP is used to guide land use decisions. According to the NLUP "the primary objective is to provide a strategic framework to guide land development in Guyana". The plan builds upon a number of national policies and strategies that have a direct relevance for land use and land management and to enable financial resources to be targeted at optimal land uses at the regional level (NLUP, 2013). These include the National Development Strategy (NDS 1996), the Poverty Reduction Strategy (PRS 2000, 2004, 2011), the Land Use Baseline Document (1996) which led to the Draft Land Use Policy (2004, 2007), the National Competitiveness Strategy (NCS 2006) and the Low Carbon Development Strategy (LCDS 2010). The need to make land-use decisions on a national and regional scale in a single system, make GIS a great tool for integrating in planning processes. In Guyana the vast majority of data that can be mapped and used in a plan is at the national level i.e. small scale, of 1:1 million or smaller. The output maps for the NLUP will be at 1:2.5m and 1:1m scales. GIS technology for Land Use Planning (LUP) can be best summarised as "Geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions. GIS organises geographic data so that a person reading a map can select data necessary for a specific project or task. Data can be used to develop thematic maps which can help to make decision about that particular sector or issue. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available" (ESRI, 2011).	
Institutional /Organizational	The Guyana Lands & Surveys Commission will be the lead Agency responsible for the implementation of this technology. However, there will be a high level of collaboration with other sector agencies since the LUP is a shared implementation approach among the various sectors. Also, data will be shared with institutions with GIS capacity for their use.
Adequacy for Current Climate	This technology is not climate dependent.

Size of Potential Beneficiary	At the policy making level, this will be useful for land use planners and decision makers. Guyana has an existing Land Use Plan and its use can be greatly enhanced through the spatial analyses of land resources and its multiple uses. Communities and investors are also primary beneficiaries.
Disadvantages	• Lack of/ inadequate data and capacity may limit the intended use of the technology; • As a multi-criteria tool, there will be a need for a range of data types, criteria etc which may need to be collected; and • Low level of interest due to high cost and complexity of the technology.
Endorsement by experts	Decades after Canadian Roger Tomlinson's (acknowledged father of GIS) breakthrough, this technology is everywhere. It is a proven technology which has gained traction worldwide with the internet and open source services. ESRI, is a leader in GIS products and services and is accessible online. It is widely used by all categories of stakeholders, planners, educators, students, researchers etc.
Capital Costs	
Cost to implement/Operate/Maintain	*Implementation:* • Expected to be high and will include procurement of computer systems and accessories, training, data collection/updating. Software will be open sourced. May need to hire additional staff for this unit. Will require capacity building in GIS/Modeling land use and risk mapping; and • Estimated, cost for hardware (equipment) is US$60,000. *Operation/Maintenance*: • Recurring costs will include, periodic training, maintenance of equipment and salaries for staff. However, existing resources such as data and skills will be utilised; and • Estimated cost over a five year period: US$554,600.
Development Impacts – direct/indirect benefits	
Adaptation benefits	Spatial mapping/modelling makes it possible to estimate the widest range of impacts of existing trends of population, and of economic and environmental change. For example, a range of environmental scenarios can be investigated through the projection of future demand for land resources from population and economic activities.
Economic Impacts	• Generate employment since additional staff may be required; • Promote investment opportunities; and • Can increase budgetary allocations of institutions.
Social Impacts	• Reduce loss suffered from natural disaster such as flood & forest fires due to improved planning; • Reduce incidence of land use/development conflict; • Control overcrowding and illegal settlement; and • Increase awareness of land use challenges and climate change.
Environmental Impacts	• Contribute to the reduction of the impact due natural disaster such as flood, forest fires etc; • Improve understanding of natural resources and predict changes; • Protect vulnerable habitats and ecosystems; • Guide the sustainable harvesting of natural resources; and

	• Improve urban and rural planning.
Local Context	
Status of Technology	There is a Land Use Policy and Planning Section, a Land Information and Mapping Division and an IT Unit within the GLSC. Current GIS capacity include, Senior & Junior GIS Specialist, GIS Technicians, Cartographer and IT personnel. To date, a number of digitized maps have been developed by the GL&SC for sectors such as, water resources, available land, vegetation types etc.
Market potential	The results of this technology can be diffused readily among institutions, which can then make more informed decisions about their sector. Various socio-economic, demographic and environmental scenarios can be investigated through GIS mapping and projections.
Acceptability to stakeholders	As a multi-criteria decision-making analytical tool, GIS mapping/modelling of land use is highly acceptable among planners. Other stakeholders, such as educators and researchers have also expressed the need for improved planning of the country's towns, cities and communities.
Opportunities and Barriers	*Opportunities:* • Improved understanding of Guyana's resources and land use changes; and • Promote implementation of National Land Use Plan; *Barriers:* • May not be a high priority of government; and • Often slow to implement due to the high capital cost and lack of specific skills in the sector/country;
Time Frame	Medium to long term

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