Office of Climate Change
Ministry of the Presidency

UNEP DTU PARTNERSHIP

TECHNOLOGY NEEDS ASSESSMENT REPORT II

BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR ADAPTATION

FINAL REPORT

May 11, 2017

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Acronyms

AWS	Automatic Weather Station
BA	Barrier Analysis
BAEF	Barrier Analysis & Enabling Framework
CARDI	Caribbean Agriculture Research Development Institute
CDB	Caribbean Development Bank
CDC	Civil Defence Commission
CIMH	Caribbean Institute of Meteorology and Hydrology
CPACC	Caribbean Planning for Adaptation to Climate Change
CRSAP	Climate Resilience Strategy and Action Plan
DI	Drainage and Irrigation
DTU	Technical University of Denmark
EDF	European Development Fund
EPA	Environment Protection Agency
EDWC	East Demerara Water Conservancy
ET	Evapotranspiration
EWS	Early Warning System
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GDF	Guyana Defence Force
GINA	Guyana Information Agency
GIS	Geographic Information Systems
GLSC	Guyana Lands and Surveys Commission
GoG	Government of Guyana
GRDB	Guyana Rice Development Board
GuySuCo	Guyana Sugar Corporation
GWI	Guyana Water Incorporated
Ha	Hectares
IDB	Inter- American Development Bank
IMF	International Monetary Fund
INC	Initial National Communication
NDC	Nationally Determined Contributions
IRWR	Internal Renewable Water Resources
JCCCP	Japan-Caribbean Climate Change Project
MIPA	Ministry of Indigenous People Affairs
LCDS	Low Carbon Development Strategy
LFA	Logical Framework Analysis
MMA/ADA	Mahaica, Mahaicony, Abary/Agriculture Development Authority
MoA	Ministry of Agriculture
MPWI	Ministry of Public Works & Infrastructure
MOTP	Ministry of the Presidency
NAREI	National Agricultural Research and Extension Institute
NDIA	National Drainage and Irrigation Authority
NDS	National Development Strategy
NGO	Non-Governmental Organisation
NLUP	National Land Use Plan
NWC	National Water Council
OCC	Office of Climate Change
PAC	Protected Areas Commission
PRS	Poverty Reduction Strategy
SNC	Second National Communication
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TWG	Technology Working Group
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

This report on Barrier Analysis and Enabling Framework (BAEF) discusses adaptation technologies for three sectors, namely: (1) Agriculture, (2) Water, and (3) Coastal Zone and Low-lying Communities. For each sector, the report addressed the following:

- Preliminary target of technology transfer and diffusion of each of the adaptation technology;
- Identifying and prioritising the barriers using the following Barrier Analysis (BA) tools: review of relevant literature (policies, action plans, annual reports, technical reports, etc.), informal/bilateral meetings, brainstorming, a site visit, and the Logical Framework Analysis (LFA), also known as 'Problem Tree' to decompose barriers and complete root cause analysis;
- Assessing the possible measures to address the barriers for the transfer and diffusion of each technology and;
- Identifying the enabling environment and support to enhance the uptake of the technologies.

A barrier is defined as ***"A reason why a target is adversely affected, including any failed or missing countermeasures that could or should have prevented the undesired effect(s)"[1].*** Barriers can be economic and non-economic. Non-economic barriers include, policy and regulatory, institutional capacity, skills, technical support, environmental and, information and awareness (Nygaard,I & Hansen, U, 2015). A BA is a rapid assessment tool used for identifying causes/determinants hindering the achievement of those desired effect(s).

In July 2016, Guyana completed the first phase of the TNA process, in which the three critical sectors and technologies were prioritised for adaptation. In the final output, the following eight (8) technology options were prioritised for the BA:

1. **Agriculture Sector**
   (i) Freshwater harvesting for inland Regions: Empoldering of water collection areas
   (ii) Agrometeorological system for forecasting and early warning
2. **Water Sector**
   (i) Ground water mapping and modeling
   (ii) Surface water mapping and modeling
   (iii) GIS mapping and modeling for water catchment protection.
3. **Coastal Zone and Low-Lying Communities Sector**
   (i) Mapping and modeling of coastal processes for the construction of seawalls and groynes
   (ii) National early warning system for flood and drought
   (iii) Energy efficient mobile pumps for flood control.

The BA for Guyana was completed through a participatory, multi-stakeholder process, engaging direct and indirect influencers at the policy, technical, institutional and beneficiary levels. Stakeholders included the

[1] Nygaard, I. and Hansen, U. (2015). Overcoming Barriers to the Transfer and Diffusion of Climate Technologies: Second edition. UNEP DTU Partnership, Copenhagen.

Ministry of the Presidency (MOTP), Ministry of Indigenous Peoples Affairs (MIPA), Ministry of Public Works and Infrastructure (MPWI), Environment Protection Agency (EPA), Office of Climate Change (OCC), Guyana Water Incorporated (GWI), Hydromet Service -Ministry of Agriculture (MoA), National Agricultural Research & Extension Institute (NAREI), National Drainage and Irrigation Authority (NDIA), Guyana Sugar Corporation (GuySuCo), UN Food and Agriculture Organisation (FAO), Inter-American Institute for Cooperation on Agriculture (IICA), Mahaica-Mahaicony-Abary Agriculture Development Authority (MMA/ADA), West Watooka Farmers Association, Guyana National Broadcasting Authority (GNBA), Guyana Rice Development Board (GRDB) and the Protected Areas Commission (PAC).

The consultant prepared initial lists of barriers for each technology based on background review of similar technologies, national situation, strategies, annual reports, national budget, etc. Possible barriers were brainstormed and placed into two general categories: economic/financial and non -economic. This initial list was presented to stakeholders in the Technology Working Groups (TWG). The TWG reviewed the initial lists and prioritised the barriers using a qualitative measure of 'relative importance' - '*high, medium or low'.* Barriers which were considered of 'high' importance were ranked in numerical hierarchy and the top one or two selected to be decomposed. The selected barriers were considered 'killer/critical' barriers which can prevent the successful transfer of a technology and/or its benefits. For each of the selected barrier, problem/objective trees were mapped to identify root causes/effects and measures/benefits (See Appendix I A, B & C). The barriers prioritised for the respective sectors, included, high capital cost, limited financing sources, inadequate national budget, lack of coherent policy, overlapping institutional roles, weak technical capacity, lack of research, and low level of awareness. The prioritised barriers were then assessed for linkages and possible enabling measures identified to create a framework to overcome the barriers for each technology.

To date, several assessments and studies have been completed that indicate Guyana's vulnerability to the impacts of climate change. These include the following five (5) 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 (iv) intense storms affecting people and property, and (v) risks of wild fires (due to excessive dry periods). The prioritised technologies, target Guyana's need to build capacity in research, forecasting and early warnings, integrated water resource management and sea defense infrastructure to mitigate against the impending hazards and improve planning at all levels. As a result, it is vital to strengthen the policy framework, deploy/secure financing and develop technical capacity to allow for the transfer and diffusion of adaptation technologies.

Chapter I – Process for the Identification of Barriers and Measures

The identification of barriers followed the guidelines provided by the TNA guidebook series "Overcoming Barriers to the Transfer and Diffusion of climate technologies". The process included: background reviews, a site visit and stakeholder consultations. The key objectives of the BA were:

- Identify the economic/non-economic barriers for each technology;
- Prioritise barriers to select two/three critical/killer barriers;
- Identify root causes and possible measures for the critical barriers prioritised; and
- Outline an enabling framework to overcome the barriers.

Desk Review

In the first step of the BA, the consultant completed a review/research of the relevant literature, including existing national policies, regulations, plans, strategies, annual reports and case studies from other countries. The information gathered from this review was complimented with informal interviews (face to face, telephone, email), input from sector group members, other institutional experts and end users.

An initial list of possible barriers was prepared by the consultant, guided by the background research. Barriers in the initial list were grouped into two main categories: economic/financial barriers and non-financial barriers. Non-financial barriers included the following sub-categories: policy/legislative, institutional, human skills, social, cultural, environmental, technology capacity and information/awareness. The list was then provided to the TWG for their review and prioritisation. The TWG discussed each barrier, clarifying/refining/removing/adding barriers as necessary.

Field Visit

The consultant along with other sector group members and government officers participated in a visit to a local freshwater empoldered site in Region 9 on August 26, 2016 (See Figure 2). The site visit was facilitated by the OCC in collaboration with the UNDP-JCCCP funded project to support water harvesting in Region 9.

Technology Working Groups

The analyses of technologies for each of the three sectors were completed over a three-day period, one day of working group activity per sector. TWGs were formed to work on the BA for each technology. The consultant in collaboration with the TNA team, identified stakeholders for each TWG. Participants included representatives from government, non-governmental organisations and end users, namely, MOTP, EPA, OCC, GWI, Hydromet Service - MoA, NDIA, GuySuCo, UNFAO, IICA, MMA/ADA, West Watooka Farmers Association, GBA, and GRDB. See *Appendix II (a), (b) & (c)* for details of participants.

Prioritisation of Barriers

***Brainstorm barriers*:** Stakeholders reviewed and modified/added to the initial list of possible economic/financial and non-economic barriers. Each barrier was carefully analysed and screened to retain only the essential ones based on stakeholders' knowledge in the area, experience acquired and lessons learned from local implementation (where existing) of the technology.

Select and categorise: Using a qualitative measure of relative importance, barriers were classified as high, medium or low. This was necessary since all barriers were not considered equally or highly important.

Rank barriers: A numerical hierarchy was applied to barriers considered 'high' importance, with 1 being the highest ranked. Based on the rationale to decompose only the 'killer/critical' barrier/s, it was decided that the two highest ranked barriers should be decomposed using the LFA. Table 1 below shows an example of the categorisation and ranking applied.

Table 1*: Categorisation and Prioritisation Process for Barriers*

No	BARRIER	CRITERIA - IMPORTANCE			
		High	Med	Low	RANK
	ECONOMIC AND FINANCIAL				
1	Barrier A		X		
2	Barrier B	X			2
	NON-FINANCIAL				
3	Barrier C	X			1
4	Barrier D			X	

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

1. Broad categories of barriers (e.g., economic and financial)
2. Barriers within a category (e.g., high cost of capital)
3. Elements of barriers (e.g., high interest rate)
4. Dimensions of barrier elements (e.g., an interest rate of 15% per annum for households)

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

Chapter 2 – Agriculture Sector

In the agriculture sector, the following technologies have been prioritised for the BA: (i) Freshwater empoldering; and (ii) Agrometeorological forecasting and early warning.

The technologies focused on the needs related to water conservation and management, crop management and planning to enhance Guyana's adaptive capacity to climate change. This chapter will discuss the preliminary targets for the transfer and diffusion of the prioritised technologies, the barriers which are likely to hinder/prevent their deployment/uptake and the possible enabling measures to overcome those barriers. The analysis will examine linkages among the barriers and identify possible solutions to create an enabling framework.

2.1 Preliminary Targets for Technology Transfer and Diffusion

This section will provide a broad overview of the target of the technologies and the potential beneficiaries likely to be affected by changing climate. The targets for the technologies were: 1) Freshwater empoldering to store excess water for the dry periods in drought prone areas and stimulate/sustain inland agriculture development and 2) meteorological system for forecasting and early warning to reduce risk of crop loss during extreme weather events, promote climate smart agriculture and improve productivity, food security and farmers' livelihood.

Agriculture is also the main livelihood activity for many households, most of whom are in the coastal zone. Many engage in small scale farming as a source of livelihood and to supplement their income. Hinterland communities also depend heavily on the sector for their subsistence. At a macro-economic level, Guyana is considered food secure, since much of its agriculture produce is consumed in the domestic market. However, in recent years, Guyana's agriculture sector has been hard hit by excessive flood and drought conditions, influenced by climate variability and change. Agriculture in Guyana will be affected by the alternating conditions of excessive rainfall, flooding and drought (GoG, 2012). Increased temperature will tend to increase crop water demand (evapotranspiration, ET). While coastland agriculture is largely irrigated, many crops in the hinterland such as cassava, spices, etc., are rain fed, and therefore seasonal rainfall is very critical. With the increase in the frequency of high intensity precipitation events in Guyana, more field flooding is likely, creating problems for field operations and possible crop losses.
Monitoring the climate is very important for agriculture, because it allows for better yield forecasts, planning of agricultural activities and assists in decision making (Gaspar,N.A et al, 2015). In recent years, the GoG has been promoting agriculture diversification, as an adaptation measure and is investing more in inland agriculture, promoting crop variety and farming systems. In 2013, a National Strategy for Agriculture 2013-2020 was prepared to provide a detailed roadmap of the sector's needs and plans. The strategy is based on twenty-five (25) priority areas which include water security and weather forecasting (GoG, 2013). A Disaster Risk Management Plan was also developed for the sector (MoA, 2013). In 2010, development of the sector

was framed within the context of a low carbon economy, to nurture investment in 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 (LCDS, 2010). Recently, the MoA began advancing initiatives in drought prone regions, e.g. Region 9, to promote agriculture diversification and is currently scoping out locations for water harvesting ponds (MoA, 2016).

2.2 Barrier Analysis and Possible Enabling Measures for Freshwater Harvesting: Empoldering of Water Collection Areas

2.2.1 General Description of Freshwater Harvesting: Empoldering of Water Collection Areas

Guyana has many large wetland areas, including ponds, swamps, seasonally flooded forests, lakes, mangroves and conservancies. The conservancies are the 'backland' or upper stream catchment areas. The major rivers include the Essequibo, Demerara and Berbice; smaller ones include the Mahaica, Mahaicony, Abary and Canje. The rivers of eastern Guyana cut across the coastal zone, but they provide limited water access to the inland regions (GoG, 2012). Based on climate assessments, inland regions are projected to experience more drought like conditions. Droughts represent important economic losses both for the nation and the people affected. The economic losses due to the 1997/98 and 2009/10 droughts are estimated at US$ 29m and US$14.7m, respectively (EWS Protocol, 2015).

Empoldering involves the damming of a catchment area and capturing the overflow of excess water (Mekdaschi Studer et al, 2013). The basic components of this type of water harvesting system are (i) catchment or collection area, (ii) runoff conveyance system, (iii) storage component, and (iv) application area. This method ensures water is stored and available locally, especially the outlying or inland regions to prevent food insecurity and displacement of population because of drought. The deployment of the technology in the agriculture sector contributes to climate change adaptation by providing a source of water for crops, livestock and inland fishery in dry conditions. The catchment also allows for the storage of excess water during periods of extreme rainfall and thus reduces the impacts of flooding on communities.

Freshwater harvesting is a mature technology in Guyana. Historically, this has largely been undertaken on a macro scale by the government. Most water demand in Guyana is for irrigation purposes, which is derived from water conservancies (Regions 2, 3, 4 and 5), and from the rivers through pumping in Region 6. The East Demerara Water Conservancy (EDWC) is one of the major water conservancy systems in Guyana. It is a freshwater impoundment located in Region 4. It is bounded to the north by a forty-mile earthen dam structure and to the south by the natural topographic rise composed largely of ancient coastal dune formations. The area consists of an impoundment of approximately 550 hectares (GoG, 2012).

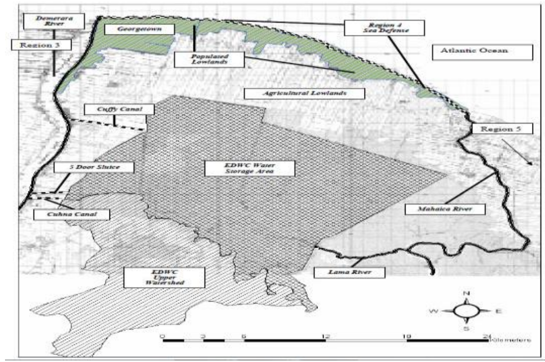


Figure 1: East Demerara Water Conservancy, Guyana. Source: SNC, 2012.

Figure 2 shows an empoldered catchment area at JR Farms located in Region 9. This region is prone to drought like conditions. The reservoir covers an area of 7,889 hectares, with an estimated water holding capacity of 1,499 cubic metres (JR layout Plan). The JR Farm empolder is considered a large-scale investment and is projected for aquaculture development.

Figure 2: Empolderment of water at JR Farm, Region 9, Guyana. *Source: MOA, 2016.*

2.2.2 Identification of Barriers for Freshwater Empoldering

Freshwater empoldering was categorised as a non-market good based on the definition for non-market technologies. It is more likely to be implemented as a public good by the GoG as part of national planning for the sector and may attract donor support. Following the process detailed in Chapter 1, the initial list of barriers prepared by the consultant was reviewed and prioritised by the TWG, as shown in Table 2 below. The TWG included representatives from government, non-governmental organisations and end users, namely, MOTP, EPA, OCC, GWI, MoA, NDIA, GuySuCo, UNFAO, IICA, MMA/ADA, West Watooka Farmers Association, GNBA and the GRDB (See *Appendix II (a)* for details of participants). The consultant also participated in a site visit to a large scale freshwater empoldering project at JR Farm in Region 9 (See Figure 2) and observed some of the challenges that need to be overcome for the successful deployment of this type of technology.

Based on the prioritisation, the top three barriers listed below were considered 'killer/critical' barriers. *High capital and maintenance cost* was decomposed to identify root causes and measures.

1. High capital and maintenance cost
2. Unclear policy for freshwater empoldering
3. Low acceptance by local culture

Table 2: Prioritisation of Barriers for Freshwater Empoldering

Categorisation and Prioritisation of Barriers					
CATEGORY	**BARRIER**	**CRITERIA - IMPORTANCE**			
		High	**Med**	**Low**	**Rank**
Economic and Financial	High capital and maintenance cost	X			1
	Uncertain/Limited funding sources		X		
	Limited/Lack of incentives			X	
	Low return from economic ventures	X			
	Limited access to banking services			X	
	High taxation/Duty on materials			X	
	High investment risk (protection measures)	X			
Non-Financial	Unclear policy for freshwater empoldering	X			2
	Low government priority			X	
	Overlapping regulatory authority		X		
	Conflicting uses in national planning		X		
	Lack of updated research on water resources	X			
	Limited monitoring resources			X	
	Limited availability of local technical skills for design & construction			X	
	Unknown impact on river/stream dynamics		X		
	Reduce water availability downstream		X		
	Affect ecosystem health		X		
	Perceived as a large-scale investment which can only be afforded by a few			X	
	Viewed as private enterprise driven			X	
	Low acceptance by local culture	X			3
	Limited local knowledge of operational requirements			X	
	Lack of awareness of intended and long -term benefits (water availability during periods of prolong drought, water for agriculture, food security)		X		

2.2.2.1 Economic / Financial Barriers and Measures

Macro-catchment water harvesting requires significant financial resources, which can be a strong barrier to the widespread and rapid diffusion of the technology. Since mainly inland freshwater harvesting is targeted, cost will be influenced by the remoteness of locations, scale of the technology, studies to be completed and, the construction and maintenance of freshwater harvesting systems. Inland areas often suffer from a lack of access to capital, reliable transportation, increased material costs, lack of local skills and technical support, limited market opportunities and slow bureaucratic process, which will have varying levels of impact on the uptake of this technology.

This section outlines the root causes and measures identified for the prioritised barrier – ***High capital and maintenance cost*** as shown in Table 3. See *Appendix I (A)* for problem/objective trees. High capital and maintenance cost include construction of dams, conveyance and storage systems. Other barriers and possible measures are also listed.

Table 3*:* Measures for Barrier- High capital and maintenance cost

CRITICAL BARRIER	ROOT CAUSE	MEASURE
High Capital and Maintenance Cost	• High labour, equipment and material costs; • Lack of local availability of technical skills for studies, design and construction; • High consultancy fees; • Taxes/duties/insurance fees on equipment /materials which may need to be imported; • Limited local suppliers of equipment and spares; and • High transportation cost to/from coastal areas for services/supplies.	• Encourage financial incentives, such as tax breaks and low interest credit on equipment and machinery to be used for this technology; • Facilitate the availability of technical skills locally to provide support to investors, offsetting huge consultancy fees for studies and designs; • Provide reliable transportation infrastructure and services to enable easy/quick access/ movement of materials and goods; and • Encourage investment of local suppliers for materials and equipment.

Other Financial Barriers

- Uncertain/limited funding sources;
- Limited/ lack of incentives for private sector participation;
- Low returns from economic ventures due to insecure markets, poor infrastructure and services;
- Limited access to banking services in inland areas to support economic spin offs;
- High taxation/duty on materials for construction and maintenance; and
- High investment risk due to limited markets and protection systems.

Possible Measures

- Engage private/public partnerships for water harvesting;
- Identify international funding for water harvesting technology;
- Conduct market studies for possible economic ventures; and
- Support access to market opportunities and financial services.

2.2.2.2 Non-financial Barriers and Measures

Non-financial barriers as shown in Table 2, were grouped into sub-categories, such as, policy and regulation, technical capacity and social/cultural/behavioural. Many of the barriers in this category were considered high/medium importance. The possible measures listed below were based on information gathered during stakeholder discussions, consultations and background research by the consultant.

Barriers

Policy and Regulation:

- Unclear policy on freshwater empoldering;
- The technology may be considered a low priority among other national development priorities;
- Overlapping regulatory authority among several institutions, such as, the EPA, MoA, GWI and MMA/ADA; and
- Conflicting uses in national planning.

Technical Capacity:

- Lack of updated research on water resources throughout the country;
- There is limited availability of resources for monitoring of water catchment;
- Limited availability of technical skills locally for the design and construction of large scale water impoundment infrastructure;
- Unknown impact on river and stream dynamics due to the lack of research and modeling;
- Reduced water availability downstream and;
- Effect on ecosystem health.

Social/cultural/behavioural

- Perceived as a large-scale investment which can only be afforded by a few;
- Driven by private enterprise;
- Low acceptance by local culture e.g. downstream communities may resist upstream water impoundment;
- Limited local knowledge of operational requirements; and
- Lack of awareness of immediate and long-term benefits, such as, water and food security and economic development.

Possible Measures

- Establish clear national policy for water management, which includes the use of natural areas for water storage and use;
- Update existing regulations to reflect clear lines of authority among the various institutions;
- Promote research to provide updated data and baseline on the status of water resources on a national scale;
- Build and strengthen institutional capacity to monitor water catchments/basins;
- Promote awareness of the likely impacts of climate change, such as, drought and flood, and the need for water management;
- Promote information and technical support on agriculture and possible business ventures; and
- Promote opportunities for inland communities to participate in shared management of water resources.

2.3 Barrier Analysis and Possible Enabling Measures for Agrometeorological System for Forecasting and Early Warning

2.3.1 General Description of Agrometeorological System for Forecasting and Early Warning

A typical agro-meteorological system consists of several Automatic Weather Stations (AWS) and/or agro-met stations installed at strategic locations, which collect/store localised weather data including, wind speed & direction; precipitation; humidity; temperature; solar radiation; sunshine duration and soil moisture/temperature (TNA Fact Sheet, 2016). 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. The instruments are equipped with a 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 as per the needs and use of such information. In addition, a telemetry system allows for remote access through mobile or other forms of communication in real time (TNA Fact Sheet, 2016).

Agro-climatic data can help to determine the water available for 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. Currently, this technology is lacking in Guyana. The Hydromet Service which is tasked with providing agrometeorological services only provides weather and climate information to extension workers and farmers.

2.3.2 Identification of Barriers and Measures for Agrometeorological System

An Agrometeorological system is categorised as a public/non-market good. It provides a public service and is widely established by governments. The initial list of barriers was reviewed and prioritised by the TWG as shown in Table 4 below. Based on the prioritisation, the three barriers listed below were considered critical barriers. Barriers 1 & 2 were decomposed to identify root causes and measures. Prioritised critical barriers:

1. Inadequate budget allocation

This was identified as a common barrier among the technologies by stakeholders. It seeks to capture the view that, based on the capacity needs (staff, training, equipment etc) to operate and sustain this type of technology, the existing budget may not be adequate. Highly sophisticated agro-met systems can be costly to operationalise/sustain. Budget availability has a strong influence on the sophistication and scale of application of the technology. There is also the view that, institutions are often strapped with limited financial resources, which are shared among other program activities and this can hinder the successful transfer of this technology.

2. Inadequate compensation for skills
3. Inadequate communication infrastructure

Table 4: Prioritisation of Barriers for Agrometeorological System

Categorisation and Prioritisation of Barriers for Agrometeorological System					
CATEGORY	**BARRIER**	**CRITERIA - IMPORTANCE**			
		High	**Med**	**Low**	**Rank**
Economic and Financial	High initial investment cost	X			
	Moderate maintenance cost			X	
	Inadequate national budget allocation	X			1
	Limited external funding		X		
	Inadequate compensation for technical skills	X			2
Non-Financial	Not an urgent priority of government		X		
	Inadequate communication infrastructure	X			3
	Ad hoc inter-agency coordination		X		
	Limited local research		X		
	Limited availability of technical skills at the local level	X			
	New technique may be perceived as too technical and unreliable by community users	X			
	Low interest and slow to absorb at the community level		X		
	Limited employment opportunity			X	
	Lack of financial incentive to develop relevant skills		X		
	Lack of awareness of how to integrate into farming schedules		X		
	Limited knowledge on the range of benefits and impact on food security to farmers			X	

2.3.2.1 Economic/ Financial Barriers and Measures

This section outlines the root causes and measures for the two prioritised barriers: (i) Inadequate budget allocation (ii) Inadequate compensation for skills. The measures identified were based on the LFA and discussions by the TWG (See *Appendix I (A)* for problem/objective trees). Other financial barriers and possible measures are also listed.

Table 5*:* Measures for Barriers: Inadequate budget allocation and inadequate compensation for skills

BARRIER	ROOT CAUSE	MEASURE
Inadequate budget allocation	• Disconnect between planners and finance agency; • Limited understanding of technology need and urgency; • Low level of awareness by decision makers; • Weak justification for agromet system in planning which is caused by limited technical capacity; • High loss of technical skills due to poor remuneration package and lack of	• Include adequate budget for agromet system/service in national allocations; • Improved collaboration between planners and budget office/agency; • Improve understanding and recognition of technology need among decision makers; • Strengthen justification for agromet system in national planning; • Develop robust recruitment policy; • Provide adequate remuneration

	incentives to pursue studies in agrometeorology; and • Limited national budget resulting in allocation to high priority sectors.	package to attract and retain skills; • Promote incentives for studies and career to support agrometeorology
Inadequate compensation for skills	• Inadequate human resource policy caused by a lack of expertise in HR; • Inconsistent implementation of current HR policy; and • Lack of professionalism in recruitment.	No measures were identified by the TWG due to limited time. However, based on the causes, possible measures may include: • Strengthen human resource expertise and policy; and • Implement fair and equitable approach in the recruitment process.

Other Financial Barriers

- High initial investment cost;
- Moderate maintenance cost; and
- Limited external funding.

Possible Measures

- Identify and source external financing for capacity building;
- Diversify source of financing; and
- Develop revenue generating capacity through services and data provided.

2.3.2.2 Non-financial Barriers and Measures

Non-financial barriers (Table 4), were grouped into sub-categories below. No critical barrier was decomposed from this category. However, the a few possible measures were identified by the consultant based on information gathered during stakeholder discussions and background research.

Barriers

Policy/ Planning:

- Not an urgent priority of government; and
- Ad hoc inter-agency coordination;

Institutional Capacity

- Require efficient communication infrastructure;
- Limited availability of technical skills at the local level; and
- Limited local research;

Social/Cultural:

- New technique may be perceived as too technical and unreliable by community users;
- Low interest and slow to absorb at the community level;
- Limited employment opportunity;
- Lack of financial incentive to develop relevant skills;
- Lack of awareness of how to integrate into farming schedules; and
- Limited knowledge on the range of benefits and impact on food security to farmers.

Possible Measures

- Strengthen inter-agency collaboration (Hydromet Service, NAREI, Guyana School of Agriculture (GSA), UG), OCC, etc);
- Improve collaboration between planners and farmers;
- Promote research with local academic institutions and through regional collaboration;
- Increase awareness of technology need among farmers, extension workers and decision makers; and
- Strengthen technical capacity through access to training.

2.4 Linkages of the Barriers Across Technologies

Stakeholders play a predominant role in the identification and understanding of the key barriers so that they can be effectively addressed. The barriers hindering the uptake of freshwater empoldering in water catchment areas and hydro-meteorological systems for forecasting and early warning technologies were found to be technology specific and existing at each level: policy, regulation, financial availability, institutional, technical and human capacity, and education. The following linkages among the prioritised and other barriers were identified:

High Capital/investment Cost

The issue of cost is an enormous barrier to the successful transfer of technologies in the sector. Freshwater empoldering in hinterland locations require significant preparation of land and design of dams to contain and transport excess water, while ensuring minimal disruption of the natural functions of the ecosystem. This type of technology is more likely to be undertaken by a large-scale investor or as a community-based system. According to estimates provided by JR Farms, to date, some US$30M has been invested in the aquaculture venture.

The cost for agro-meteorological systems varies according to the degree of sophistication required. A national scale system will require more financial resources for new infrastructure and technical capacity, where needed. However, there is a lack of data on both technologies to derive a financial estimate on the varying scales of implementation.

Inadequate Funding: National Budget and External Financing

There is no doubt that adequate finance is a major factor in determining the uptake of a technology by a country. As in large scale water empoldering, private investors may rely on partnerships and the banking system, which offer more coverage for possible market and non-market risks. However, apart from private financing and input from central government, there is scarce financial support for the diffusion and uptake of freshwater empoldering technology. Currently, through the JCCCP Project executed by the UNDP, a total of US$50,000 to US$100,000 is provided to each project within five focal areas. Water resource management is one of the focal areas, with two priority areas for interventions: rainwater harvesting and water collection and storage (UNDP, 2016). Despite the importance of agriculture to Guyana’s economy, there has been a decline in the services provided in agro-meteorology over the past decades. However, in recent years, there have been efforts to revitalise the agromet sub-division in the Hydromet Service.

Inadequate Technical Capacity

It is recognised that there is limited or a lack of technical capacity locally that can affect the rapid and successful diffusion of freshwater empoldering and agrometeorological system technologies in Guyana. Specialised skills to conduct surveys, design and the construct dams for water empoldering and transmission will be required. It is noted that the lack of such skills may slow down the uptake of the technology by private individuals, as well as, communities. Additionally, low compensation for skills have contributed to the difficulty in attracting and retaining relevant expertise and this has led to the decline in the delivery of agromet services in Guyana. Currently, the agromet sub-division is poorly staffed with no qualified agro-meteorologist, limited data collection equipment and weak information dissemination service to farmers and other users.

Policy and Planning

There is no specific policy on freshwater empoldering. This technology addresses water management mainly for agricultural purposes. There are multiple institutions which has responsibility for water management in Guyana, namely, the MoA, NDIA and EPA. It is understood that there are overlapping roles among the institutions. This has contributed to fragmented management, challenges in stakeholder awareness on regulatory requirements and poor planning. On the other hand, two key water management institutions (NDIA and Hydromet Service) are located within the agriculture ministry which can help to advance technologies for agriculture expansion and sustainability. In addition, the agrometeorological unit, which forms part of the Hydromet Service, is well placed within the MoA to enhance policy support, collaboration with local/regional research institutions/programs, farmers' organisations/groups, extension officers and promote awareness on the use/application of agrometeorology among policy makers and farmers. Climate assessments have shown that Guyana's agriculture sector will be seriously affected by changes in weather patterns and it is important to strengthen its agrometeorological capacity to aid forecasting and provide early warnings.

Limited Research and Information

It has been recognised that there is a dearth of research and data for informed decision-making on the localised impacts of climate change on water resources and agriculture. Increased drought-like conditions and extraction of ground water needs to be monitored and studied to inform scientific reasoning in decision-making. However, reliable and consistent water resources and ecosystem data (e.g. river/stream dynamics and biodiversity) are severely lacking.

2.5 Enabling Framework for Overcoming Barriers

More than 25,000 small farmers depend on agriculture as a source of livelihood. It is also, historically, a lead revenue earner for the country and has enabled Guyana to be food secure. However, the sector is also extremely vulnerable to the impacts of climate change, and some has already been felt with increasing drought like conditions, high-intensity rainfall which causes flooding and salt water intrusion. These threats have resulted in the loss of crops and livestock, with cascading socio-economic consequences. Many farmers are ill prepared to mitigate the impending threats because of a lack of resources and information. As an adaptation measure, the GoG has committed to advancing inland agriculture where the risks associated with flooding is lessened.

This section addresses the possible enabling measures for overcoming the two killer barriers identified, as well as other barriers. The measures were assessed based on the LFA, stakeholder discussions/feedback and review of the country's national programs/plans within the sector agencies. Table 6 shows the list of possible enabling measures for the two prioritised technologies, namely, freshwater empoldering of water catchment areas and agrometeorological systems for forecasting and early warning.

Table 6: Enabling Framework for Technologies in the Agriculture Sector

TECHNOLOGY	ENABLING MEASURES
Freshwater harvesting: Empoldering of water collection areas	▪ Clear policy guidance on freshwater resource utilization; ▪ Conduct research to identify areas suitable for freshwater empoldering; ▪ Conduct market studies of possible agriculture initiatives and provide incentives to encourage investment; ▪ Provide low cost options for design and construction of dams, holding ponds and conveyance systems; ▪ Encourage/support partnerships and community collaboration for shared ownership and responsibility; ▪ The MoA provides technical advice and support to interested persons/organisations/groups/communities; and ▪ Showcase successful technology application to stimulate interest and promote awareness.
Agrometeorological System for forecasting and early warning	▪ Committed budget line in national allocations for agrometeorological services at the Hydromet Service, MoA; ▪ Financial resources made available for adequate, well maintained observation networks of high spatial density that include Automatic Weather Stations (AWS). Particular emphasis should be placed on enhancing the quality and detail of biological information; ▪ Diversify source of financing for technical support and capacity building; ▪ Implement an operational policy to enable a more focused approach in agrometeorology; ▪ Provide compensation package to attract and retain technical skills. Sufficient competent staff dedicated to agro-meteorology is necessary to deliver information requested by farmers and extension officers; ▪ Identify and secure support for training and research There is a paucity of scientific and statistical data needed to inform policy and decision making on the impacts of changing weather patterns crops, pests and diseases; ▪ Promote local and regional collaboration, and data sharing among government agencies, NGOs and the private sector, for example, Caribbean Institute for Hydrology and Meteorology(CIMH), Caribbean Agriculture Research Development Institute (CARDI), MoA, Hydromet, NAREI, GWI, EPA, GRDB, GuySuCo, UNFAO, IICA; ▪ Awareness and sensitisation of farmers, rural community groups, and the general public to the importance of weather and climate information in farming and the interpretation of relevant weather and climate products; and ▪ Provide field demonstrations on the application of agrometeorology to extension workers and farmers.

Chapter 3 – Water Sector

3.1 Preliminary Targets for Technology Transfer and Diffusion

The continued extraction of water among the key economic sectors (agriculture, fisheries, forestry, mining, energy and manufacturing) may have already contributed to water stress conditions, and it is concluded that climate-induced impacts will likely exacerbate the effects. It is likely that water scarcity may become more severe in already stressed areas. Based on projections, 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). In the urban center of the capital Georgetown and on the coast, residents depend on groundwater supply to meet their domestic needs. Estimates show that approximately 94.4 percent of water withdrawal in 2010 was for agricultural purposes, 4.2 percent for municipal and 1.4 percent for industrial purposes (FAO, AQUASTAT).

Institutionally, 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 and protection, are shared with agencies/mechanisms such as, the MPWI, MoA and Water Users Associations (WUA) and the EPA. There is also provision for a National Water Council (NWC) and a national water policy. The NWC is presently inactive, however, there are plans to resuscitate the council.

In the water sector, capacity exists at varying degrees. Despite having long established national institutions overseeing water-related matters, there is a lack of monitoring data to make informed decisions on the efficient use and management of water resources. The last known water resource assessment was completed in 1998 by the United States Army Corps. Climate assessments have shown that Guyana will experience water deficits, increased evapotranspiration due to increases in temperature and decreased annual precipitation, with significant temporal and spatial variations. Overall, the country will be confronted by a general drying trend (GoG, 2012).

Scientific and updated data is vital to water management and investment in water related infrastructure projects, such as, the location of wells, hydropower and sea/river defenses. Generally, hydrological data and technical capacity is limited. Limited research has also been undertaken to better understand the status of the country's water resources. As Guyana pursues its development goals and confronts the challenges of climate change, there is an urgent need to have a more integrated approach to water management. There is a general acceptance that decision-making on the utilisation of the country's water resources must be guided by sound scientific reasoning. As a result, existing policies need to be enforced and changes made where necessary. Institutions need to be equipped with adequate resources to discharge their mandate. These include equipment and skills to coordinate data collection, collation and analysis.

3.2 Barrier Analysis and Possible Enabling Measures for Mapping and Modeling of Groundwater Resources

3.2.1 General Description of Mapping and Modeling of Groundwater Resources

The Water & Sewerage Act, 2002 mandates the Hydromet Service to monitor and manage Guyana's groundwater resources, and to develop and operate a national groundwater resources data base. License to abstract water and permission to drill wells are reviewed by the MoA. Considering the risks posed by increased extraction and climate change, there is an urgent need to monitor and determine the long-term viability of the country's groundwater resources. Updated data on well inventory and characteristics, such as, pumping rates and piezometric heads have been severely lacking. Coupled with a low level of interest and awareness among the major stakeholders, the management of groundwater has been inadequate. With a growing demand in the economic sectors, the monitoring and management of the aquifers is becoming an increasingly important issue. Based on estimates by the 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. Many aquifers are also capable of offering natural protection from contamination, so untreated groundwater is usually cleaner and safer than its untreated surface water equivalent.

Groundwater mapping and modeling is a highly scientific and complex process. Currently, this technology does not exist in Guyana. The simulation of ground-water flow systems using computer models is standard practice in the field of modern hydrological studies. Models are used for a variety of purposes that include education, hydrologic investigation, water management, and legal determination of responsibility. This technology will include significant hardware and software components. It involves intensive data collection, validation, preparation, storage and analysis. Preparation of observation wells, data logging instruments, computer systems and mapping/modeling software are some of the key components required. In addition, this technology will require strong technical capacity to use the models and interpret findings.

3.2.2 Identification of Barriers and Measures

The GoG is responsible for the management of groundwater resources therefore, the technology for mapping and modeling of groundwater will be implemented by the GoG and is categorised as a public/non-market good. The initial list of barriers was reviewed and prioritised by the TWG as shown in Table 7. The TWG included representatives from the government, non-governmental organisations and end users, namely, Hydromet Service, GWI, GuySuCo, MMA/ADA, MNR, MOTP, MIPA, GL&SC, EPA, PAC and OCC. See *Appendix II(b)* for details. The two critical barriers prioritised and decomposed were:

I. Lack of baseline /scientific data for decision making; and
II. Low level of awareness and interest in the long-term benefits of groundwater security.

Table 7: Prioritisation of Barriers for Groundwater Mapping and Modeling

Categorisation and Prioritisation of Barriers for Groundwater Mapping and Modeling					
CATEGORY	**BARRIER**	**CRITERIA - IMPORTANCE**			
		High	**Med**	**Low**	**Rank**
Economic and Financial	High initial investment cost (hardware, software, training)	X			
	Maintenance cost		X		
	Lack of national budget allocation	X			
	Uncertain/Limited funding sources (external)			X	
	Poor compensation for technical skills	X			
Non-Financial	Weak policy commitment	X			3
	Not an urgent priority of government		X		
	Adhoc planning	X			
	Weak inter-agency coordination	X			
	Weak institutional capacity	X			
	Limited technical skills - data analysis and modeling	X			
	Lack of updated research on water resource and users	X			
	Require intensive training	X			
	Low level of awareness and interest of long term benefits water security	X			1
	Lack of relevant baseline data	X			2

3.2.2.1 Economic/ Financial Barriers and Measures

This section outlines the economic/financial barriers identified. This includes consideration of cost for all the components (hardware, software and orgware) to implement the technology for mapping and modeling of groundwater in Guyana. Taking into consideration the barriers and their relative importance, stakeholders indicated that the economic and financial barriers were not critical barriers which needed to be addressed for the satisfactory diffusion of this technology. Note, four of the five economic/financial barriers identified were considered high to medium importance (See Table 7). Below is a list of the economic/financial barriers identified and possible measures which may be considered.

Barriers

- High initial investment cost, such as, the preparation of observation wells; data logging instruments; computers; database; modelling software; consultancies;
- High to moderate maintenance cost for the wear and tear of field equipment; software and ongoing training;
- Limited or lack of national budget allocation to specifically develop the capacity to manage groundwater resources;
- Uncertain/limited external funding sources and;
- Poor compensation for technical skills.

Possible Measures

- Allocate adequate national budget for groundwater management, including attractive salary and compensation package for technical skills;
- Use existing wells and data collection capacity to reduce capital cost;

- Introduce diverse cost recovery financial arrangements for groundwater services; and
- Identify and secure other sources of financial support external funding agencies.

3.2.2.2 Non-Financial Barriers and Measures

The prioritised barriers identified for decomposition are non-financial. This section outlines some of the root causes and measures identified for those barriers as shown in Table 8 below. The measures identified were based on the LFA and from discussions by the TWG (See *Appendix I (B)* for problem/objective trees). Other non-financial barriers are also listed. However, no measures have been identified.

Other Non-Financial Barriers

- No clear policy commitment;
- Not an urgent priority of government;
- Ad hoc planning for ground water resources;
- Weak inter-agency coordination;
- Weak institutional capacity;
- Limited/lack of technical skills – data analysis & modelling;
- Lack of updated research on water resource and users; and
- Require intensive training.

Table 8: Measures for barriers: Lack of baseline/scientific data and low level of awareness

CRITICAL BARRIER	ROOT CAUSE	MEASURE
Lack of baseline /scientific data	• Limited budget within institutions to conduct systematic data collection and storage; • Considered a low priority among other overriding national interests; • Low level of appreciation/understanding of the need/value of scientific data for decision making; • Focus on short-term planning; • Lack of available technical skills locally; and • Low interest and poor compensation/incentives for skills.	• Provide adequate budget to national institutions for scientific assessments; • Raise priority level among key national interest; • Implement long-term planning for groundwater management; • Improve appreciation /understanding of value of data in groundwater management; • Promote/support research in institutions; and • Provide attractive compensation and incentives to build technical capacity locally.
Low level of awareness and interest of the long-term benefits of groundwater security	• Strong cultural perception of the abundance of water; • Limited understanding of the value of groundwater; • Weak communication system to water users and decision makers on water resource management; • Weak institutional capacity; • Limited budget to undertake research; and • Low national priority due to a focus on short-term planning and overarching national development programs.	• Promote education/awareness activities to effect a change in cultural perception and increased appreciation of groundwater among all stakeholders, including decision makers, manufacturers and the public; • Strengthen communication system to water users and decision makers on water resource management; • Designate institution with clear roles and responsibility; • Strengthen institutional capacity/skills to provide data and disseminate information; • Promote research in groundwater resources as a matter of national policy; • Allocate adequate budget to undertake research; and • Recognise groundwater management as a high national priority and implement in long-term national planning.

3.3 Barrier Analysis and Possible Enabling Measures for Mapping and Modeling of Surface Water

3.3.1 General Description of Mapping and Modeling of Surface Water

Guyana is referred to as "land of many waters". The country's terrain is crisscrossed by a vast network of rivers, creeks and conservancies. The Hydromet Service is the regulatory authority for the management of surface water in Guyana. The surface water section of this institution is tasked with the the collection, processing and analysing of surface water data (water level, discharge, water quality and sediment transport); expansion and maintenance of the surface water station network; the publication of an annual hydrological bulletin; updating and maintenance of the hydrological database and research on hydrological phenomena (2015, MoA, Annual Report). In terms of capacity, there are currently sixty-one (61) surface water-level monitoring stations of which sixteen (16) monitor water levels continuously with water level recorders, 10 operate manually and 30 using Frog Loggers (automatic stations) to transmit water level data from the East Demerara Water Conservancy (EDWC) (2015, MoA, Annual Report)

Mapping of water is a prerequisite for water availability, accessibility, fair utilisation and management. Effective data regarding surface water availability demands the 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 characteristics, stream flow, field staff and water engineers, software etc. Despite its lack of adequately qualified personnel, the Hydromet Service continues to collect surface water data from a few areas. However, this data is not being applied in scientific assessment to guide national water management. At the basic level, mapping and modeling requires, skilled personnel, computer and field equipment and software programs to run the models.

3.3.2 Identification of Barriers and Measures

The technology for mapping and modeling of surface water is resource intensive and more likely to be implemented by the government, therefore, it is categorised as a public/ non-market good. The initial list of barriers was reviewed and prioritised by the TWG as shown in Table 9 below. TWG participants included representatives listed in S*ection 3.2.2*. The No. 1 barrier – *Overlapping role of multiple institutions* was decomposed to identify root causes and possible measures. See Appendix I (B) for problem/objective trees.

Table 9*:* Prioritisation of Barriers for Surface Water Mapping and Modeling

Categorisation and Prioritisation of Barriers for Surface Water Mapping and Modeling					
CATEGORY	**BARRIER**	**CRITERIA - IMPORTANCE**			
		High	**Med**	**Low**	**Rank**
Economic and Financial	High initial investment cost, including cost for field equipment and computer systems			X	
	High to moderate maintenance cost due to high risk of wear/tear/loss of field equipment and regular training	X			3
	Limited or no national budget allocation	X			
	Limited external funding	X			
	Inadequate compensation for technical skills	X			
Non-Financial	Not an urgent priority of government	X			
	Overlapping role of multiple institutions (Hydromet, NDIA, MPWI) and lack of coordination	X			2
	Limited availability of technical skills – engineers and knowledge of models		X		
	May be perceived as too complex and resource intensive			X	
	Require ongoing training		X		
	Low interest among the private sector		X		
	Lack of financial incentive to develop relevant skills (training)	X			
	Limited understanding of immediate and long-term benefits among water users	X			1

3.3.2.1 Economic/Financial Barriers and Measures

Four of the five economic/financial barriers listed below were categorised as highly important (See Table 9). However, no measures were identified for the barriers in this category. Stakeholders concluded that the critical barriers were mainly non-financial for surface water mapping and modeling in Guyana.

Barriers

- High initial investment cost, including cost for field equipment and computer systems
- High to moderate maintenance cost due to high risk of wear/tear/loss of field equipment and regular training
- Limited or no national budget allocation: There is no known budget for this type of technology;
- Limited external funding
- Inadequate compensation for technical skills

3.3.2.2 Non-financial Barriers and Measures

The top two prioritised barrier identified were non-financial: (i) Limited understanding of immediate and long-term benefits among water users (ii) Overlapping role of multiple institutions. The TWG recommended that barrier (ii) be decomposed for this technology, since a similar barrier relating to (i) was decomposed for the technology on groundwater. This section outlines some of the root causes and measures identified for the barrier – *Overlapping role of multiple institutions*. See Appendix I (B) for problem/objective trees. Other non-financial barriers are also listed.

Table 10: Measures for barrier: Overlapping role of multiple institutions

CRITICAL BARRIER	ROOT CAUSE	MEASURE
Overlapping role of multiple institutions	• New policies are not merged with existing ones resulting in overlapping policies; • Lack of overarching objective for surface water management; • Surface water management viewed in isolation in terms of its multiple uses and geographic span; • Fragmented institutional management • Lack of a national guiding body, such as the National Water Council; • Weak political support; and • Bias in decision making which may reflect personal preference.	• Provide overarching and clearly defined policy and objectives for surface water management; • Newly developed policies must be coherent with existing provisions; • Strengthen institutional processes and professionalism in decision making, that is, decisions should be based on sound scientific reasoning; • Develop holistic surface water management plan to address multiple uses and geographic scope; and • Activate /resuscitate the National Water Council and provide strong political support.

Other Non-Financial Barriers

- The technology is not considered an urgent priority by government
- Lack/limited availability of technical skills – engineers and knowledge of models
- May be perceived as too complex and resource intensive
- Require ongoing training
- Low interest among the private sector
- Lack of financial incentive to develop relevant skills (training)

3.4 Barrier Analysis and Possible Enabling Measures for GIS Mapping for Water Catchment Protection

3.4.1 General Description of GIS Mapping for Water Catchment Protection

Water catchment/watershed protection is recognised as important for the sustainable utilisation of land and water resources. Geographic Information System (GIS) is a highly effective and versatile technology for evaluation, management and monitoring of natural resources and the environment. GIS use spatial and temporal data and aid as an integrative planning tool for watershed management. It is a system designed to capture, store, manipulate, analyse, manage and present geographically referenced data, and can be used for scientific investigations, resource management and planning. For example, in water catchment monitoring, this technology may be used to find wetlands that need protection from pollution. GIS improves calculations for watershed characteristics, flow statistics, debris flow probability etc. Technologies like Remote Sensing and GIS helps us by giving a quicker and cost effective analysis for various applications with accuracy for planning. It also gives a better perspective for understanding the problems and therefore helps to find better solutions in national planning.

The objective of mapping is to have 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). This technology includes engineering hardware and software components, such as, computers (desktop & field notebooks), servers, data collection, GIS tools, numerical models and training/capacity building.

3.4.2 Identification of Barriers and Measures

The technology for water catchment protection is likely to be diffused by the GoG, with possible external financial/technical support and is therefore categorised as a public/ non-market good. However, this can also be implemented by private /research institutions through collaboration with the GoG. The initial list of barriers was reviewed, and prioritised by the TWG as shown in Table 11 below. The TWG participants included representatives identified in *Section 3.2.2*. The following non-financial barriers were prioritised and decomposed:

I. Low level of awareness among policy makers and users
II. Lack of national policy and planning

Table 11: Prioritisation of Barriers for Water Catchment Protection

Categorisation and Prioritisation of Barriers for GIS Mapping and Modeling for Water Catchment Protection					
CATEGORY	**BARRIER**	**CRITERIA - IMPORTANCE**			
		High	**Med**	**Low**	**RANK**
Economic and Financial	Moderate initial investment cost		X		
	Indirect funding from institutional budget which may be limited	X			
	No known external funding source	X			
Non-Financial	Lack of national policy /planning – not an urgent focus of institutional planning and unclear roles	X			2
	Require multiple Agency coordination which may result in low level of commitment to undertake responsibility	X			
	Limited/Unreliable baseline data		X		
	Limited availability of technical skills at the local level		X		
	Difficult to retain skilled personnel, e.g technical skills in data collection, modeling and analysis	X			3
	May be perceived as too complex and time consuming, resulting in loss of interest			X	
	Low private sector interest			X	
	Low levels of awareness for water catchment protection among policy makers and water users of immediate and long term benefits	X			1

3.4.2.1 Economic/ Financial Barriers and Measures

The economic/financial barriers listed below were considered high to medium important (See Table 11). However, none was considered a critical barrier which would hinder the implementation of this technology. There is available GIS capacity in Guyana and data available within the institutions, significantly reducing the cost of implementation and lowering the ranking of barriers above. As a result, no measures were identified for the three barriers identified in this category.

Barriers

- Moderate initial investment cost;
- Indirect funding from institutional budget which may be limited; and
- Limited external funding

3.4.2.2 Non-financial Barriers and Measures

The two prioritised non-financial barriers identified are: (i) Low level of awareness among policy makers and users (ii) Lack of national policy and planning. This section outlines some of the root causes and measures identified for the barriers as shown in Table 12 (See *Appendix I (B)* for problem/objective trees). Measures were also guided by findings from the review of strategy/plans/programs for the water sector. Other non-financial barriers are also listed.

Table 12: Measures for barriers: Low level of awareness and lack of national policy and planning

CRITICAL BARRIER	ROOT CAUSE	MEASURE
Low level of awareness among policy makers and users	• Undervalue of water resource based on the general perception that water is abundant in Guyana; • Lack of strong scientific data to guide reasoning; • Lack of communication systems to decision makers and water users; • No clear institutional responsibility and lack of interest among institutions; • Low level of appreciation for science based decisions; and • Weak promotion of critical reasoning in education system	• Water recognised as a high value resource through the promotion of education and awareness programs; • Provide adequate funding and support for research; • Establish coordinating body and designate responsible institution for information dissemination and communication; • Promote critical/science based reasoning in education.
Lack of national policy and planning	• Fragmented approach to water management; • Lack of coordinating body and data sharing culture; • Lack of technical body to drive specific policy; • Low level of awareness among policy makers; and • Lack of scientific data to guide policy.	• Promote a holistic approach to water management; • Establish a coordinating and technical bodies to drive the development of relevant policy for water catchment protection; • Define mandate through consultations and research; • Strengthen information/data sharing systems; • Promote awareness among policy

		makers and programmes to increase understanding and appreciation of water as a valuable resource; • Provide funding and support for research for decision making.

Other Non-Financial Barriers

- Require multiple agency coordination which may result in low level of commitment to undertake responsibility;
- Limited/Unreliable baseline data;
- Limited availability of technical skills at the local level;
- Difficult to retain skilled personnel, for example, technical capacity in data collection, modeling and analysis;
- May be perceived as too complex and time consuming, resulting in loss of interest; and
- Low private sector interest.

3.5 Linkages of Barriers Identified Across Technologies

The common barriers for the three technologies in the water sector were related to policy and planning, technical and institutional capacity, finance and low level of awareness.

Policy and Planning

The regulatory authority for the management of water resources in Guyana is dispersed among the MoA, which is tasked with the management of ground and surface water resources, the GWI being responsible for potable water supply and the EPA with responsibility for pollution prevention and watershed protection. Other agencies such as the Ministry of Public Works & Infrastructure (MPWI), NDIA and MMA/ADA have specific roles in drainage and irrigation services. This current multi-agency approach has contributed to challenges relating to overlapping responsibilities and coordination. Poor policy coordination can have a significant impact on the successful diffusion of the technologies, particularly as it relates to ownership and continuity. Thus, there is a need to develop a more cohesive policy framework which will enable the clarification of roles and responsibilities to aid in more efficient planning for the water sector in the future.

The urgent need to create Geographic Information System (GIS) ready datasets and use GI applications for nation building is becoming more evident by government officials and other stakeholders. Empirical information and data, particularly spatial data should form a key pillar on which decisions are made.

Low Level of Awareness

Currently, Guyana lacks updated scientific baseline data on its ground and surface water resources, as well as, its watersheds. There is a general low level of awareness and appreciation among decision-makers and water users of the status of the country's water resources and its value. There is also a low level of interest to pursue studies in hydrology and build a career within the discipline due to the lack of opportunities for employment and poor compensation for skills. Coordination and collaboration across the various water management institutions is also challenging. With limited resources, agencies tend to prioritise activities which are core to their mandate and the prevailing developmental targets of the country. However, with increasing pressure on water resources from development activities and climate change, there is an urgent need to raise the level of awareness and establish a more holistic approach to water management. Policy need to be guided by strong scientific reasoning. Efforts towards these can be pursued through the establishment of a national coordinating body and a functional National Water Council.

Institutional Roles and Capacity

Generally, the institutions /systems governing the various aspects of water resources in Guyana are scattered among several institutions. Over time, weak coordination and information sharing systems have contributed to overlapping roles among the institutions. For example, the EPA has an overarching mandate for the protection of the environment, which include water resources and the MoA has responsibility for ground and surface water resources also. This overlapping can hinder the seamless transition of technologies, where institutional turf wars may arise and resources are limited.

The lack of technical skills and resource limitations are important factors that determine the capability and scope of the technologies. As Guyana continue to experience the impact to its water resources from climatic changes and changing development patterns, the need to develop technical capacity has become more urgent than ever. Presently, there is a lack of skills in the ground and surface water disciplines. Based on its 2015 Annual Report, the water resources division of the Hydromet Service currently does not fulfill its mandate satisfactorily. The report cited the continued shortage of senior technical staff to lead in data collection, analysis and publication. The surface water section currently has no hydrologist, hydrological officer, hydrological superintendent or senior hydrological technicians and its core operation staff consists of Hydrological Technicians I and Technical Assistants who are ill-equipped to provide the level of service required. The groundwater section has no dedicated staff.

GIS in Guyana has experienced relatively significant growth since the 1990's, which started in the natural resources sector. Agencies with significant GIS capacity include the EPA, GFC, GGMC and the GL&SC. Many other private and public organisations have also embraced GIS technology to varying degrees. However, one of the key limitations of using GIS technology in Guyana is the availability of reliable data sets.

Financing and National Budget

Adequate financing and national budget allocations were recognised as another root of the barriers for the uptake of technologies. Financing for the water resources section of the Hydromet Service is included in its overall annual allocation in the national budget. Current revenue streams are poorly implemented. License fee for the abstraction of water is not being done to its full potential. In addition, hydro-meteorological data is provided to consumers at a minimal cost. According to the Service, over G$21M worth of data was freely provided to support national development (2015, Annual Report). The report highlighted the immense potential of the Service to generate its own income, especially in areas of aviation meteorology and ground water hydrology. This revenue generating potential can be strengthened with the diffusion of ground and surface water technologies. Also, targeted national budget allocations can help to raise the profile on the importance of water resource management and the technologies among policy makers and strengthen institutional capacity.

3.6 Enabling Framework to Overcome Barriers

There is no integrated water resource management in Guyana. The management of water resources in Guyana is shared between two key agencies, the MoA and GWI. The MoA, through its agency, the Hydromet Service, overlooks ground and surface water management, while, the NDIA is responsible for drainage and irrigation. The GWI is responsible for domestic (potable) water supply. Additionally, the EPA has a mandate for watershed protection. The fragmented roles among the institutions have posed challenges to the holistic management of water resources in Guyana. This section addresses the possible enabling measures for overcoming the critical barriers identified across all of the technologies for the sector. The measures were compiled and clarified (where necessary) to reflect stakeholder's contributions, the national situation regarding the technologies and information gathered from background reviews.

Table 13: Enabling Framework for Technologies in the Water Sector

Technology	Enabling Measures
Groundwater mapping and modeling	• Promote education/awareness to increase appreciation of groundwater among all stakeholders, including decision makers, manufacturers and the public; • Recognise groundwater management as a high national priority and implement in long-term national planning; • Promote research in groundwater resources as a matter of national policy; • Designate institution with clear role and responsibility; • Strengthen institutional capacity/skills to provide data and share information; • Allocate adequate national budget for groundwater research and assessments; • Provide opportunities for technical training and capacity building; • Provide attractive compensation package to retain technical skills; and build local capacity; and • Strengthen communication systems to water users and decision makers on water resource management.
Surface water mapping and modeling	• Provide overarching and clearly defined policy and objectives for surface water management; • Develop holistic surface water management plan to address multiple uses and geographic scope; • Activate /resuscitate the National Water Council and provide strong political support • Promote awareness among policy makers and users on the importance of scientific data for surface water management; • Allocate adequate national budget for surface water management; • Provide opportunities for technical training and capacity building; • Provide attractive compensation package to retain technical skills; and • Promote collaboration and research.
GIS mapping for water catchment protection	• Promote a holistic approach to water management and define institutional mandate through consultations and research; • Promote awareness among decision makers and users on water as a high value resource and the importance of water catchment/watershed; • Establish coordinating and technical bodies to drive a national policy for water catchment protection; • Strengthen collaboration and data/information sharing systems among institutions; and • Provide adequate funding and support for research to guide decision making and build capacity.

Chapter 4 - Coastal Zone and Low-Lying Communities Sector

4.1 Preliminary Targets for Technology Transfer and Diffusion

About 90% of Guyana's population of approximately 780,000 reside on the coastal plain. The country's towns, major settlements and most commercial, industrial and other economic activity are undertaken within the coastal zone. Much of this coastal plain lies at elevations between 0.5 m and 0.7 m below 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. It is estimated that 49% of the sources of the country's gross domestic product (GDP) are in areas at risk of significant flooding (CDB, 2013).

Guyana's vulnerability to sea level rise and risk to flooding are key reasons for strengthening efforts to protect the coastal zone and other low-lying communities. The strengthening of sea defense infrastructure, capacity in early warning systems and flood/drought response actions will contribute to a reduction in the country's vulnerability to catastrophic weather events and enhance the country's adaptive capacity. These actions have been recommended in previous assessments, policies and action plans/strategies for the sector: National Communications (INC (1998) & SNC (2012), Guyana's National Development Strategy (NDS, 2002), Climate Change Adaptation Policy and Implementation Strategy for Coastal and Low-Lying Areas (2002), Poverty Reduction Strategy (2006),Integrated Coastal Zone Management Plan (ICZM, 2008), Early Warning-Situation Report (2009) Low Carbon Development Strategy (LCDS, 2010), National Strategy for the Agriculture Sector (2013), Disaster Risk Management Plan for the Agriculture Sector (2013), Nationally Determined Contributions (NDC, 2016), Climate Resilience Strategy & Action Plan (CRASP, 2015), Strategic Environmental Assessment (SEA, 2015) for the Sea Defense Sector, Sea and River Defense Sector Policy (2015), National Disaster Risk Management Plan and Implementation Strategy (2013).

The successful implementation of policies and plans will require significant resources to transcend the country's continued challenges in financing and technical capacity, institutional arrangements and appreciation/awareness of climate related risks and solutions. At the political level, the GoG has committed to adaptation measures, which include upgrading infrastructure and assets to protect against flooding and the establishment of early warning systems (NDC, 2016).

4.2 Barrier Analysis and Possible Enabling Measures for Mapping and Modeling of Coastal Processes

4.2.1 General Description of Mapping and Modeling of Coastal Processes

Guyana's 430 km-long coastline is protected from coastal flooding by a system of natural and man-made sea defenses, as well as an extensive network of drainage and irrigation canals many of which were constructed 150 years ago, (CDB,2013). Inventory and other recent surveys, conducted by the MPWI, indicate that the "sea defenses comprise approximately 180 km of man-made structures and 186 km of earthen embankments, mud-banks, mangroves, sand bars and other formations. These are intended to prevent erosion, saline intrusion and flooding, and protect life and property in communities along the coastal plain and riparian areas (CDB, 2013). Despite the significant investments to rehabilitate sections of Guyana's sea defense system, the 2014 survey of the country's sea defense structures, which covered 91.2% of the total length, shows that 2.28 km (1%) is in critical condition, 20.53km (9%) is poor and 80.22 km (34.4%) is in fair condition (Budget Speech, 2016).

In 2009, the GOG developed a policy framework for the Sea and River Defense Sector and, with support from its development partners, and established a GIS based Shore-Zone Management System (SZMS), at present used only for its comprehensive condition survey of the natural and man-made sea defenses. Other needs identified through a capacity building study, funded by the European Development Fund (EDF) included further policy development, institutional strengthening and the design of a coastal management programme (CDB, 2013). In 2015 and 2016 the GOG budgeted G$1.274B and G$1.383B respectively for sea and river defense works (Budget Speech 2016). Since the 1990s, The EDF and CDB have provided financial support for the strengthening of Guyana's sea defense.

With resource limitations, Guyana's sea defense structures are maintained mainly, through repairs and construction of sea walls/groynes. However, there is a lack of scientific capacity to study and monitor coastal hydrodynamic/oceanographic processes to better inform design and construction of these physical infrastructure. The importance of this technology could be best summed up in the following: "Nearshore hydrodynamic as part of the general oceanic circulation is an important factor when considering the issue of the stability of built infrastructure, of its long-term functionality or of the possibility for its destruction as a result of coastal erosion. The impact of longshore currents, subsoil condition, tides and wave climate should be evaluated prior to construction. Modeling is a useful tool to assess coastal currents, sediment transportation and the risk for erosion. For example, the movement of sandbanks can locally lead to the regression of mangroves and exacerbate the impact of wave action on the seawall" (Staljanssens, M, et al, 2008). Modeling simulates life situation through physical or computer models and explore different ways a situation can develop, based on differing influencing factors. 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, modeling (physical, numerical and composite) is often employed to simulate the main phenomena in the coastal region. This technology involves the extensive use of data, such as, hydrology, flood defense conditions and or ground surface information.

4.2.2 Identification of Barriers and Measures

The technology for mapping and modeling of coastal processes is categorised as a public/ non-market good. The study of coastal hydrodynamics is a resource intensive activity undertaken by governments and/or research institutions. This type of technology can be supported through collaborative agreements with local/external academic/research institutions, such as, the University of Guyana. The initial list of barriers was reviewed and prioritised by the TWG as shown in Table 14 below. The TWG participants included representatives from key institutions, namely, MPWI, GL&SC, NDIA, CDC, IAST, Caribbean -Terrestrial Solutions, OCC, NDIA, MMA/ADA and MIPA. See Appendix II (C) for details of participants.

The two critical barriers prioritised and decomposed for this technology were:

I. Insufficient/ limited allocation in national budget
II. Limited/weak institutional capacity

Table 14: Prioritisation of Barriers for Mapping and Modeling of Coastal Processes

Categorisation and Prioritisation for Mapping and Modeling of Coastal Processes					
CATEGORY	**BARRIER**	**CRITERIA - IMPORTANCE**			
		High	**Med**	**Low**	**RANK**
Economic and Financial	High initial investment cost because of required engineering studies, engineering hardware/software components, such as, computers, servers, data collection, GIS tools, numerical models and continuous training/capacity building	X			
	Insufficient national budget allocation for sustainability and maintenance	X			1
	Reliance on external financing		X		
Non-Financial	Unsatisfactory compensation for technical skills	X			
	Lack of implementation of the policy for coastal zone management	X			
	Need high level of policy maker buy-in for sustainability		X		
	Overlapping Legislation for different aspects of coastal zone/shore zone management			X	
	Unclear institutional roles			X	
	Weak inter-agency coordination		X		
	Loss of interest/momentum in holistic coastal zone management			X	
	Weak institutional capacity: skills in coastal engineering and modelling	X			2
	Lack of in-depth technical studies and consistent, long-term data, including, aerial photography to support the technology implementation	X			
	Require intensive and ongoing training			X	
	May be viewed as too resource intensive			X	
	Benefits more visible over the long-term, which may cause complacency among implementers and beneficiaries			X	

4.2.2.1 Economic / Financial Barriers and Measures

The economic/financial barriers identified for this technology were prioritised as high to medium importance (Table 14). The top critical barrier '*insufficient allocation in national budget'* was decomposed to identify root causes and measures as shown in Table 15. See *Appendix I (C)* for problem/objective trees.

Table 15: Measures for barrier: Insufficient allocation in national budget

CRITICAL BARRIER	ROOT CAUSE	MEASURE
Insufficient/Limited allocation in national budget	• Lack of strategic planning by agency caused by a lack of awareness of its importance and expertise to guide planning; • Limited awareness of technology importance by the budget office; • Weak intra-agency coordination to develop budget proposals which result in inadequate justification by agencies; • Priority given to urgent issues and focus on visible program interventions; and • Limited national capital base.	• Implement strategic planning by agency through increased awareness and dedicated human resource to guide strategic planning; • Raise awareness of the importance of this technology by the budget office through adequate justification provided by agencies and intra-agency coordination to develop budget proposals; • Promote collaborative meetings and provide training on budget preparation; and • Expand national capital base for budgeting to include more scientific based decision making.

<u>Other Economic/Financial Barriers</u>

- High initial investment/capital cost (engineering studies, engineering hardware/software components, such as, computers, servers, data collection, GIS tools, numerical models and continuous training/capacity building);
- Limited access to and the availability of financial resources for the sustainability of this technology;
- High maintenance cost from wear and tear of field equipment and software management;
- Heavy reliance on external financial/technical assistance; and
- Poor compensation for technical/special skills e.g. engineers

4.2.2.2 Non-financial Barriers and Measures

This section outline the root causes and measures identified for the barrier prioritised in this category – *Limited /weak institutional capacity.as* shown in Table 16 (See *Appendix I (C)* for problem/objective trees). Other non-financial barriers listed below included challenges in policy/planning, institutional capacity, technical capacity and education/awareness. The possible measures seek to address high importance barriers on policy, capacity and awareness.

Table 16: Measures for barrier: Limited/weak institutional capacity

CRITICAL BARRIER	ROOT CAUSE	MEASURES
Limited/weak institutional capacity	• Loss of skilled staff due to unattractive compensation and lack of retention policy; • Lack of emphasis on research and development; • Focus more visible interventions and prioritisation of scarce resources (financial and non-financial); and • Limited expertise/training in specialised fields.	• Public sector reform: review overlapping policies, institutional roles and salaries/ benefits to retain skilled/experienced staff; • Widen focus on programmes and interventions; • Widen financial and non-financial resource base; and • Strengthen emphasis on research and development.

<u>Other Non-Financial Barriers</u>

Policy/Planning:

- Lack of a comprehensive policy for coastal zone management;
- Overlapping Legislation for different aspects of coastal zone/shore zone management; and
- Need high level of political buy-in for sustainability

Institutional Capacity:

- Unclear institutional roles;
- Slow bureaucratic process; and
- Weak inter-agency coordination;

Technical Capacity:

- Limited support infrastructure, for example, ready supply of materials and equipment for field work etc.
- Lack of technical studies and consistent, long-term data, including, aerial photography etc.; and
- Require intensive and ongoing training;

Education/Awareness:

- Perceived as resource intensive which may discourage uptake;
- Benefits more visible over the long-term, which may cause complacency among implementers and beneficiaries; and
- Loss of interest/momentum in holistic coastal zone management.

Possible Measures

- Implement policy for coastal zone management;
- Strengthen inter-agency coordination for coastal zone;
- Raise awareness of coastal zone management and technology among policy makers and key stakeholders; and
- Provide support for research and capacity building within local institutions in coastal engineering.

4.3 Barrier Analysis and Possible Enabling Measures for Early Warning System for Flood and Drought

4.3.1 General Description of Early Warning System for Flood & Drought

EWS are well recognised as a critical life-saving tool for floods, droughts, storms, bushfires, and other hazards (WMO, 2016). An effective EWS need four essential components (WMO, 2016, GoG-EWS, 2009):

1. Detection, monitoring and forecasting the hazards. EWS capacities are supported by adequate resources (e.g., human, financial, equipment, etc.) across national to local levels and the system is designed and for long-term sustainability;
2. Analyses of risks involved;
3. Dissemination of timely warnings - which should carry the authority of government; EWS stakeholders are identified and their roles and responsibilities and coordination mechanisms clearly defined and documented within national to local plans, legislation, directives, Memorandums of Understanding (MoUs), etc.; and
4. Activation of emergency plans to prepare and respond.

These four components need to be coordinated across many agencies at national to local levels for the system to work. Failure in one component or lack of coordination across them could lead to the failure of the whole system. The issuance of warnings is a national responsibility; thus, roles and responsibilities of various public and private sector stakeholders for implementation of EWS should be clarified and reflected in the national to local regulatory frameworks, planning, budgetary, coordination, and operational mechanisms (GoG-EWS, 2009, CDC/UNDP, 2013).

Currently, the Civil Defence Commission (CDC) oversees disaster response and collaborates/coordinates with other institutions, such as, the private sector and non-governmental organisations. Essentially, Guyana already has several components promoting the establishment of an EWS (GL&SC, 2009). Although there is no legal framework, the four components of an EWS is reflected in the work of institutions such as, the GL&SC & EPA which provides data/information on risk knowledge; MoA-Hydromet Service with functions for monitoring and warning; Guyana Information Agency (GINA), as well as NGOs which communicate /disseminate warnings and; response/preparedness capabilities provided by the CDC, Guyana Defence Force (GDF), Red Cross, NDIA, etc. (GL&SC, 2009).

The establishment of a functional EWS in Guyana needs to be a priority of the government. Given that the two main hazards confronted are flood and drought, with far reaching socio-economic and developmental consequences, a national scale EWS must be able to forecast climatic and weather related events across different temporal scales. The implementation of an EWS will include the strengthening of meteorological services, establishment of communication infrastructure and response systems across the country, reducing the loss of assets and life.

4.3.2 Identification of Barriers and Measures

EWS is categorised as a public/ non-market good. The initial list of barriers for EWS was reviewed and prioritised shown in Table 17. The following prioritised barriers were decomposed to identify root causes and measures:

I. Reliance on government funding to sustain coordination and response action
II. Limited training and public education

Table 17: Prioritisation of Barriers for EWS

Prioritisation of Barriers for Early Warning System					
CATEGORY	**BARRIER**	**CRITERIA - IMPORTANCE**			
		High	**Med**	**Low**	**Rank**
Economic and Financial	High investment cost – communication infrastructure throughout the country	X			
	High operational and maintenance cost from regular training, testing		X		
	Reliance on government (national budget) to sustain coordination/ response	X			1
Non-financial	Develop/implement legal framework for EWS		X		
	Lack of coordination of strategies to address flood and drought	X			
	Lack of designated institution to oversee and manage a national EWS			X	
	Limited coordination among multiple institutions (CDC, GL&SC, Hydromet, EPA etc)		X		
	Duplication of roles among agencies			X	
	Need designated emergency shelters			X	
	Lack of IT infrastructure, particularly in hinterland regions; lack of downscaled regional forecasting; centralized communication system needed.	X			
	Problems of data /information sharing among institutions.			X	
	Limited research to provide credible data on disasters which can contribute to planning and emergency preparedness			X	
	Current data exist on the meteorological characteristics.			X	
	Limited information on historical flood and drought disasters and impacts			X	
	Lack of sufficient/adequately trained personnel with the with skills, such as, emergency responders, maintenance crew			X	
	High turnover rate of skilled personnel and lack of incentive to develop relevant skills	X			3
	Need specialisations in climatology and forecasting; GIS; Data base management; scenario building and planning		X		
	May be perceived as too complex and resource intensive			X	
	Limited training and public education	X			2
	Low interest/participation among key stakeholders	X			
	Limited local knowledge of EWS Limited information/knowledge/understanding of disasters and emergency among most vulnerable stakeholder groups	X			

4.3.2.1 Economic/ Financial Barriers and Measures

The critical barrier identified in this category was the heavy reliance on financial resources from the government to implement and sustain an early warning system. Table 18 outlines the root causes which contribute to this barrier and the measures which can be taken.

Table 18: Measures for barrier: Reliance on government funding

CRITICAL BARRIER	ROOT CAUSE	MEASURE
Reliance on government funding	• Legislation /regulation/policies focus on government having sole responsibility for disaster management; • Inadequate assessment of costing and needs caused by a lack of tools (software,hardware)/ human capacity to complete assessments; • Lack of adequate budget and weak decision making for EWS; • Competition with other national programs within a limited budget; • Lack of/limited access to diverse financing options • Lack of knowledge/information of non-government financing options; • Lack of strategy framework for private partnerships;	• Revise/update legislation/regulations to widen scope of responsibility and rapid diffusion of EWS; • Conduct adequate assessment and costing of needs; • Provide tools and training to strengthen capacity to complete assessments; • Allocate sufficient funds in national budget for implementation of EWS framework/policy; • Diversify revenue stream through access to information on financial options; • Framework strategy developed for private partnership/collaboration;

<u>Other Economic/Financial Barriers</u>

- High capital cost – communication infrastructure across the country needed;
- High maintenance cost for regular training and testing, day to day operation and sustainability;
- Narrow revenue stream/sources of funding.

4.3.2.2 Non-Financial Barriers and Measures

Limited training and public education was identified as a critical, non-financial barrier. Table 19 outlines the root causes and measures for this barrier. Other non-economic barriers and possible measures are also listed below.

Table 19: Measures for barrier: Limited training and public education

ROOT CAUSE	MEASURE
• Inadequate financial resources for training due to the low priority status for training in EWS; • Low disaster awareness culture – disaster occurrences not frequent /severe to stimulate heightened interest; • Lack of incentive to stimulate strong interest as a career, including limited employment opportunity; • Lack of EWS expertise (specific & general**)**	• Provide adequate budget and ongoing training; Develop/implement training plan and public education activities; • Promote positive change in disaster awareness culture; • Provide attractive incentives to develop local skills and encourage careers/specialisations for EWS; • Create more employment opportunities.

<u>Other Non-Financial Barriers</u>

Policy:

- Unclear legislative framework specific to EWS;
- Lack of comprehensive strategies to address flood and drought.

Institutional:

- Lack of designated institution to oversee and manage a national EWS;
- Limited coordination among institutions (CDC, GL&SC, Hydromet, EPA etc);
- Lack of designated emergency shelters.
- Lack of IT infrastructure, particularly in hinterland regions;

Technical Capacity:

- Lack of sufficient/adequately trained personnel with skills, such as, emergency responders, maintenance crew etc.;
- High turnover rate of skilled personnel due to unattractive salaries and lack of incentives;
- Strong need for specialisations in climatology and forecasting; GIS; data base management; scenario building and planning

Research:

- Lack of downscaled regional forecasting; centralised communication system;
- Weak data /information sharing among institutions;
- Limited research to provide credible data on disasters to aid planning;
- Limited information on historical flood and drought disasters and impacts;

- Data limited to meteorological characteristics.

Education /Awareness:

- May be perceived as complex and resource intensive;
- Perception that government has sole responsibility; and
- Limited information/knowledge/understanding of disasters and emergency response among most vulnerable stakeholder groups;

Possible Measures

- Coherent framework/ legislation for EWS;
- Clear institutional role and responsibility for EWS;
- Strong collaboration among institutions and communities;
- Establish efficient data/information sharing systems;
- Strengthen technical capacity through provision of adequate tools and training;
- Promote research to generate data and develop strong understanding of disaster events in Guyana; and
- Increase awareness among the general population to develop appreciation for EWS and stakeholder buy-in;

4.4 Barrier Analysis and Possible Enabling Measures for Energy Efficient Mobile Pumps

4.4.1 General Description of Energy Efficient Mobile Pumps

During the biannual seasonal heavy rains, the water inundating the residential areas in the coast during the high tides can only be drained with pumps. Heavy rains together with persistent high tides impede the appropriate drainage of the flooded areas, triggering the overflow of drainage waters. During high tide, the drainage of surplus water into the sea is impossible through the sluices. The system suffers from the impact of sea level rise because an adequate discharge window is no longer available. As the sea level continues to rise and the discharge window continues to shrink, the ability to manage water levels becomes seriously compromised.

Mobile pumps are easily towed and ready to pump very large volumes of water within minutes of reaching a location. With minimal training, it can be operated by one person. A mobile pump is likened to a complete pump station on wheels. For example, the hydra flow mobile pump is a submersible axial or mixed flow pump, driven by a hydraulic pump and motor with flexible hydraulic lines. Other pumps are fitted with a long, fixed shaft. The portability of the mobile pumps permits easy movement to various locations where large volumes of water need to be pumped. Everything needed for pumping is mounted on a trailer. Typically, the pumps comprise a diesel engine, water pump, fuel tank, hydraulic oil reservoir, discharge pipe, discharge hose, and a safety shutdown system (MWI Pumps). According to the NDIA, there are currently 33 mobile pumps throughout the country, with discharge capacity between 20 – 120 cubic metres/sec. However, high fuel cost for the operation of the pumps is a challenge to its effective use. Energy efficient pumps will significantly reduce operational and maintenance costs, due to the use of clean energy or more energy efficient engines (TNA Report, 2016).

4.4.2 Identification of Barriers and Measures

Historically, mobile pumps for flood control were provided by the GoG within its national budget. It is categorised as a public/ non-market good, since it provides a public service and has been the sole responsibility of government. The initial list of barriers was reviewed, and prioritised by the TWG as shown in Table 20. The top two barriers prioritised and decomposed were:

I. High capital / maintenance cost (new pumps, retro-fitting existing ones)
II. Weak interagency collaboration

Barrier No I. was reviewed and corrected following observation by stakeholders that the LFA did not consider the technology in terms of ‘energy efficiency’. The consultant reviewed the LFA and modified the relevant causes accordingly, based on knowledge and information gathered about the technology.

Table 20: Prioritisation of Barriers for Energy Efficient Mobile Pumps

Categorisation and Ranking of Barriers for Energy Efficient Mobile Pumps					
CATEGORY	BARRIER	CRITERIA - IMPORTANCE			
		High	Med	Low	Rank
Economic and Financial	High cost for large capacity and location of equipment		X		1
	High operational cost – mechanical parts/deployment/security	X			
	Rely on national budget priority of institution		X		
	High investment cost for private sector			X	
	Narrow market opportunity			X	
Non-financial	Single institution responsible			X	
	Ad hoc / reactive approach to use of pumps			X	
	Low interest due to seasonal use – only seen as useful during times of crisis			X	
	Weak inter-agency collaboration for the deployment of pumps	X			2
	Alternative flood/drought control measures may deter interest			X	

4.4.2.1 Economic/Financial Barriers and Measures

High capital and maintenance cost was considered a critical to the acquisition of this technology. Essentially, high capacity, clean energy equipment has significantly higher procurement cost. It will also be costly to re-engineer existing technology to improve energy efficiency. Table 21 outline the root causes contributing to this barrier and the measures which can be applied to overcome it.

Table 21: Measures for barrier – High Capital and maintenance cost

CRITICAL BARRIER	ROOT CAUSE	MEASURE
High capital and maintenance cost	• High cost for new pumps; • High cost to retrofit existing pumps to make more energy efficient; • Lack of local specialised skills; • High cost for spares and service which may not be available locally; and • Recurring labour cost for operation and security.	• Increase national budget allocation to upgrade stock of pumps; • Develop local skills through specialised training to upgrade/maintain equipment; • Stimulate interest in local market to supply materials and services; • Offset labour cost through energy savings

Other Financial Barriers

- Reliance on national budget to procure and maintain; and
- Narrow market opportunity, limiting private sector investment.

Possible Measures

- Identify/secure other sources of financing; and
- Encourage private sector involvement through business partnership/opportunity, tax concessions etc.

4.4.2.2 Non-Economic Barriers and Measures

This section outline the decomposition of the critical barrier – *Weak interagency collaboration,* as shown in Table 22. Root causes were identified by the TWG. However, no measures were specifically identified. Based on the root causes identified and stakeholder discussions, the following possible measures may be considered.

Table 22*: Measures for barrier – Weak inter-agency collaboration*

CRITICAL BARRIER	ROOT CAUSE	MEASURE
Weak interagency collaboration	• Insufficient exchange/sharing of information • Narrow institutional interest; • Lack of information sharing policy/protocol • Unclear roles/responsibility for response actions; • Perceived lack of benefits; • Limited collaborative activities/partnerships	• Establish information sharing protocol to improve the sharing of information and efficient response to deploy pumps; • Improved collaboration between institutions on the sharing of resources; • Provide clarity on roles and responsibilities among agencies, such as, the NDIA and MMA/ADA • Increase awareness of benefits

Other Non-Financial Barriers

- Responsibility of a single institution (NDIA);
- Ad hoc / reactive approach to use of pumps;
- Low interest due to seasonal use – only seen as useful during times of crisis;
- Alternative flood/drought control measures may deter interest; and

4.5 Linkages of the Barriers Identified

High Capital Cost

One of the main barriers identified for the rapid deployment of the technologies prioritised in the coastal sector is cost. High capital cost identified for mapping and modeling, EWS and mobile pumps technologies by stakeholders. Although Guyana has the capacity to construct seawalls, there is a need to strengthen the scientific basis for this activity. The mapping and modelling of coastal dynamics is highly technical and requires significant resources, such as, equipment and skills in engineering/ oceanography. The implementation of EWS will require setting up of communication centers and systems, and hiring if skilled staff across the country. Ongoing training and capacity building will also add to the cost due to the lack of local skills and high attrition rate in engineering, meteorology and other technical disciplines. Guyana relies on mobile pumps to aid in its flood control measures. Pump size and quantity depend on the volume of water they are required to remove in a specified time, measured in cusecs (cubic metres/second). Generally, the cost for mobile pumps includes brand, capacity and transport to the location.

Limited Financial Resources

Generally, national budget is targeted towards development priorities within the sectors, such as, repair and construction of sea defenses, and disaster response actions, as in flood and drought control. Sector agencies have limited resources to conduct research and strengthen institutional capacity, or to establish new systems, such as EWS.

The sea defense sub-division national public expenditures for sea defenses is inadequate, as the Ministry's budget is shared with other infrastructure works such as roads and bridges (Staljanssens, M, et al, 2008). The European Development Fund (EDF) has been the major external contributor to sea defenses programmes in Guyana. Other donors included the IDB and CDB. Since the 1990's the country has benefited from financing agreements through the EDF for shoring up sea defense structures, institutional strengthening and capacity building. In April 2016, the GOG and the CDB launched a US$30.9M Sea and River Defense Project for the reconstruction and improvement of 5.4km of sea and river defenses in eight critical areas (CDB, 2016). However, limited availability of funds mean that work is carried out when funds are available rather than when the works needed (Staljanssens,M, et al, 2008). The restriction of funds impedes the development of research capacity to inform sea defense planning in a more scientific and systematic manner. This indicates the need to enhance public and political awareness as to the critical importance of sea defenses to the future of the national economy.

While Guyana has developed an EWS Framework, there is no functional EWS. The EWS Framework, 2013 stated "An EWS require finance to operate, to respond quickly to events, and to develop new capacities and improve performance (e.g. evaluation, training, practice alerts), detail ways that routine operational costs are minimized if the EWS is based on existing institutions", such as, the CDC. The CDC, whose mandate is to coordinate disaster response actions, is dependent on government funding. In August 2016, the CDC was allocated G$55.7M in supplementary provision to strengthen its disaster response capacity CDC, 2016). The Framework also emphasized that “resources must be allocated wisely and priorities should be set, based on risk assessment analysis, for long and short-term decision-making, such as investing in local Early Warning systems, education, or enhanced monitoring and observational systems.” Additionally, significant funding is needed towards flood control, including the construction/maintenance of flood control structures, namely, drains, dams, sluices, conservancies, and stationary/mobile pumps.

In summary, there is limited budgeting from central government for the successful implementation of the technologies in this sector, and will therefore require external financial support.

Institutional Capacity

One of the major challenges in Guyana is overlapping responsibilities among institutions and unclear roles. There are several agencies with intersecting jurisdiction over coastal zone management which create a sense of confusion. For example, the responsibility for the construction and maintenance of the sea defenses, rests with the Sea and River Defenses Division but the maintenance and operation of sluice gates, and the drainage of freshwater into the sea is the responsibility of the NDIA. There is also the role of other agencies such as, the MMA/ADA and GuySuCo. In terms of disaster management, the CDC is responsible for the coordination of disaster preparedness and response, and has prepared an EWS Framework. However, clear roles of partnering institutions and committees are lacking. Disaster response mechanisms are felt to be insufficient to give appropriate warnings of imminent flooding to guarantee the safety of the general public. For example, the early warning radar system implemented is thought to be too regional in scope and insufficient for localised flood warnings (Staljanssens, M et al, 2008).

Technical Skills

Agencies face a continuous migration of skilled personnel and suffer from a recurrent lack of human resources leading to a severe lack of capacity. At the MPWI, according to the SEA, there is a high vacancy rate within the Sea and River Defenses Division. In the Work Services Group, there is a shortage of qualified staff, experienced in the specialist disciplines related to the management of sea and river defenses. This has been aggravated by low levels of remuneration, especially in junior positions. The Hydro-meteorological Services face the problem of lower wages in comparison with other Caribbean countries. Commonly stated reasons for dissatisfaction are the lower salaries than in other governmental agencies, the temporary nature of contracts and unclear conditions of employment, and project staff leaves soon after training for the private sector or abroad (MoA, Annual Report, 2015, SEA, 2008). In addition, mechanical skills to retro-fit existing diesel fuel pumps, if this option is feasible/practical, and perform maintenance on more advanced pumping systems which are more energy efficient, may not be available locally.

Policy and Regulations

There are two principal items of legislation referring to sea and river defenses, the Sea Defenses Acts (CAP 64:01) and (CAP 64:02). This legislation makes provision for the establishment of a Sea and River Defense Board (SRDB), charged with the care, maintenance, management and construction of the sea defenses. The Acts also empower the Minister of Public Infrastructure to make regulations to protect and conserve the foreshore (GOG-MPWI, 2015). Other supporting legislation include the Environmental Protection Act (CAP 20:05) which provides for an integrated coastal zone management programme. The Drainage and Irrigation Act (May 2004) provides for the establishment of the NDIA, with the purpose of establishing an effective mechanism for the management and financing of the drainage, irrigation and flood control system.

The Forests Act (Act no. 6 of 2009) as it relates to coastal protection and sea/river defenses rests in its mandate on mangrove forests. Key policy and strategy documents also recognise Guyana's commitment to coastal protection in its development planning. For example, the NDS 2001-2010 and Public Sector Investment Program 2005-2009 which places a high priority on the construction, rehabilitation and maintenance of sea defenses. Guyana's PRSP also, states that *"the objectives set for the sea defense programme are to reduce breaches, build local capacity to do maintenance and rehabilitation works and increase community participation in the inspection and protection of the sea defense system"* (PRSP, 2006). The ICZM (2008) which was intended to guide stakeholders involved in integrated coastal zone management. The Action Plan provided technical information on natural resources, mangrove management, hydrological and climate data, aerial photographic coverage, infrastructure monitoring, surveys and the legal and institutional framework needed. Other policy and strategies supporting coastal zone protection have been listed in *section 3.1.*

With the existing polices and legislation, clearly, there are overlapping roles of institutions, which needs to be addressed in the future. While the acquisition and deployment of pumps for flood control seems straight forward, the mapping and modeling of coastal processes and the establishment of an EWS will need clear and strong policy support and, a high level of awareness and appreciation among decision-makers.

Public Education and Awareness

There is general consensus that there is a low level of awareness of the importance/value of developing these technologies among decision makers/officials and key stakeholders (a cross cutting problem across all sectors). Officials generally recognise the existence of comprehensive legislation and regulations but emphasise the general lack of law enforcement, as well as, the significant lack of coordination between authorities. All groups of stakeholders buy-in are critical to the success of a technology. Like all 'public good' technologies, the more involved policy makers are in the process, the stronger will be the ownership of the technology. This is also similar for the day-to-day implementers and end users/beneficiaries.

Research and Information Sharing

There is a paucity of research and updated data in coastal processes, hydrology, localised climate impacts etc. This has been highlighted for many of the technologies. There is no doubt that Guyana needs an improved and more systematic approach for monitoring geomorphological processes impacting Guyana's coastline, which will increase the availability of accurate data required for coastal zone management. Greater efforts must also be dedicated to the collection of data on the impact of coastal flooding. However, it appears that data availability and collection, as well as the national capacity for modeling and monitoring climate change in relation to sea defenses constitute the most severe limitation.

4.6 Enabling Framework for Overcoming Barriers

There is a lack of sustained efforts towards integrated coastal zone management in Guyana. The protection and development of the coastal zone is effected through the mandate of each institution, such as, the MPWI, EPA and the GL&SC. Despite the best intentions, this limitation has contributed to a fragmented, crisis reactive approach to coastal natural hazards. This section addresses the possible enabling measures for overcoming the prioritised critical barriers likely to hinder the uptake of the technologies in the coastal zone sector. The enabling framework outlined in Table 23 includes measures identified through this BA for the technologies within the coastal zone sector.

Table 23: Enabling Framework for Technologies in the Coastal Zone Sector

Technology	Enabling Measures
Mapping and modeling of coastal processes for the construction of sea walls and groynes	• Implement strategic planning by agency through increased awareness and dedicated human resource to guide strategic planning for coastal zone protection; • Provide financing from national budget and diversify financing sources; • Raise awareness of the importance of this technology by the budget office through adequate justification provided by agencies and intra-agency coordination to develop budget proposals; • Promote collaborative meetings and provide training on budget preparation; and expand national capital base for budgeting to include more scientific based decision making • Review overlapping policies, institutional roles and salaries/ benefits to attract and retain skilled/experienced staff within the public sector; • Widen focus on programmes and interventions; and • Improve emphasis on research and development in national planning.

Early warning system for flood and drought	▪ Revise/update legislation/regulations to improve coherence and clarify institutional roles and responsibilities; ▪ Conduct adequate assessment and costing of needs, including human capacity; ▪ Provide tools and training to strengthen capacity to complete assessments; ▪ Allocate sufficient funds in national budget for implementation of EWS framework/policy; ▪ Diversify revenue stream through access to information on financial options; ▪ Framework strategy developed for private partnership/collaboration; ▪ Provide adequate budget ongoing training and public education activities; ▪ Develop/implement training plan; ▪ Promote positive change in disaster awareness culture; ▪ Provide attractive incentives to develop local skills and encourage careers/specialisations for EWS; and ▪ Create more employment opportunities.
Energy efficient mobile pumps for flood control	▪ Increase national budget allocation for transition to new technology; ▪ Include in procurement policy for 'energy efficient' equipment; ▪ Develop local skills through specialised training to upgrade/maintain equipment; ▪ Stimulate interest in local market to supply materials and services; ▪ Establish information sharing protocol to improve the sharing of resources/information and strengthen efficient response actions; ▪ Provide clarity on roles and responsibilities among agencies for the deployment and use of pumps; and ▪ Increase awareness of benefits, mainly financial, of energy efficient equipment.

Conclusion

The BAEF was completed following a satisfactory participatory process. The method followed the guideline provided in the TNA Handbook ‘Overcoming Barriers to the Transfer and Diffusion of Climate Technologies’. The analysis involved a diverse group of participants from the government, non-government, media, international agencies, farmers and other end users, who participated in a one-day workshop for each sector to assess the barriers. Despite the limitations of time and other engagements, participants showed keen interest in the technologies and process. Discussions during the feedback sessions and breaks were engaging and informative for everyone.

The barriers identified, categorised, ranked and decomposed, showed a common pattern. Barriers which were ranked as ‘critical/killers’ included, policy, financial, institutional, human and technical capacity, and awareness of the technology. Financial resources were identified as an important barrier for the transfer of six of the technologies. However, stakeholders felt that with good collaboration, expertise and strong justification, the financial resources can be acquired. Other top critical barriers identified were: Limited awareness/appreciation of the value of the technologies among decision-makers, weak policy & planning and weak institutional capacity (hardware & software). The measures identified were informed by the objective trees developed, feedback discussions, informal interviews and relevant literature.

This report will now inform the preparation of the Technology Action Plan which will outline the actions/activities necessary for the implementation of the technologies.

List of References

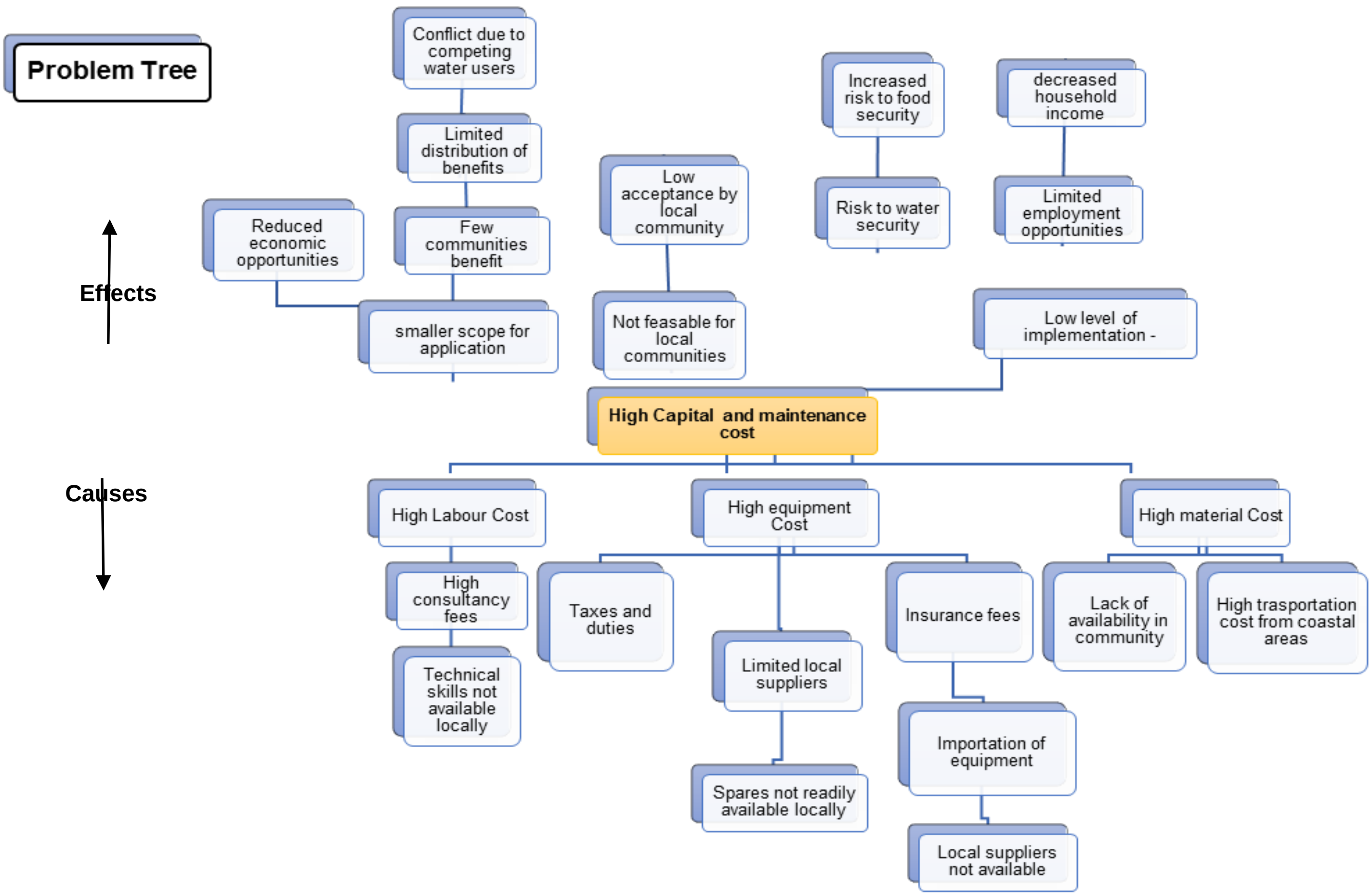
1. Boldt, J., I. Nygaard, U. E. Hansen, S. Trærup (2012). Overcoming Barriers to the Transfer and Diffusion of Climate Technologies. UNEP Risø Centre, Roskilde, Denmark, 2012
2. Budget Presentation (2016). Minister of Public Works and Infrastructure. Hon. Minister Patterson. http://www.mopi.gov.gy/index.php/minister-s-speechs/minister-patterson/budget-presentation-2016
3. Caribbean Community Secretariat (CARICOM, 2016). Regional News: CDB Launches Sea & River Defense project in Guyana.
4. Caribbean Development Bank (2013). *Sea and river defense project – Guyana. Appraisal Report*
5. Caribbean Development Bank (2015). *Sea and river defense resilience project – Guyana Final Review*. Available at: http://www.caribank.org/uploads/2015/01/BD84_13_Sea-and-River Defenses Resilience
6. Civil Defence Commission & United Nations Development Programme (2013): *Early Warning Systems Framework.*
7. Clements R J, Haggar A, Quezada and J. Torres (2011), *Technologies for Climate Change Adaptation – Agriculture Sector*, X. Zhu (Ed.), UNEP Risø Centre, Roskilde.
8. Coastal Inlet research program: Coastal Modeling System
9. http://cirp.usace.army.mil/pubs/other/FY16_CIRP_CMS_WU_FS.pdf
10. Food & Agriculture Organisation (FAO) http://www.fao.org/nr/water/aquastat/countries_regions/guy/index.stm
11. Government of Guyana (2015). *Sea and river defense sector policy*
12. Government of Guyana, (2012): *Guyana Second National Communication to the United Nations Framework Convention on Climate Change*
13. Government of Guyana (GoG), (2013): *Guyana National Land Use Plan, 2013*. Guyana Lands and Surveys Commission.
14. Government of Guyana (GoG), 2010 (updated 2013). *Guyana Low Carbon Development Strategy*.
15. Government of Guyana (GoG), (2015): *Climate Resilience Strategy and Action Plan for Guyana. Draft for Consultation*.
16. Government of Guyana (GoG), (2013): *National Strategy for Agriculture in Guyana 2013-2020 – Vision 2020*. Ministry of Agriculture.
17. Government of Guyana (2002). Guyana Climate Change Adaptation Policy and implementation strategy for coastal and low-lying areas.
18. Guyana of Government of Guyana, 2001. Geographic Information Systems Policy. Ministry of Natural Resources.
19. Guyana Lands and Surveys Commission (2009): *Early Warning System – Situation Report*
20. Lands & Surveys Commission, (2010): *Early Warning System Study*.
21. Hydromet Service, MOA (2015). Annual Report.
22. Indigenous Herald (2011). GIS in Watershed Management. Available at http://www.indigenousherald.com/index.php/features/278-gis-in-watershed-management
23. International Monetary Fund (2002): Poverty Reduction Strategy Paper – Guyana. Joint Staff Assessment.
24. International Monetary Fund, 2006. Guyana: Poverty Reduction Strategy Paper Progress Report 2005.
25. Mekdaschi Studer, R. and Liniger, H. (2013): *Water Harvesting: Guidelines to Good Practice.* Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.
26. MWI Corporation – Hydra Flow Pumps http://mwi-egypt.com/ProductDetails.aspx?id=1
27. National Drainage and Irrigation Authority (NDIA) (2016). *Country-wide drainage and irrigation pump status report*.
28. Nygaard, I. and Hansen, U. (2015). Overcoming Barriers to the Transfer and Diffusion of Climate Technologies: Second edition. UNEP DTU Partnership, Copenhagen
29. Ministry of Natural Resources (2016). National Policy for Geographic Information System – Unofficial draft.

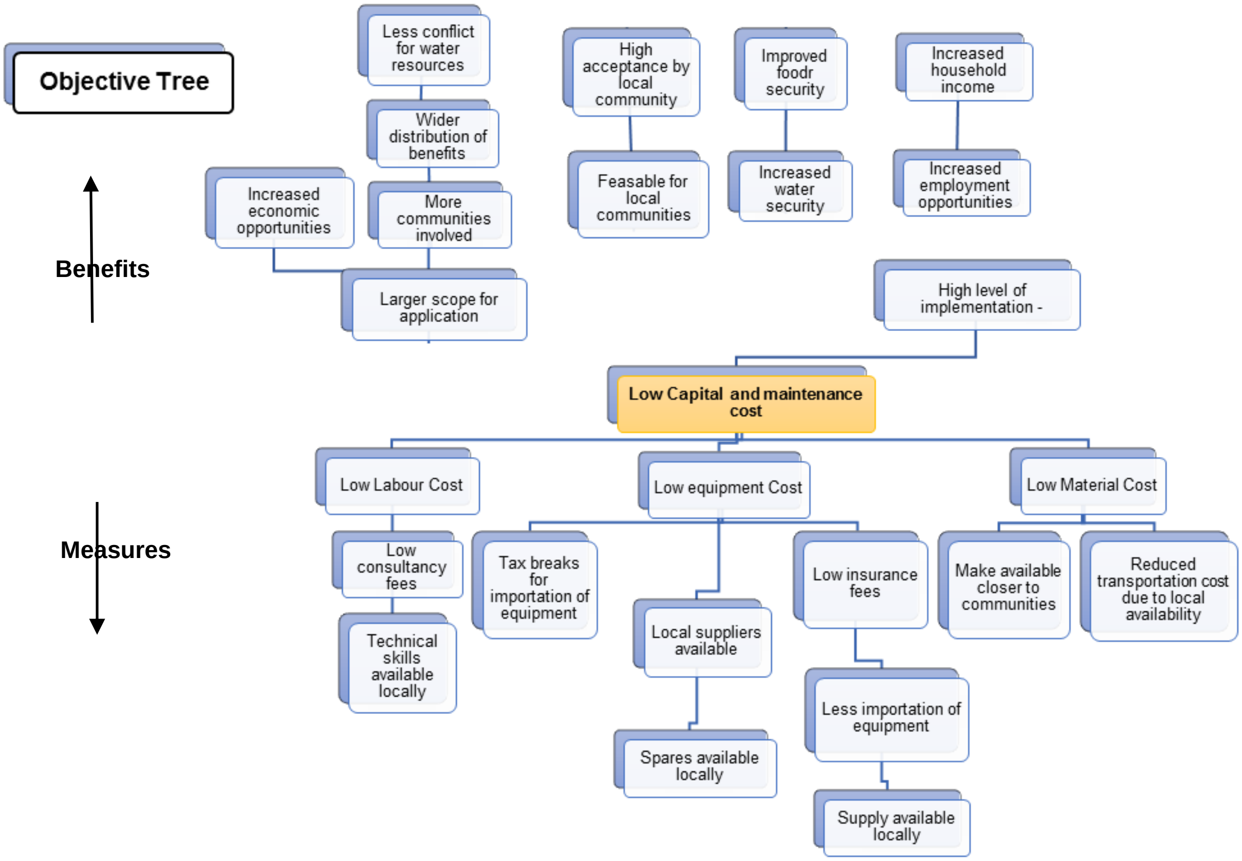
30. Quezada, Alicia et al (Not dated). Decentralised Community Run Early Warning Systems. UNEP RISØ Centre. Available at: http://www.climatetechwiki.org/content/decentralised-community-run-early-warning-systems.
31. Staljanssens,M, Simpson,M, Wernerus, F. IBF International Consulting. (2008). Strategic Environmental Assessment of the Sea Defense Sector Policy in Guyana – Draft report.
32. UNDP (2015). Criteria for Project Concept Notes – Japan-Caribbean Climate Change Project
33. UNEP (2015): *Identification and Engagement of Stakeholders in the TNA Process – A Guide for National TNA Teams*. Edited by J. Rogat.
34. United States Army Corps of Engineers. Hydrologic Engineering. Available at: http://www.hec.usace.army.mil
35. United States Army Corps Engineers, (1998): *Water Resources Assessment of Guyana*
36. United States Geological Survey (USGS) http://water.usgs.gov/software/.

Appendix I (A): Logical Problem and Objective Tree – Agriculture Sector

Technology (i): Freshwater Harvesting: Empoldering of Water Collection Areas

Barrier: *High Capital and Maintenance Cost*




Objective Tree
Benefits
Measures
Less conflict for water resources
Wider distribution of benefits
More communities involved
Increased economic opportunities
Larger scope for application
High acceptance by local community
Feasable for local communities
Improved foodr security
Increased water security
Increased household income
Increased employment opportunities
High level of implementation -
Low Capital and maintenance cost
Low Labour Cost
Low equipment Cost
Low Material Cost
Low consultancy fees
Technical skills available locally
Tax breaks for importation of equipment
Local suppliers available
Spares available locally
Low insurance fees
Less importation of equipment
Supply available locally
Make available closer to communities
Reduced transportation cost due to local availability

Technology (ii): Agrometeorological System for Forecasting and Early Warning

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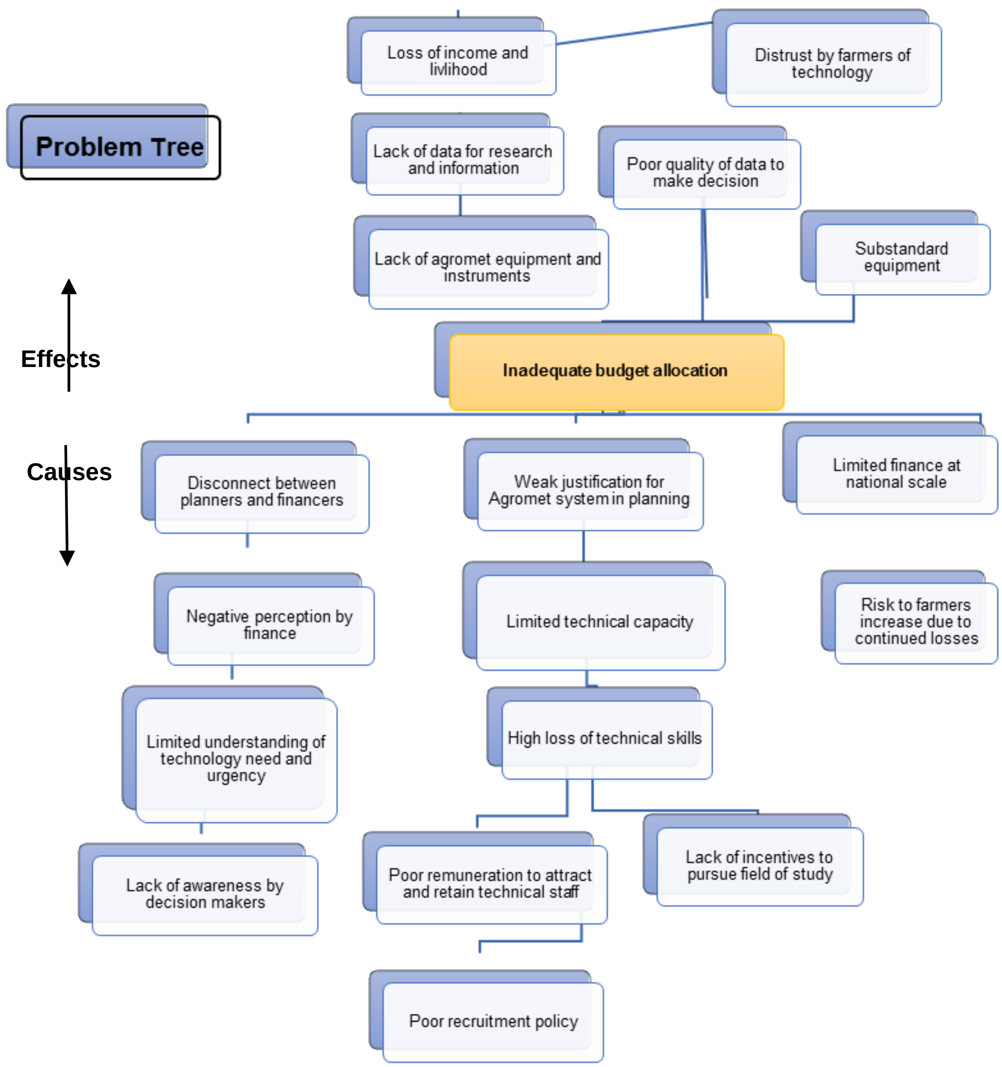
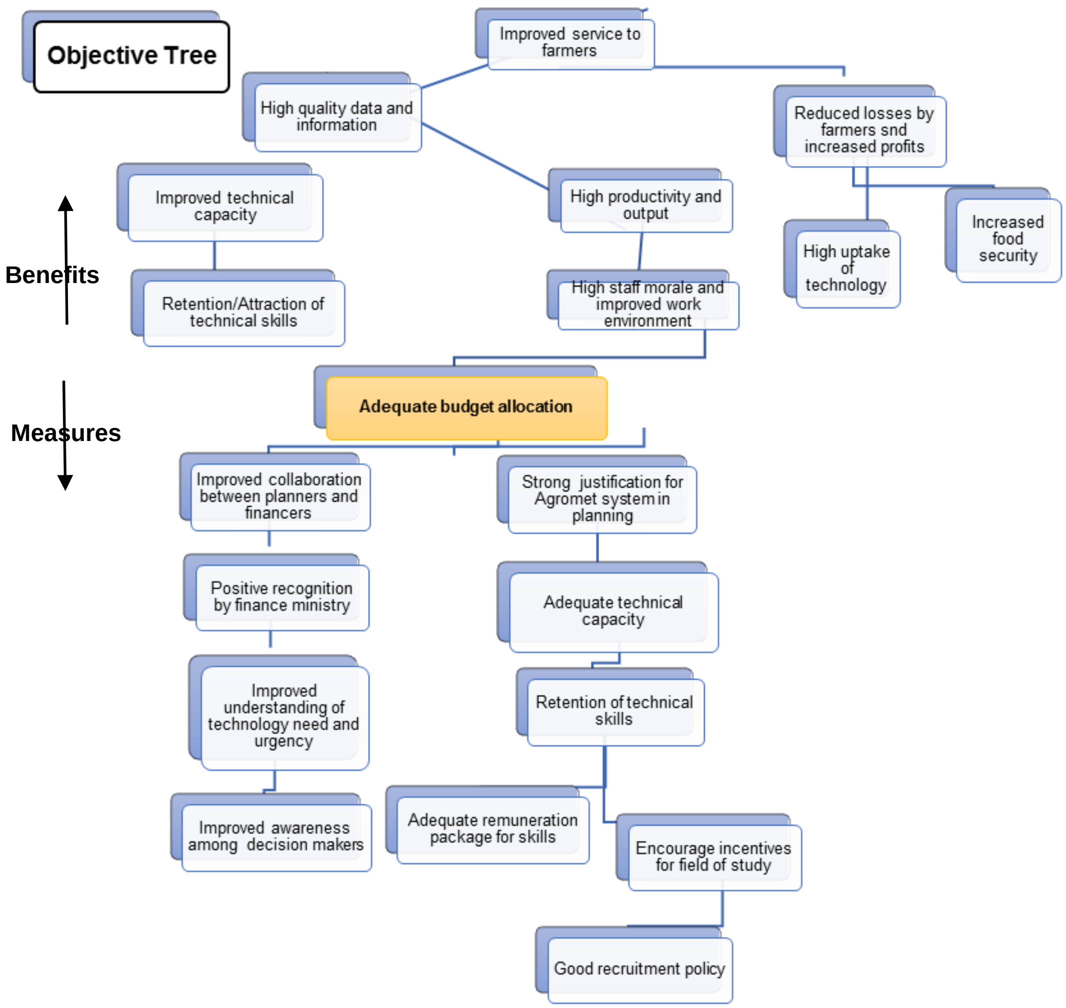
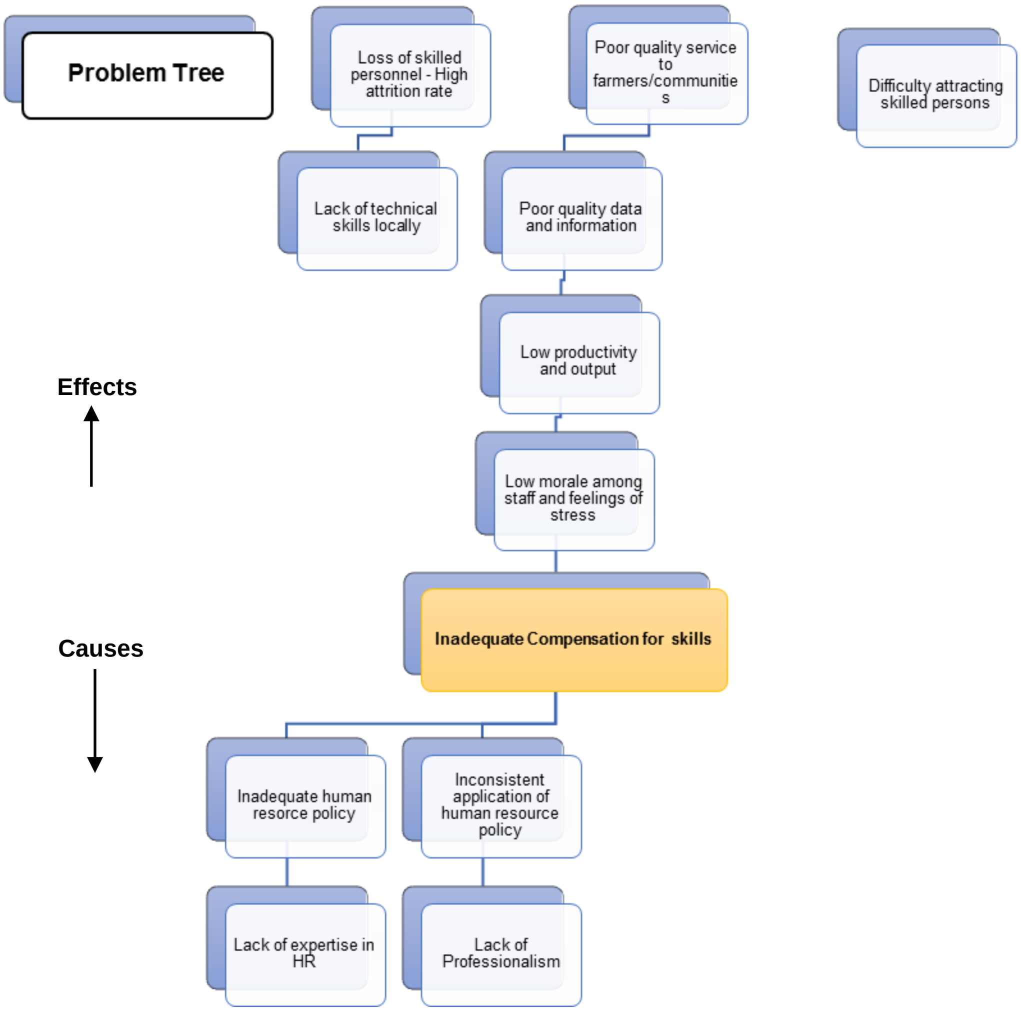
Barrier #1: Inadequate budget allocation





Objective Tree
Improved service to farmers
High quality data and information
Reduced losses by farmers snd increased profits
Improved technical capacity
High productivity and output
Increased food security
High uptake of technology
Benefits
Retention/Attraction of technical skills
High staff morale and improved work environment
Adequate budget allocation
Measures
Improved collaboration between planners and financers
Strong justification for Agromet system in planning
Positive recognition by finance ministry
Adequate technical capacity
Improved understanding of technology need and urgency
Retention of technical skills
Improved awareness among decision makers
Adequate remuneration package for skills
Encourage incentives for field of study
Good recruitment policy

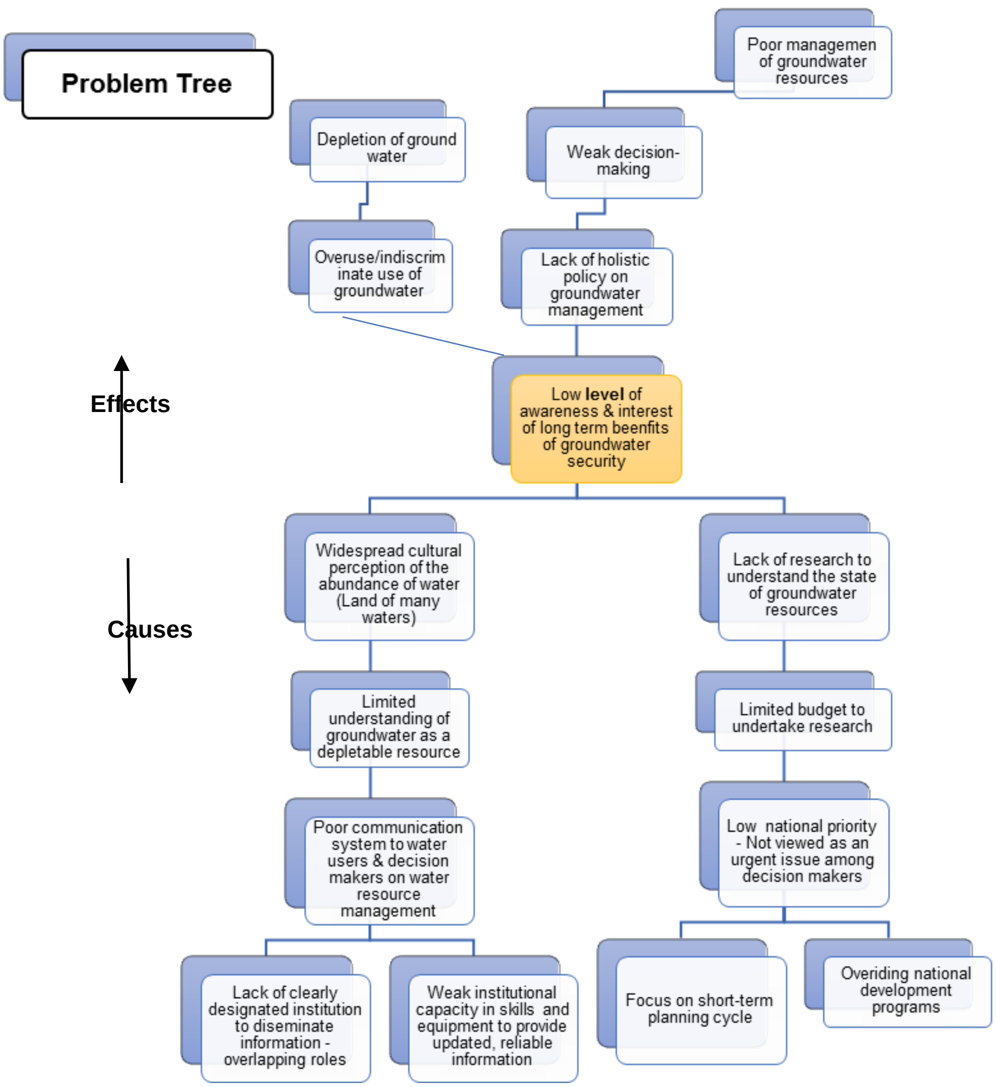
Barrier #2: Inadequate (poor) compensation for skills

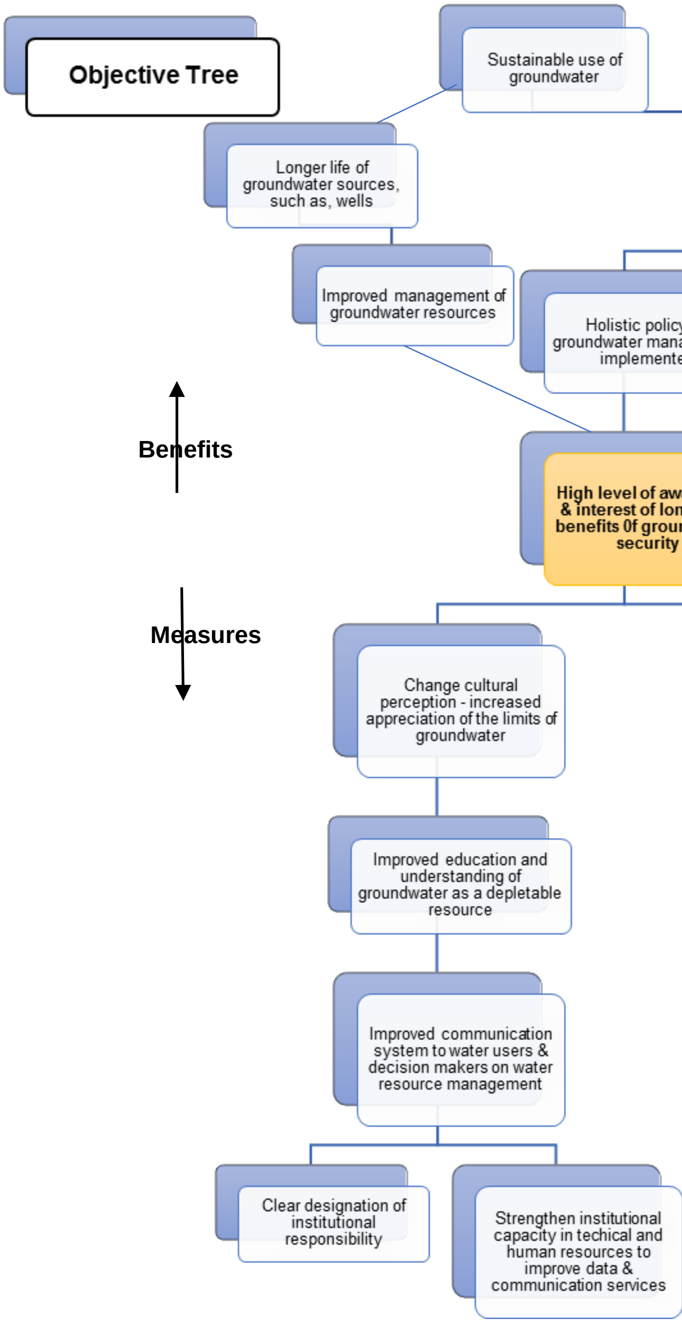


Appendix I (B): Logical Problem and Objective Trees – Water Sector

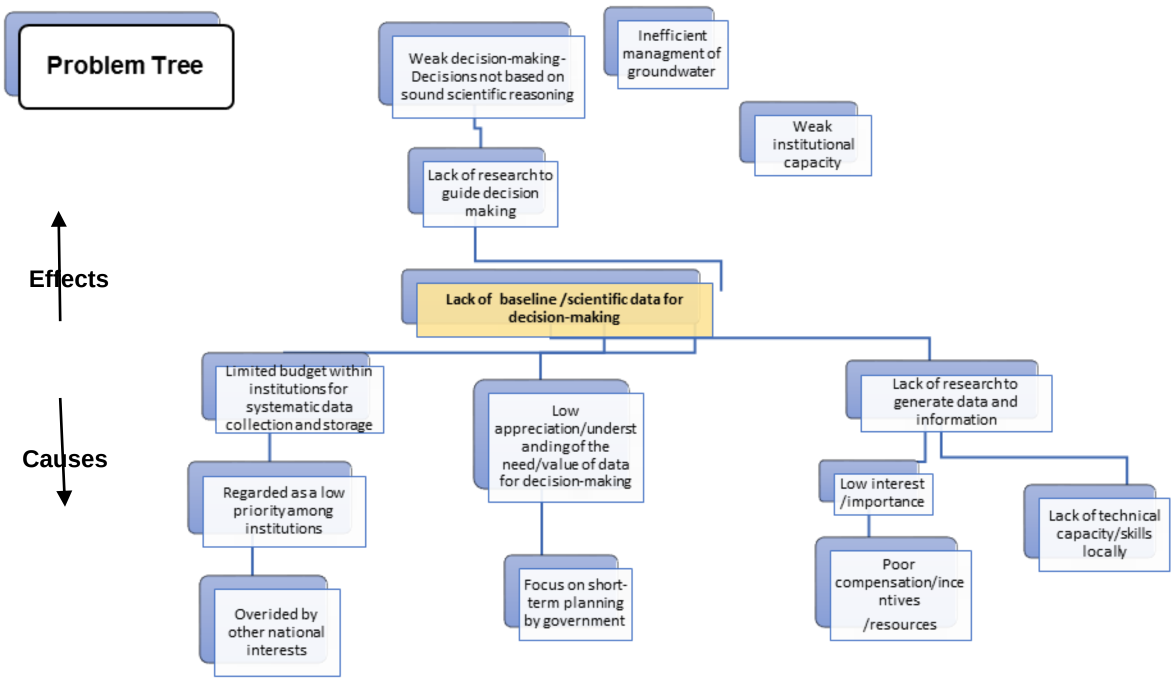
Technology (i): Groundwater Mapping and Modeling

Barrier # 1: Low level of awareness and interest of long-term benefits (water security)

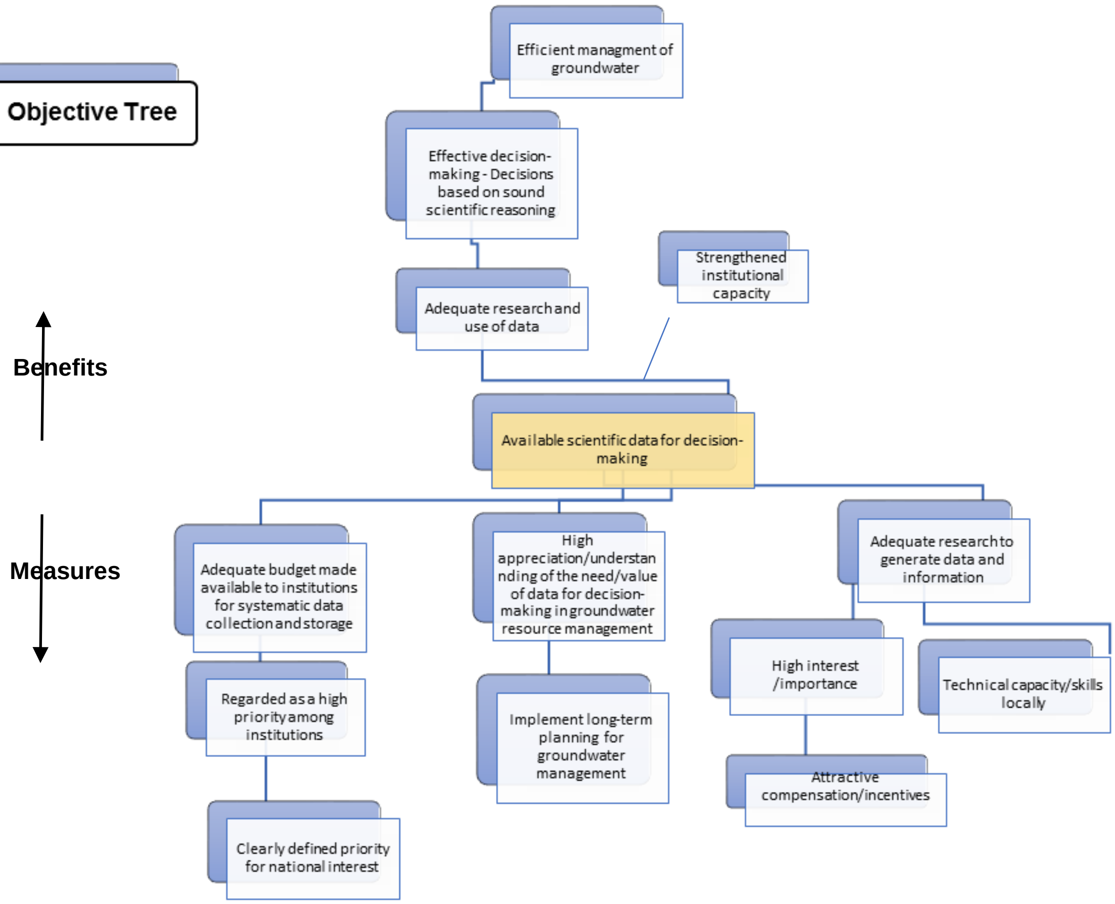



Objective Tree
Sustainable use of groundwater
Longer life of groundwater sources, such as, wells
Improved decision-making
Improved management of groundwater resources
Holistic policy on groundwater management implemented
Benefits
High level of awareness & interest of long term benefits 0f groundwater security
Measures
Change cultural perception - increased appreciation of the limits of groundwater
Promote research on groundwater resources
Assign funds/budget to undertake research
Improved education and understanding of groundwater as a depletable resource
Recognise importance/value of groundwater management and place as a high national priority
Improved communication system to water users & decision makers on water resource management
Implement more long-term planning for groundwater
Clear designation of institutional responsibility
Strengthen institutional capacity in techical and human resources to improve data & communication services

Barrier # 2: Lack of data for decision-making

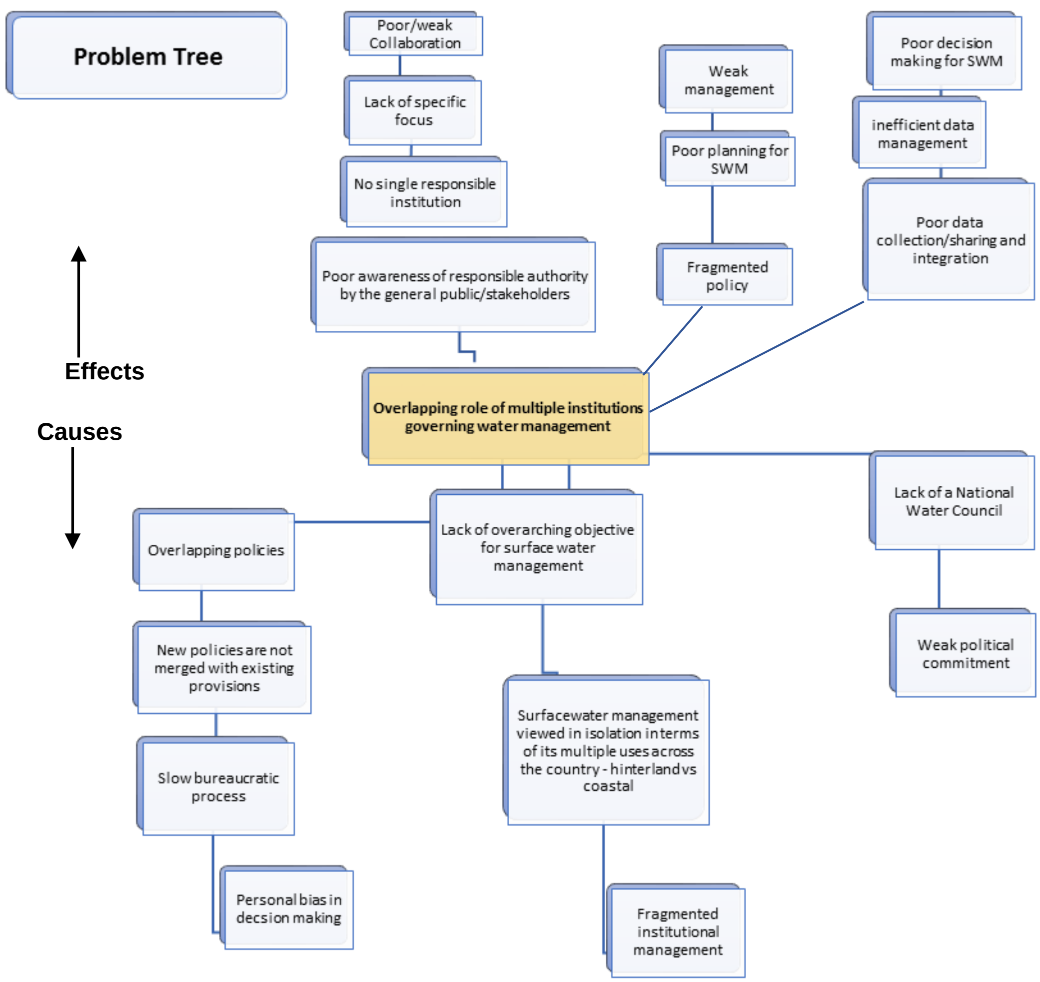


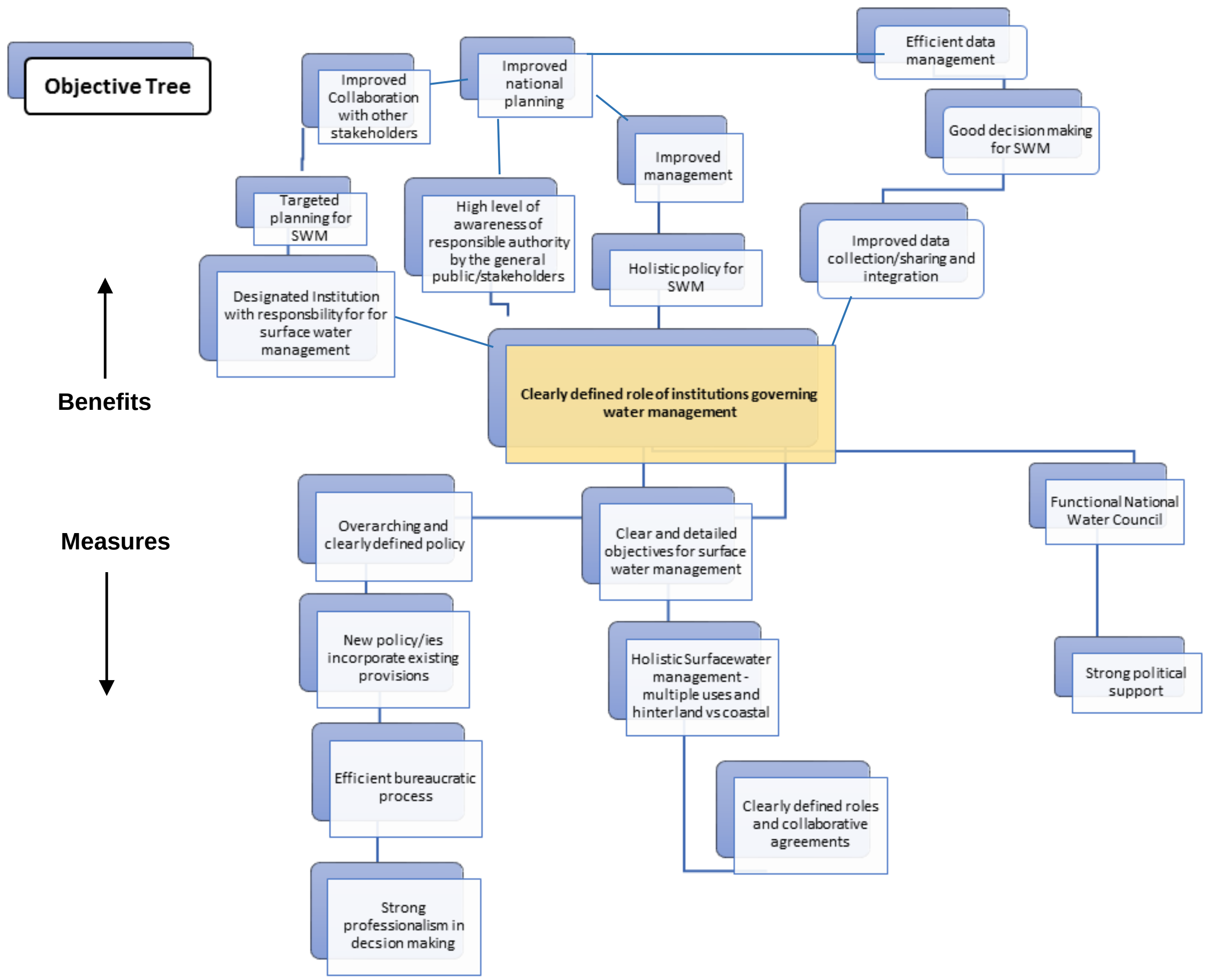
Objective Tree



Technology (ii): Surface Water Mapping and Modeling

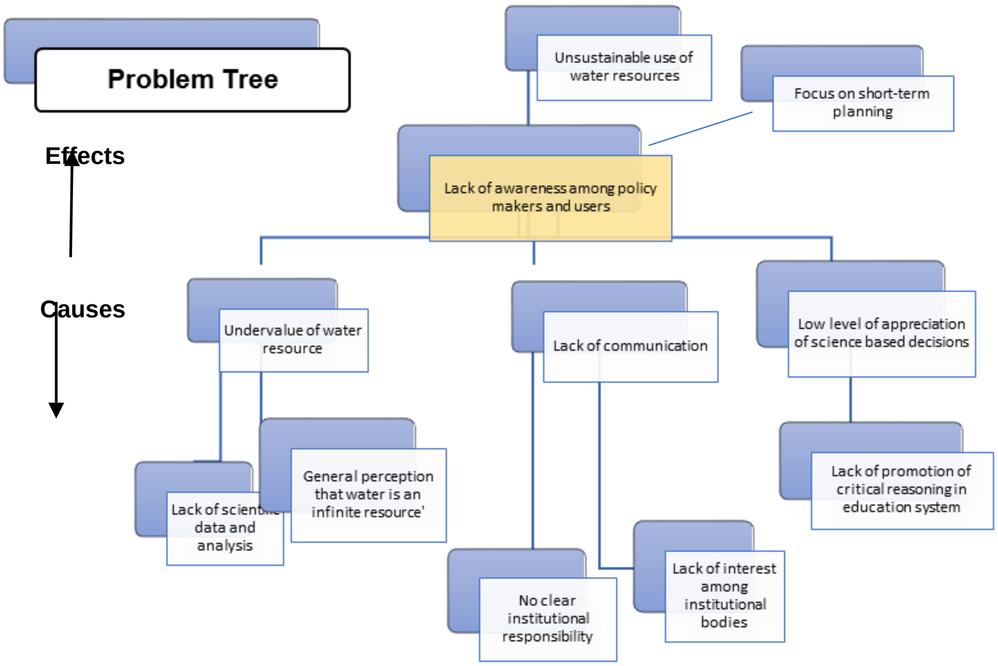
Barrier: Overlapping role of multiple institutions

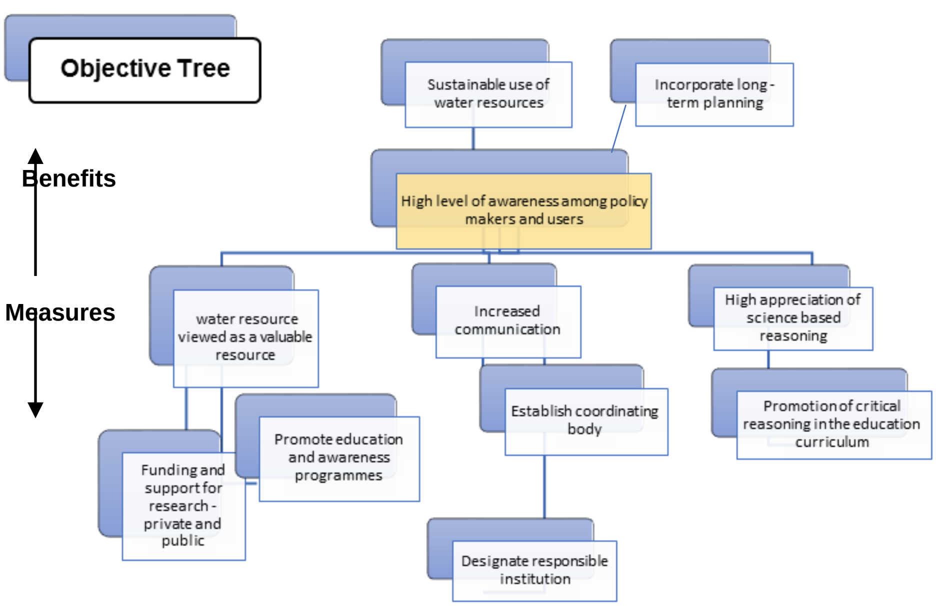



Objective Tree
Benefits
Measures
Improved Collaboration with other stakeholders
Improved national planning
Efficient data management
Good decision making for SWM
Improved management
Targeted planning for SWM
High level of awareness of responsible authority by the general public/stakeholders
Holistic policy for SWM
Improved data collection/sharing and integration
Designated Institution with responsbility for for surface water management
Clearly defined role of institutions governing water management
Overarching and clearly defined policy
Clear and detailed objectives for surface water management
Functional National Water Council
New policy/ies incorporate existing provisions
Holistic Surfacewater management - multiple uses and hinterland vs coastal
Strong political support
Efficient bureaucratic process
Clearly defined roles and collaborative agreements
Strong professionalism in decsion making

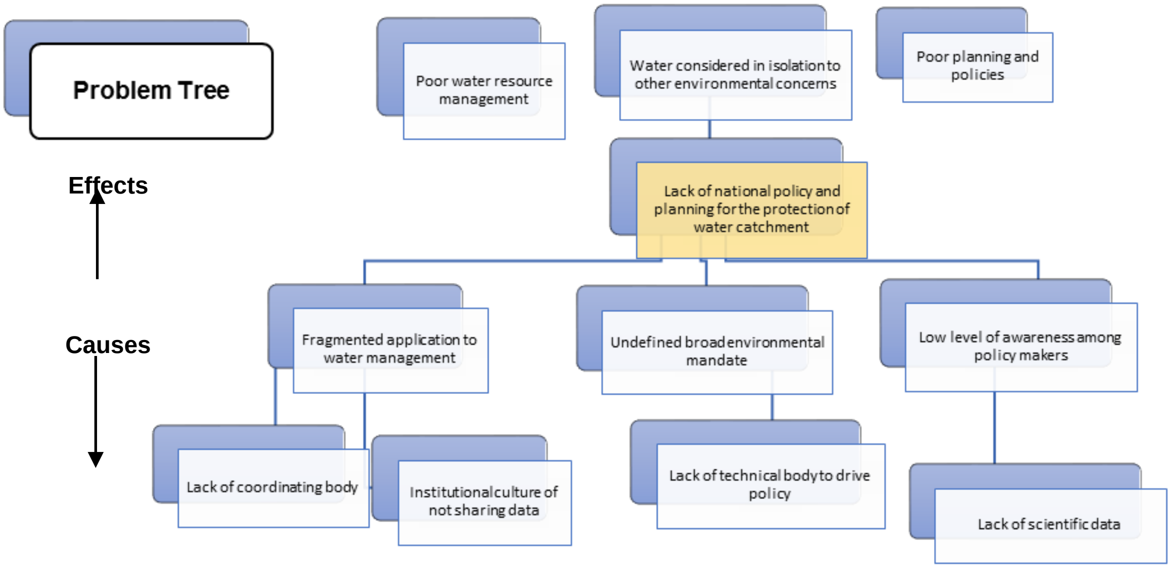
Technology (iii): GIS Mapping and Modeling for Water Catchment Protection

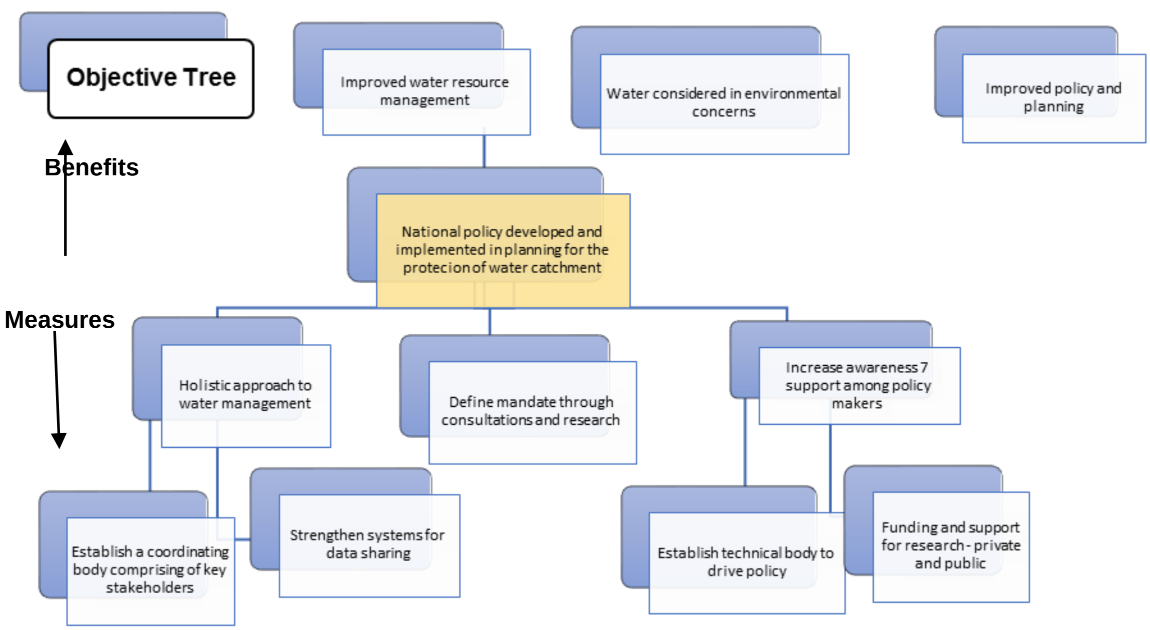
Barrier # 1: Lack of awareness among policy makers and users





Barrier #2: Lack of national policy and planning

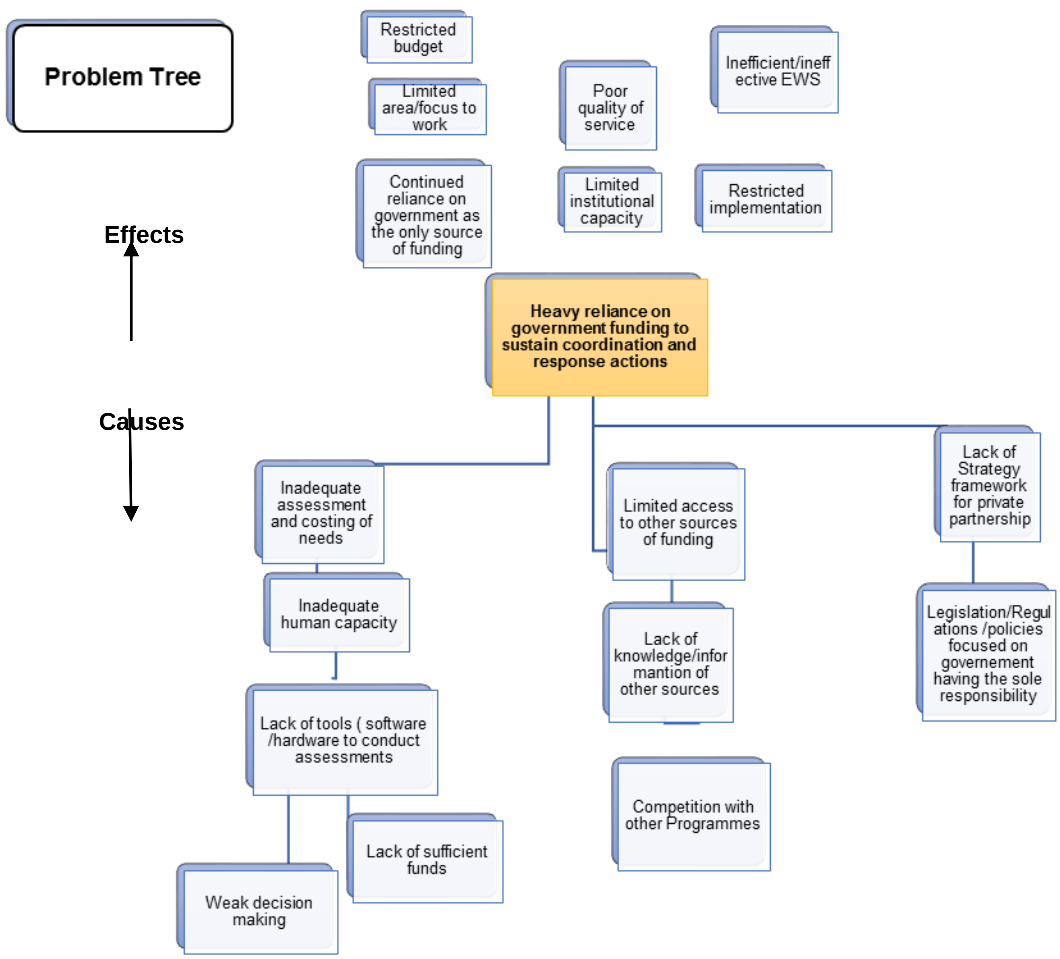


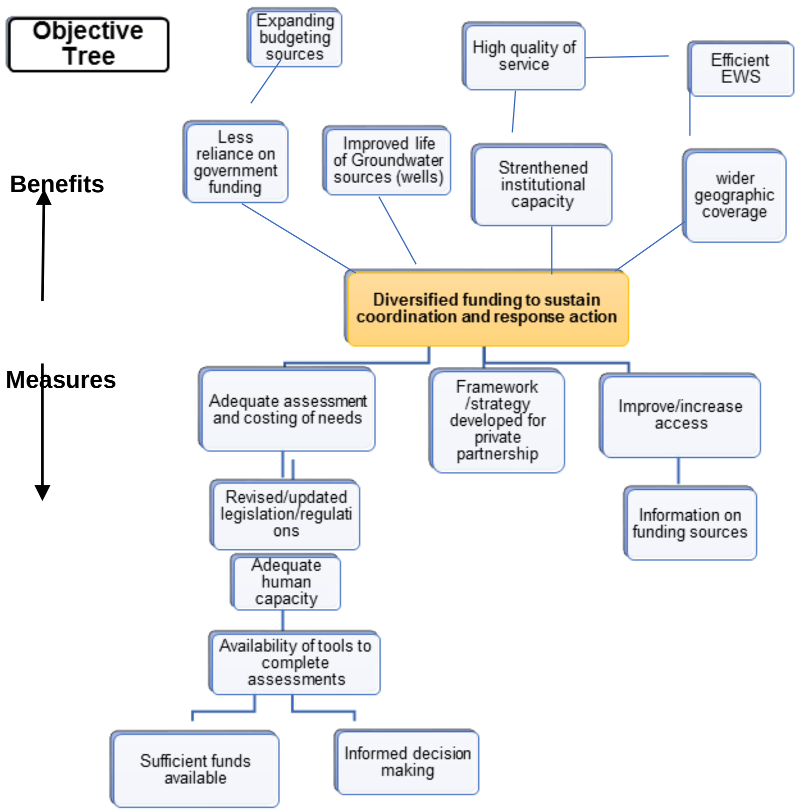


Appendix I (C): Logical Problem and Solution Trees – Coastal Zone and Low-Lying Communities

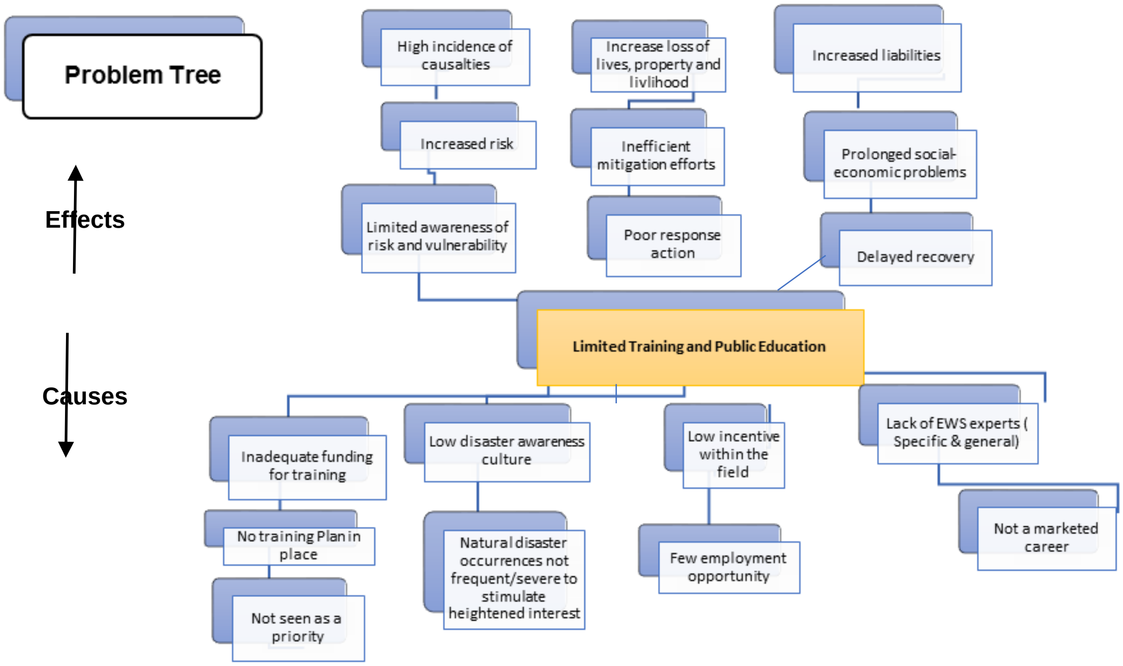
Technology (i): Early Warning System for Flood and Drought

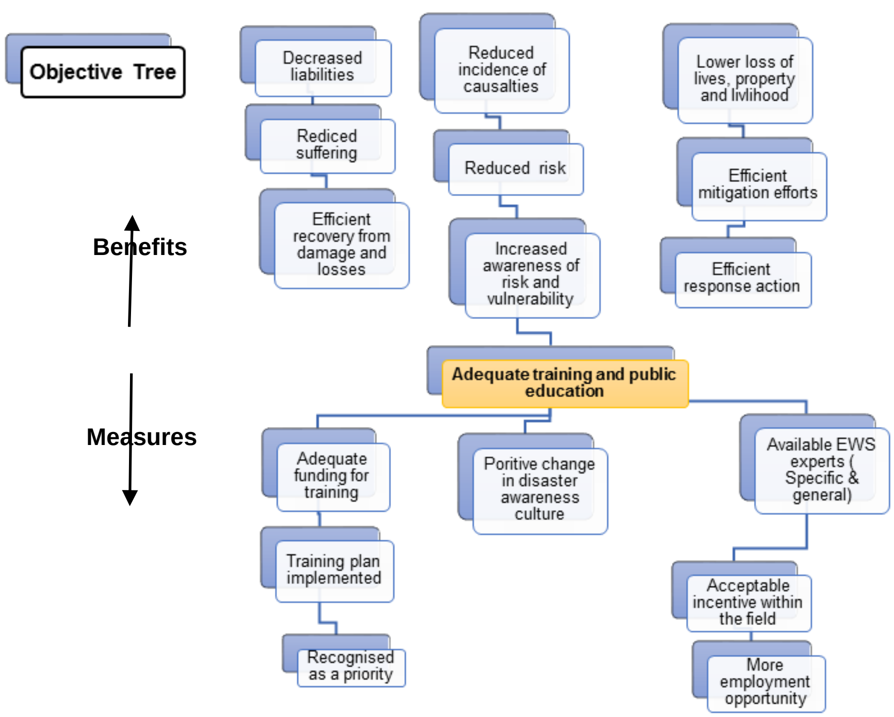
Barrier #1: Reliance on government funding to sustain coordination and response action




Objective Tree
Expanding budgeting sources
High quality of service
Efficient EWS
Benefits
Less reliance on government funding
Improved life of Groundwater sources (wells)
Strenthened institutional capacity
wider geographic coverage
Diversified funding to sustain coordination and response action
Measures
Adequate assessment and costing of needs
Framework /strategy developed for private partnership
Improve/increase access
Revised/updated legislation/regulati ons
Information on funding sources
Adequate human capacity
Availability of tools to complete assessments
Sufficient funds available
Informed decision making

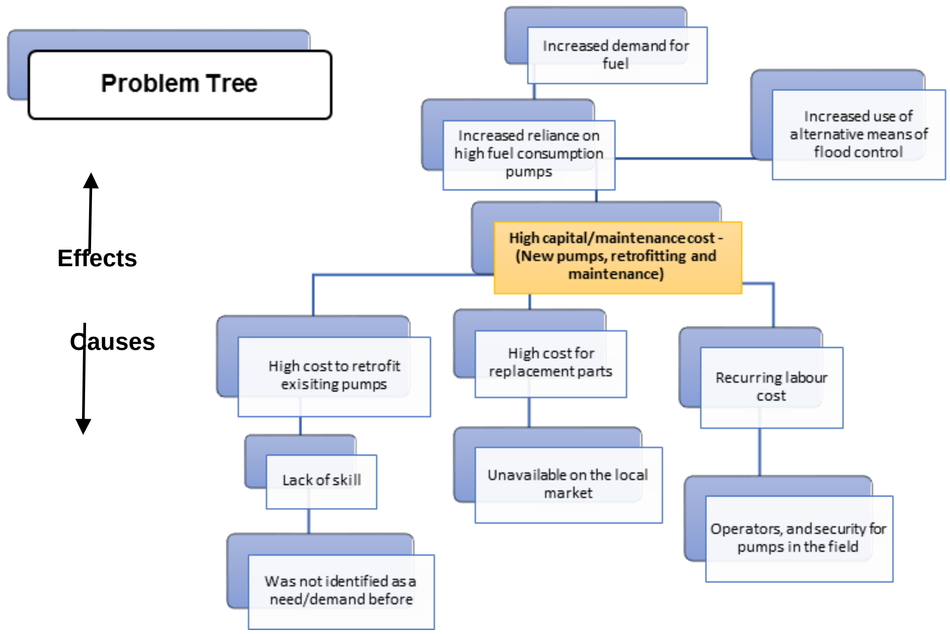
Barrier # 2: Limited Training and Public Education

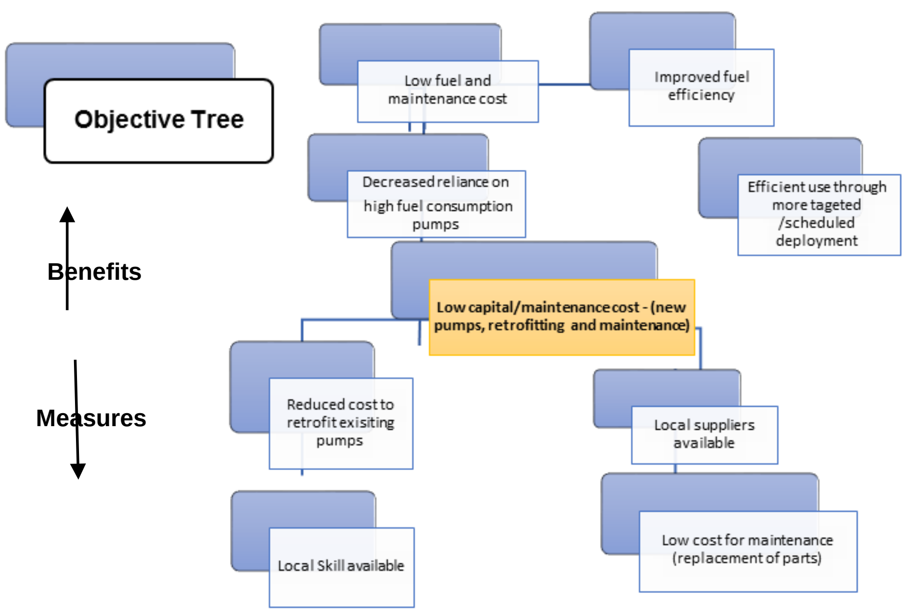




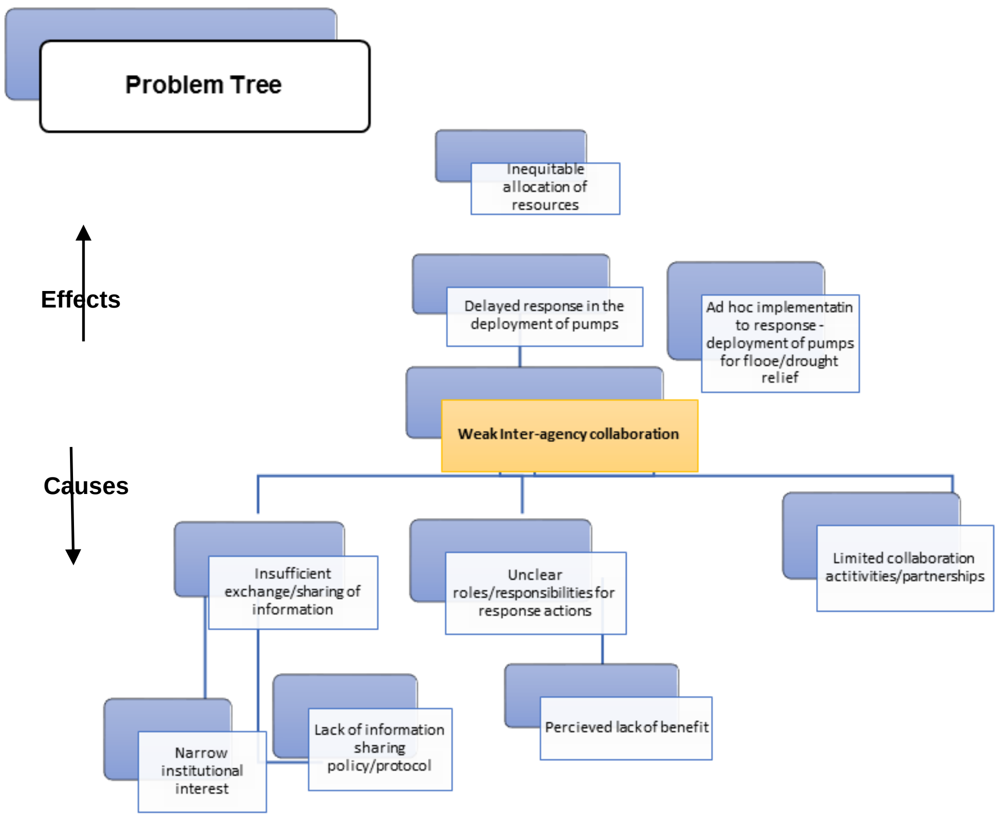
Technology (ii): Energy Efficient Mobile Pumps for Flood Control

Barrier 1: High capital/maintenance cost (new pumps, retrofitting and maintenance)



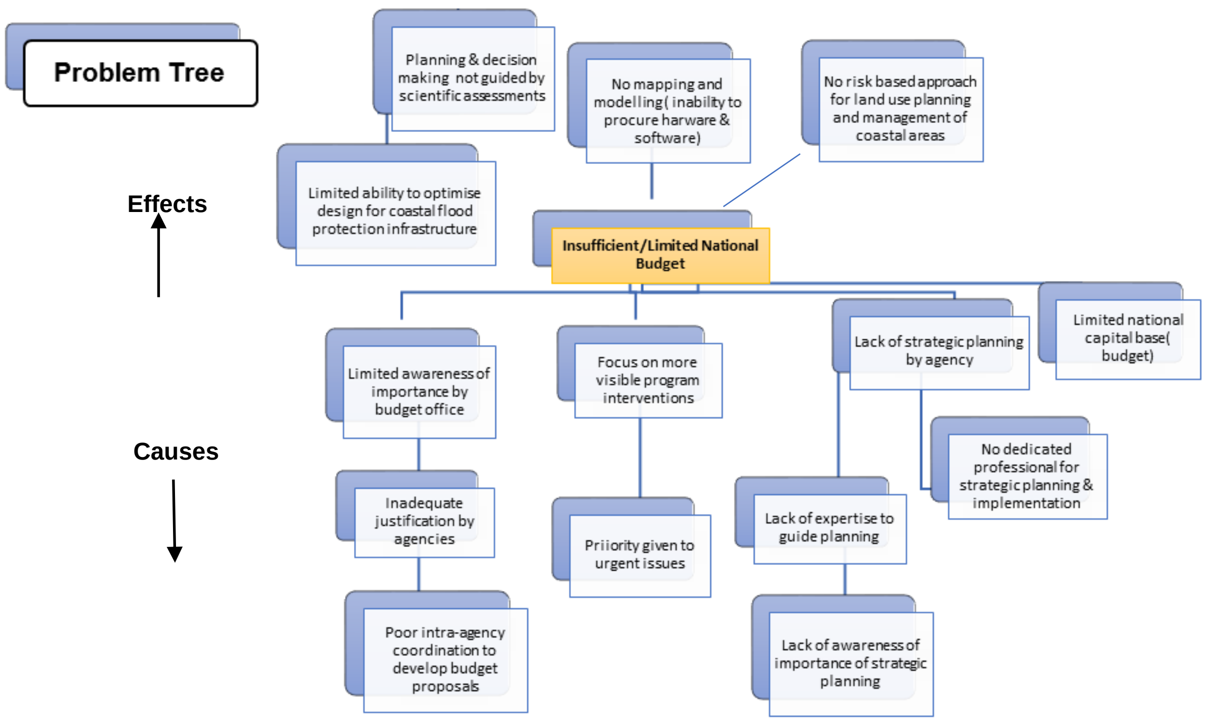


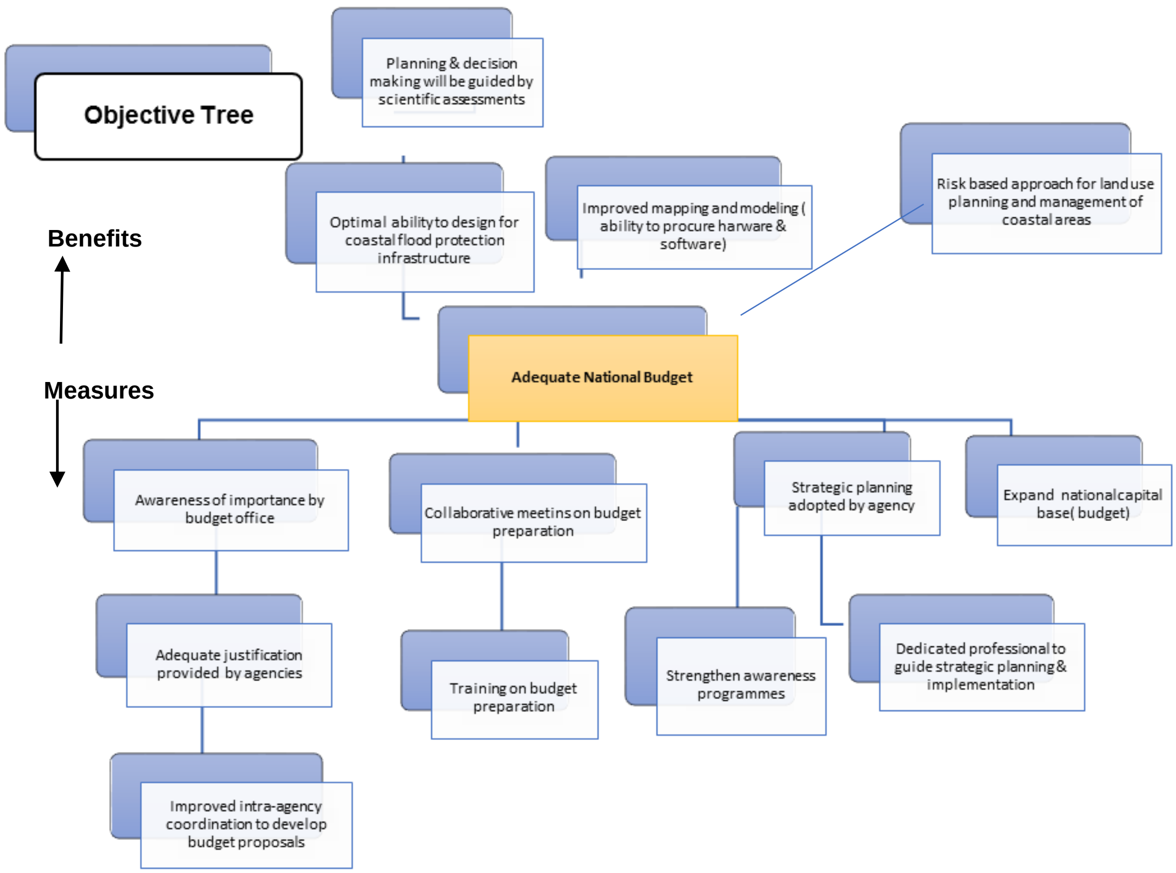
Barrier 2: Weak Inter-agency collaboration



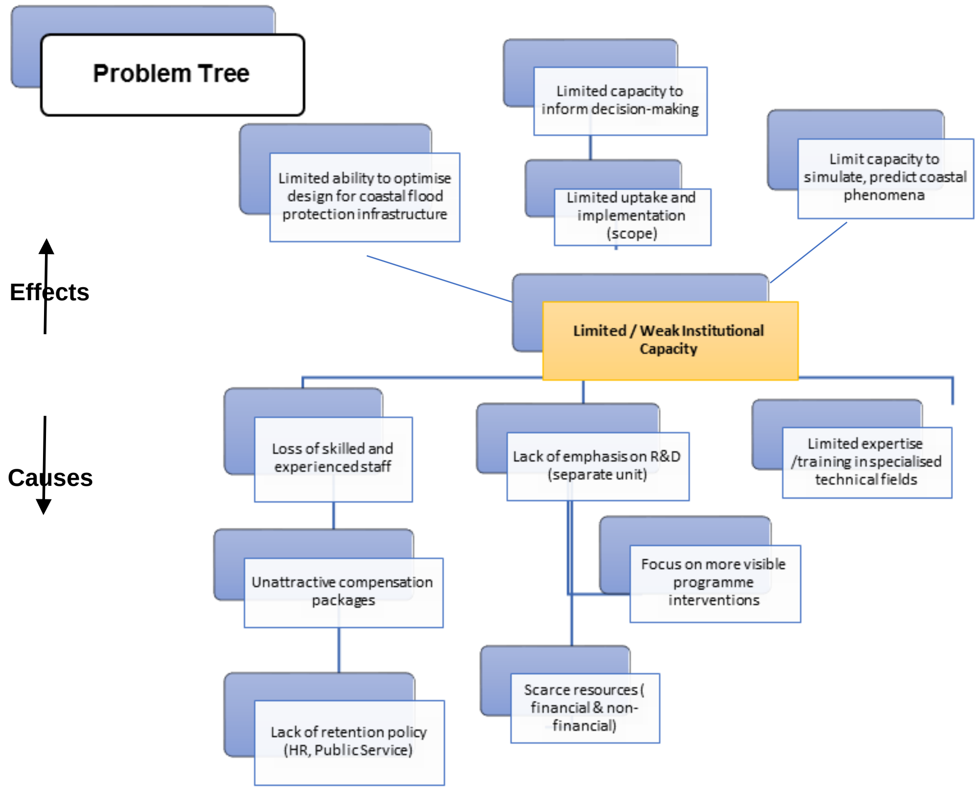
Technology (iii): Mapping & Modeling of Coastal Processes for construction of seawalls & groynes

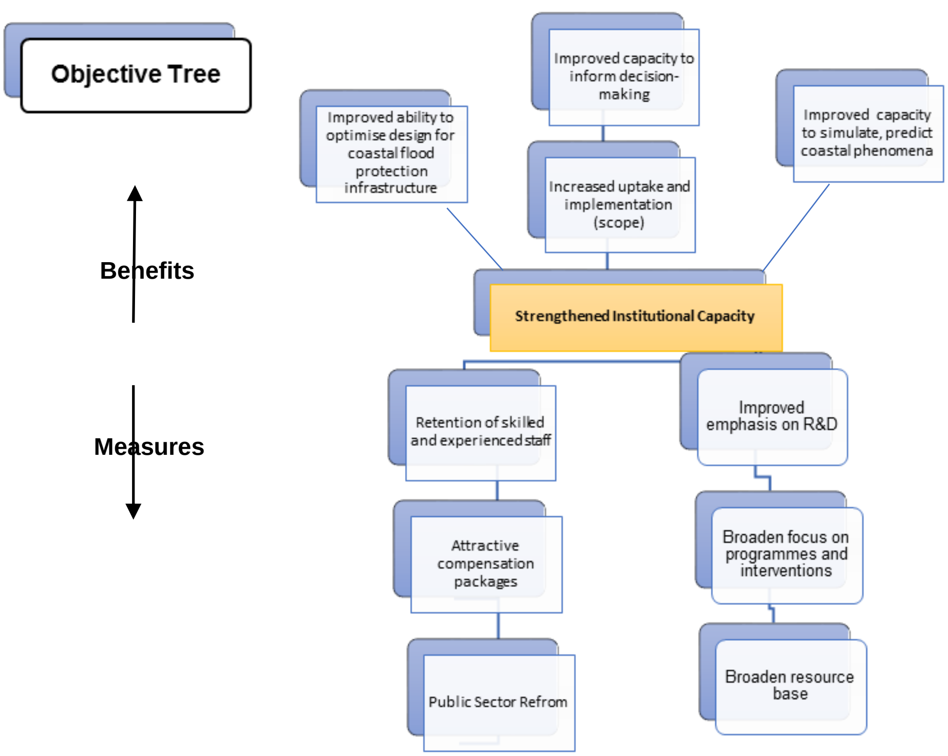
Barrier # 1: Insufficient/Limited National Budget Allocation




Objective Tree
Benefits
Measures
Planning & decision making will be guided by scientific assessments
Optimal ability to design for coastal flood protection infrastructure
Improved mapping and modeling (ability to procure harware & software)
Risk based approach for land use planning and management of coastal areas
Adequate National Budget
Awareness of importance by budget office
Collaborative meetins on budget preparation
Strategic planning adopted by agency
Expand national capital base(budget)
Adequate justification provided by agencies
Training on budget preparation
Strengthen awareness programmes
Dedicated professional to guide strategic planning & implementation
Improved intra-agency coordination to develop budget proposals

Barrier # 2: Limited/Weak Institutional Capacity





Appendix II (a): List of Participants – Agriculture Sector

No.	Name	Designation	Organisation	Email	Phone number
1	Angela Alleyne	Assistant Representative	UN Food and Agriculture Organisation	Angela.alleyne@fao.org	227-3149
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3	Arnold DeMendonca	Sustainable Rural Development	Inter-American Institute for Cooperation on Agriculture	arnold.demendonca@iica.int	226-8835
4	Arthur Johnson	Vice-Chairman	West Watooka Farmers		607-4034
5	Camille Adams	Senior Environment Officer	Environment Protection Agency	caadamsepagy@gmail.com	225-0506
6	Charles Griffith	Research Scientist – Consultant	Ministry of the Presidency	grienter@aol.com	617-0025
7	Chitranjan Jaikissoon	Supervisor	Mahaica Mahaicony Abary	chitranjan.jaikissoon@gmail.com	616-8508
8	Coretta Samuels	Research Centre	University of Guyana	nathicasam006@gmail.com	649-0063
9	Kuldip Ragnauth	Extension Manager	Guyana Rice Development Board		600-8983
10	Komalchand Dhiram	Telecom Engineer	Hydromet Service, MoA	Kdhiram2015@gmail.com	225-9303
11	Lucina Singh	Science and Technology Officer	Ministry of the Presidency	Singh.lucina@gmail.com	
12	Lall Piterahdane	Engineer	National Drainage and Irrigation Authority		641-8357
13	Orin Brown	Water Resource Manager	Guyana Water Incorporated		699-0380
14	Oscar Glasgow	Director	Guyana School of Agriculture	oscarglasgow@hotmail.com	600-0152
15	Rigby Davis	Chairman	West Watooka Farmers		444-8924
16	Rohini Kerrett	Project Manager	Office of Climate Change	projectmanagerocc@gmail.com	226 6037
17	Savion Paddy	Engineer	Mahaica Mahaicony Abary	Savior.Paddy@gmail.com	678-6311
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Appendix II (b): List of Participants – Water Sector

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Appendix II (c): List of Participants - Coastal Zone and Low-Lying Communities

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