Republic of Seychelles

BARRIER ANALYSIS & ENABLING FRAMEWORK REPORT – ADAPTATION

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SEYCHELLES BARRIER ANALYSIS & ENABLING FRAMEWORK REPORT – ADAPTATION

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List of Acronyms

CC	Climate Change
DECC	Department of Energy and Climate Change
DRDM	Department of Risk and Disaster Management
DWSP	Drinking Water Safety Plan
EBA	Ecosystem Based Adaptation
EIA	Environmental Impact Assessment
ENSO	El Niño Southern Oscillation
EPA	Environment Protection Act
GCCA+	Global Climate Change Alliance
GCM	Global Circulation Model
GEF	Global Environment Facility
GIS	Geographic Information System
INDC	Intended Nationally Determined Communication
IRBM	Integrated River Basin Management
IWRM	integrated Water Resources Management
JICA	Japan International Cooperation Agency
LIDAR	Light Imaging, Detection, And Ranging
LWMA	Landscape Waste Management Agency
MCA	Multi Criteria Analysis
MCSS	Marine Conservation Society of Seychelles
MEECC	Ministry of Environment, Energy and Climate Change
Ml	Million litres
MLUH	Ministry of Land Use and Habitat
NCCC	National Climate Change Committee
NCCS	National Climate Change Strategy
NDRMP	National Disaster Risk Management Policy
NGO	Non-Government Organisation
NISTI	National Institute of Science, Technology and Innovation
NRW	Non-Revenue Water
PCU	Project Coordinating Unit
PSC	Project Steering Committee
PUC	Public Utilities Corporation
RCP	Representative Concentration Pathway
RWH	Rainwater Harvesting
SCCF	Special Climate Change Fund
SIDS	Small Island Developing States
SLR	Sea Level Rise
SLTA	Seychelles Land Transport Agency
SMA	Seychelles Meteorological Authority
SNC	Second National Communication
SR	Seychelles Rupee
SSDS	Seychelles Sustainable Development Strategy
SSP	Seychelles Strategic Plan
TNA	Technology Needs Assessment
TNC	Third National Communication
TWG	Technical or Technology Working Group
UDP	UNEP DTU Partnership
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNISEY	University of Seychelles
US$	United States Dollar

WEAP	Water Evaluation And Planning
WIO	Western Indian Ocean

Executive Summary

With the completion of the TNA Report - Adaptation (Government of Seychelles, 2017), the second phase of the Technology Needs Assessment (TNA) project is to identify barriers hindering the acquisition and diffusion of prioritised technologies and to develop enabling frameworks to overcome the barriers and facilitate the transfer, adoption and diffusion of selected technologies in the Seychelles.

The Seychelles prioritised the water and coastal zone sectors for technical assistance under the TNA project as they are the most vulnerable sectors to the impacts of climate change (Government of Seychelles, 2017). The choice of priority adaptation sectors is also aligned with the Seychelles Nationally Determined Contributions (NDC) that has been submitted to the UNFCCC (Government of Seychelles, 2015a).

In this report, barriers hindering the acquisition and diffusion of prioritised adaptation technologies for the water and coastal zone sector have been identified, and measures to overcome the barriers and facilitate the transfer, adoption and diffusion of these technologies are elaborated. To facilitate the identification of barriers, logical problem analysis (LPA) was used to identify the root causes of the main barriers that hinder the implementation of each adaptation technology. Using a Problem Tree (PT), the main barriers were decomposed to identify the root causes of barriers, and an Objective Tree (OT) that mirrors the PT was developed to identify possible measures to overcome the root causes. The transfer and diffusion of the adaptation technologies is substantiated using cost-benefit analysis (CBA). Further, the enabling environments that will support the reduction or elimination of barriers confronting each technology are discussed.

<u>Summary for water sector</u>

Based on the technology prioritisation that has been carried out (Government of Seychelles, 2017), three technologies were analysed. The penetration levels of adaptation technologies in the water sector were defined by stakeholders and the targets were used to inform technology prioritisation in the TNA Report - Adaptation (Government of Seychelles, 2017). The targets that have been established for the adaptation technologies are:

1. **Rooftop rainwater harvesting (RWH) system at the residential level:** The project target is to install 500 liters system in 90% of the household amounting to 25,000 households over a period of 5 years, starting in 2020;
2. **Ground surface rainwater harvesting for the farming community on Mahé, Praslin and La Digue:** 50 water storage facilities with a capacity of 25,000 m^3 each will be built over a period of 10 years to provide water resources for farmers especially during periods of drought. Implementation is expected to start in 2020; and
3. **Water efficient appliances at the residential level:** The project target is to equip 90% of the household amounting to 25,000 households over a period of 5 years; starting in 2020 with dual flush toilets, water-efficient shower heads and efficient washing machine.

The adaptation technologies in the water sector faced similar barriers, including:

- Economic and financial barriers;
- Institutional, legal and policy barriers;

- Market imperfections;
- Technical barriers; and
- Lack of Information and Awareness.

The water sector adaptation technologies can be classified as consumer goods, which can be deployed at multiple sites and which can be supplied through existing market chains. The main measure to promote these technologies is through the provision of financial and economic incentives to catalyse the market, together with the necessary knowledge of the benefits of the technologies. The main measures that have been proposed are summarised in **Table 1**.

Table 1. Summary of main measures proposed for adaptation technologies in the water sector.

Barriers	Measures
Economic and financial	*Rooftop rainwater harvesting (RWH)* - Establish a subsidised loan scheme with an interest of 5% for households and Small and Medium Enterprises. The Government provides an interest rate subsidy by paying the difference between the interest paid by the client and the average prime lending rates of banks which is currently around 10%. The period of loan repayment will be a maximum of 5 year and only installation and capital costs will be eligible; - Exempting components of RWH system from VAT. *Ground surface water harvesting (GWH)* - The fiscal framework (Business Tax Act and Value Added Tax Act) for the agriculture sector is revised to ensure that GWH technology can be financed under the existing subsided loan scheme for the agriculture sector, and that the technology (and its components) is exempted from VAT (15%) to reduce capital and installation costs
Institutional, policy and legal framework (*the measures are also supportive of rooftop RWH*)	*Ground surface rainwater harvesting (GWH)* - The institutional, policy and regulatory framework for water management is revised to ensure that water rights are clearly defined for promoting efficient, equitable and sustainable use of water resources across all sectors of the economy, and in particular the agriculture sector; - In order to make GWH systems financially competitive, water tariffs solutions for the agriculture sector should be explored *Water efficient appliances* - The development of a National IWRM Plan and Water Use Efficiency, National Water Policy and the formulation of a National IWRM Indicator Monitoring Framework for Seychelles water sector; - Institutional framework for water is strengthened with the establishment of an overreaching national water institution with water committees at the district level for promoting IWRM; - Building code regulations should be revised to include

	regulations/guidelines related to water efficiency for new real estate development; - A standard and a labeling system could be introduced to ensure the quality of water efficiency imported and certified the volume of water saved by the water efficient appliances.
Market (also covers Information and awareness)	*Rooftop rainwater harvesting* - Demonstration projects are established in each district in collaboration with importers and local manufacturers to showcase the different RWH technologies (and the different components of a RWH system), demonstrate and benchmark results, and to create market linkages between suppliers and potential users of rooftop RWH systems.
Information and awareness	*Water efficient appliances* - Setting up a website or webpages within another website with basic information about water efficiency, technical information on water efficiency technologies available, information on water efficiency standards and labelling system and contact details for local suppliers of water efficient fixtures; - Writing and publishing a series of articles about water efficiency for local newspapers; - Creating and broadcasting an animated TV spot introducing water efficiency and its benefits; and - Holding exhibitions of water efficiency devices in districts. *Ground surface water harvesting* A national education and awareness campaign strategy is designed and implemented to increase awareness on climate change issues related to agriculture
Technical	*Ground surface water harvesting* - A data collection system on hydrology and geomorphology of rivers is established to support IWRM planning and decision-making; and - National capacity in water management and water engineering is strengthened by integrating modules on sustainable water management practices and water engineering in the environmental degree proposed at the University of Seychelles.

Source: TNA project

The benefit-cost ratio (BCR) of the three adaptation technologies are summarised in **Table 2**. In all cases, the benefits of the proposed measures outweigh their cost of implementation, implying that the proposed measures are economically attractive. It is pointed out that the CBA was carried out using incremental reasoning – that is to estimate the incremental benefits and costs of an adaptation technology relative to a baseline alternative (i.e. the technology that would have been adopted in the absence of the TNA project).

Table 2. Values of BCR for adaptation technologies in the water sector.

Technology	BCR
Rooftop rainwater harvesting (residential)	4

Ground surface rainwater harvesting	14.8
Water efficient fixtures (residential)	5

Source: TNA project

The similar barriers that the technologies face, coupled with the fact that they have similar market and supply chain characteristics implies that there are several synergies that may be had across all the adaptation technologies by adopting an integrated approach to designing the intervention measures and putting in place an adequate enabling environment. The main elements of an enabling environment to promote all three adaptation technologies are:

- Establishing an overreaching water institution supporting integrated water management should be established;
- Finalising an integrated water resources management policy framework;
- Updating the agriculture policy to account for climate change adaptation;
- Establishing standards for rooftop rainwater harvesting system and water efficient appliances;
- Revising building codes to integrate regulations/guidelines related to rooftop rainwater harvesting, adoption of water efficiency devices, and ground surface rainwater harvesting;
- Revising water rights to promote efficient, equitable and sustainable use of water resources across all sectors of the economy;
- Introducing a labelling system for water efficiency appliances;
- Developing regulations of the value Added Tax Act (2010) to ensure that the capital and installation costs of adaptation technologies are exempt of VAT; and
- Revising existing subsidies and loans schemes to cover adaptation technologies.

<u>Summary for the coastal zones</u>

There are no official targets for the transfer and diffusion of adaptation technologies for the coastal zones. Targets for technology diffusion have been set using the expert knowledge of stakeholders and guided by the objectives of the Nationally Determined Contribution (Government of Seychelles, 2015a):

1. **Coastal Mapping and Monitoring** on all three main islands (Mahé, Praslin and La Digue) with a special emphasis on hotspots (Table 14) that are already suffering from erosion and flooding, putting public and private critical infrastructure at risk. The mapping and monitoring will cover a total of 200 km of coastal line. This will include bathymetry, studies of coastal processes including sand movement (i.e. near-shore dynamics), waves and currents, and sea level rise (SLR). High resolution satellite imagery will be required to carry out these analyses as well as ground truthing. This technology will also include housing the data, and processing it using mapping techniques, in a centralised location where the information can be made readily available to planners and developers undertaking coastal restoration and/or physical development work in the coastal zone;
2. **Wetland restoration:** A total of 10 sites are expected to be restored over a period of 15 years. The sites are: Baie Ste Anne village; Grand Anse village; Anse Kerlan; Nouvelles Decouvertes; Anse St. Saveur – Anse Takamaka; Au Cap Wetlands; Anse Gouvernement; Cap Samy; Cote D'Or; and
3. **Integrated coastal rehabilitation (with dune restoration and coral reef rehabilitation):** It is recommended that the hot spot sites (Cote D'Or, Praslin Grand Anse, Praslin Beau Vallon, Mahé) be also included for dune rehabilitation work as these sites are already experiencing

some erosion, no major projects are underway at these sites, and they are highly vulnerable to sea level rise due to tourism developments in the area. Coral reef rehabilitation is proposed at Baie Lazare over an area of 10 ha.

LPA has shown that the common barriers hampering the uptake of coastal adaptation technologies were:

- Economic and financial barriers;
- Policy barriers;
- Institutional and coordination barriers;
- Information and awareness barriers; and
- Human capacity barriers;

The barriers faced by wetland restoration and integrated coastal rehabilitation (dune restoration and coral reef rehabilitation) are similar. Coastal mapping and monitoring is supportive of the other two soft coastal adaptation technologies. The similar barriers faced by the coastal adaptation technologies also stems from the fact that they are all public goods for which there are no markets. The main champion of the coastal adaptation technologies will be the government.

The main measures that have been proposed to promote the coastal adaptation technologies are summarised in **Table 3**.

Table 3. Summary of main measures proposed for land transport adaptation technologies.

Barriers	Measures
Economic and financial	*Coastal mapping and monitoring* - apply for grant funding from the Green Climate Fund (GCF) to support initial investment into equipment needed. A GCF project proposal focused on climate change adaptation on the coastal zone has already been initiated and can integrate the recommendations from the TNA process. *Wetland and dune restoration* - explore financial incentives such as grants schemes, CSR or other tax breaks for businesses / hotels to pay for conservation and restoration of coastal wetlands on their property; - government to acquire such properties at fair compensation to the owners, in order to set them aside for the public good.
Institutional and stakeholder coordination	*All technologies* - one institution is designated to act as a hub for planning and action, and a clearinghouse for the sharing of information. Needs capacity development of the Ministry of Environment, Energy and Climate Change, based in the Coastal Adaptation and Management Section (CAMS).
Policy and legal reform	*Coastal mapping and monitoring* - Revising the EPA in order to mandate sharing of data and reports generated by non-state actors with the national authority designated as the hub; and

Barriers	Measures
	- Revising the Town and Country Planning Act with respect to planning and/or building permit approval requiring scientific evidence that proposed developments on the coast and coastal protection measures will not have a negative impact on the coast, and that the measures are suitable for long-term protection. *Wetland and dune restoration* - Providing support for the strengthening of the Environment Protection Act (wetland policy) and its enforcement in terms of protection and rehabilitation of dune vegetation (wetlands), and favouring EBA methods for coastal protection along beaches. - Using EBA as a catalyst for new policy measures that adopt a multi-sectoral holistic approach and synergise with ongoing Integrated Coastal Zone Management (ICZM) initiatives (UNEP, 2010, 2016) and the soon to be revised National Climate Change Strategy; and - Enact the existing planning guideline for construction set back at 25m or greater (upgrade from its current status as planning guideline to law).
Human capacity	*All technologies (integrated approach to coastal adaptation)* - Allocate government funding for staffing and other operational costs to coordinate mapping and monitoring of coastal processes on a national basis with all of the stakeholders - Employing at least one full time person to coordinate data management related to coastal processes and coordinate regular liaison and data sharing with all relevant stakeholders; - Providing opportunities for student internships in government institutions and private sector organisations undertaking studies of coastal processes; - Enhancing UniSey environmental science and IT curricula related to GIS, mapping, data management, modeling, etc.; - Providing opportunities for Seychellois experts to work alongside international consultants undertaking studies of coastal processes at equivalent and fair pay rates; and - Developing partnerships with overseas universities and research institutions engaged in data collection, mapping, monitoring and modeling related to coastal processes; - Outsourcing ecosystem restoration projects to local consultants, companies and NGOs where capacity exists; - Enhancing coastal mapping, modeling and monitoring through their integration into coastal EBA restoration projects.
Information and awareness	*All technologies (integrated approach to coastal adaptation)* - Training sessions specifically targeting policy makers and planners to help them understand the impacts of climate change, and the benefits of EBA approaches to protecting the coast, in comparison with hard engineering approaches;

Barriers	Measures
	- There is a need to do an inventory of the national curriculum to see where and how climate change adaptation, including EBA, can be integrated into core programs. This kind of learning must be complimented by opportunities for students and teachers to be engaged in real-life wetland restoration projects to protect the coast; - Schools as well as communities and local businesses are key stakeholders in EBA projects and the process by which they are consulted and invited to participate is essentially an opportunity to learn wetland restoration by doing it; - Media coverage and the creation of documentaries that can be shared through television and/or the web are also important tools for awareness raising that can be implemented alongside physical restoration works to enhance the public's understanding of how wetlands, dunes and coral reef are natural adaptation technologies; - Developing media campaigns for the general public in order to promote greater understanding of climate change impacts on coastal areas, and how coastal ecosystems can help protect the coast; - Developing posters and other teaching resources for schools and communities to promote greater understanding of coastal ecosystems; - Developing and implementing a training program targeting decision-makers to help them understand ecosystem-based approaches to protecting the coast; and - Offering site visits and open days to pilot project sites using coastal ecosystem-based restoration.
Science and Technology education	*All technologies* - Building capacity in the National Institute of Science, Technology and Innovation (NISTI) to further develop STEM (science, technology, engineering and math) education in schools at all levels; - Developing and disseminating support materials and conduct teacher training to enhance climate change education in the curriculum, particularly in the science and geography programs for secondary and post-secondary schools; and - Developing media programs to make climate science understandable and relevant to the general public

Source: TNA project

The benefit-cost ratio (BCR) of the coastal adaptation technologies are summarised in **Table 4**, revealing that the benefits of the proposed measures outweigh their cost of implementation. Coastal mapping and monitoring is an exception since its benefits only accrue when implemented in conjunction with other soft and hard coastal adaption technologies. The BCR for the other two technologies have been estimated assuming there will be no residual damage following their implementation. Equations have been provided to calculate their BCR while accounting for any residual damage. The estimation of residual damage in the case of extreme coastal events was outside the scope of the TNA project.

Table 4. Values of BCR for coastal adaptation technologies.

Technology	BCR
Coastal Mapping and Monitoring	Not applicable. the calculation of BCR for coastal mapping and monitoring should be carried out in conjunction with the implementation of other coastal adaptation technologies
Wetland restoration	11.5
Integrated Coastal Rehabilitation, including dune restoration and coral reef rehabilitation	16.9

Source: TNA project

The enabling framework for the coastal zone sector should include the following:

- Financing: The present government budgetary support for soft engineering coastal protection measures needs to be enhanced;
- Ease of access to information about coastal processes: The availability of information over the long term is a critical enabling factor for the success of all coastal ecosystem based adaptation (EBA) measures. The existing GIS unit at the MEECC should be capacitated for the coordination of information gathering, storage, analysis and dissemination;
- Institutional set up: There is a need to improve the current institutional set up to enable better dissemination and use of all three technologies. There is an opportunity under the proposed Climate Change Strategy revision (through the EU-funded GCCA+ project) to make provision for improvements to the current institutional set up for climate adaptation in the coastal zone. The Coastal Adaptation and Management Section (CAMS) of the MEECC would be the focus for improving this enabling factor;
- Partnerships and coordination: Integrated Coastal Zone Management (ICZM) is not new to Seychelles and has itself been integrated into some national plans and policies such as the SSDS (2011-2020). Engaging with multiple stakeholders is an absolutely essential component of ICZM and as can be seen from each of the technologies discussed above, having a system and process for coordinating between multiple stakeholders and project partners is critical to their success;
- Policy and legislation: The National Climate Change Strategy is Seychelles policy regarding climate change. However, it does not presently have any clout. With the upcoming revision mentioned earlier, there is an opportunity to ensure that climate change adaptation is sufficiently integrated into existing laws and policies, with special attention paid to EBA methods. Enforcement of existing laws protecting the coast falls under the mandate of the Coastal Adaptation Unit. There is a need to increase their capacity for undertaking this enforcement work, and to engage with other law enforcement partners including the Police and the Tourism Police for support.
- Technical expertise: With the University of Seychelles already offering courses on coastal management, there is an opportunity to increase the number of people in Seychelles who can be involved in coastal studies and protection / restoration projects. Helping UniSey to exploring partnerships and collaboration with overseas Universities and other research institutions will give Seychellois opportunities to improve their knowledge and skills, and potentially pursue post-graduate studies in the sector.

Chapter 1 Water Sector

The Seychelles prioritised the water sector for technical assistance under the Technology Needs Assessment (TNA) project as it is one of the most vulnerable sectors to climate change in Seychelles (Government of Seychelles, 2017). The choice of this sector is also aligned with the Seychelles Nationally Determined Contributions (NDC) that has been submitted to the UNFCCC (Government of Seychelles, 2015a). Three technologies were prioritised for further analysis during the first stage of the TNA project (Government of Seychelles, 2017):

1. **Rooftop rainwater harvesting with water treatment and safe storage:** This climate change adaptation technology is based on encouraging each household to have a rainwater harvesting system with appropriate water treatment and water storage which is currently not commonly used in the Seychelles with only 4.7 % of household equipped. This technology is a priority because it has good prospects for scaling up and can contribute significantly to reduce climate vulnerability at the household level primarily by diversifying household water supply; and by increasing resilience to water quality degradation;
2. **Water efficient appliances:** The residential sector is the highest end-use sector in Seychelles. Residential water conservation efforts can make a positive contribution to reducing pressure on water resources. However, the market penetration of water-efficient appliances is limited. Encouraging each household to have water efficient devices with the appropriate policy framework is a national priority to reduce pressure on water resource and to increase the climate resilience of the population; and
3. **Ground surface rainwater harvesting:** Lack of adequate water supply during drought and seasonal dry periods can have a significant economic impact in the agricultural sector. Ground surface runoff water is important in the Seychelles because of its geology, topography and rainfall patterns. This technology is based on improving storage of surface runoff water by building gabion structures. It is a priority for the agricultural sector to have a constant and regular water supply for agricultural production thereby minimising the impact of climate change on crop and livestock production and improving the food security situation in the Seychelles.

In this chapter, barriers hindering the acquisition and diffusion of prioritised technologies for the water sector are identified and measures to overcome the barriers and facilitate the transfer, adoption and diffusion of these technologies are elaborated. The transfer and diffusion of water adaptation technologies is substantiated using detailed cost-benefit analysis (CBA). Further, the enabling environment that will support the reduction or elimination of barriers confronting each technology is discussed.

1.1 Preliminary targets for technology transfer and diffusion in the water sector

In the Seychelles, rapid surface runoff water is important because of the topography and geomorphology of the main granitic islands. Most of this water is lost to the sea. Seychelles being composed of small islands do not have much space available to build dams and flood large areas. As discussed in the TNA Report - Adaptation (Government of Seychelles, 2017), socio-economic development is expected to increase the demand for fresh water in Seychelles. In this context, the following technology targets are proposed:

1. **Rooftop rainwater harvesting (RWH) system at the residential level:** The project target is to install 500 liters system in 90% of the household amounting to 25,000 households over a period of 5 years, starting in 2020;
2. **Ground surface rainwater harvesting for the farming community on Mahé, Praslin and La Digue:** 50 water storage facilities with a capacity of 25,000 m^3 each will be built over a period of 10 years to provide water resources for farmers especially during periods of drought. Implementation is expected to start in 2020; and
3. **Water efficient appliances at the residential level:** The project target is to equip 90% of the household amounting to 25,000 households over a period of 5 years; starting in 2020 with dual flush toilets, water-efficient shower heads and efficient washing machine.

The penetration levels of adaptation technologies in the water sector were defined by stakeholders and these targets informed the multi-criteria analyses (MCA) that were used for technology prioritisation. More details can be found in the TNA Report – Adaptation (Government of Seychelles, 2017).

1.2 Barrier analysis and enabling measures for rooftop rainwater harvesting (RWH)

1.2.1 General description of RWH technology

Rooftop RWH is a technology used for collecting and storing rainwater from the roof of buildings, and in this particular case from the roofs of residential buildings. The harvested rainwater is mainly for non-potable use, including:

- Toilet flushing;
- Clothes washing – including washing machines;
- Watering the garden; and
- Washing cars and other outside uses.

Independent trials in Caribbean and South Pacific Islands have shown that a domestic RWH system can reduce significantly mains-water consumption.[1] No trials have been conducted in the Seychelles to ascertain the extent of water supply diversification that rooftop RWH can bring to households.
A rainwater harvesting system consists of three basic components:

1. The collection system;
2. The conveyance system; and
3. The storage system

Examples of rooftop RWH systems are shown in **Figure 1** and **Figure 2** for a multi-storey building and a standalone house in Seychelles, respectively.

[1] Marilyn Waite. (2012) Climate change mitigation and adaptation in small islands state: the case of rainwater harvesting in Jamaica.

Source: Michele Martin, Sustainability for Seychelles, 2016

Figure 1. Typical rooftop rainwater harvesting system in a building with 2 x 500 litre polyethylene rainwater tanks.

Source: Michele Martin, Sustainability for Seychelles, 2016

Figure 2. Typical rainwater harvesting system in household in Seychelles with a 500 litre fiberglass rainwater tank.

Collection system

Simple roof collection systems for residential buildings include the roof catchment area. A census has shown that only 4.5% of households in Seychelles have RWH tanks, while 47.1% of households have a water storage tank (National Bureau of Statistics - NBS, 2012).

Conveyance System

The incoming conveyance system usually includes gutters and downpipes, which deliver the rainwater to a storage tank. Preferably, these should be made of plastic, polyvinyl chloride (PVC) or another inert substance, as the pH of rainwater may cause corrosion of metal pipes.

The outgoing conveyance system may contain a pump and an individual pipe system to the end use or a tap system on the storage tank, depending on the location of the storage system and the end use requirements.

Storage System

Storage tanks can be located above or below ground. Above ground tanks are generally cheaper; water can be extracted by gravity if purposefully raised off the ground; cleaning and maintenance is straightforward, and cracks and leaks can be easily detected. In contrast, below ground tanks save on space.

Storage tanks can be constructed inside or outside the building, or they can be constructed as part of the building. Tanks can be constructed using different materials and can be a variety of sizes and shapes. Typical materials in this regard are reinforced concrete, fibreglass, or polyethylene. Fiberglass and polyethylene are commonly used.

1.2.2 Identification of barriers to deployment of rooftop RWH

Rooftop RWH is classified as a consumer technology as it is intended for the mass market and purchased by private consumers, including households, businesses and institutions. There are a high number of potential consumers as shown by the high number of target beneficiaries in Section 1.1. As is typical of consumer goods, the demand for a RWH system depends on consumer awareness and preferences, and on commercial marketing and promotional efforts.

A market supply chain analysis was carried out and it is shown in **Annex 1** (Market Map for Rainwater Harvesting). The supply chain includes importers of rainwater harvesting system, retailers of fittings, local manufacturers of water tanks, transporters, installers and maintenance contractors, and end users. The diffusion of RWH system requires an enabling environment for the demand-supply chain, and the services and inputs providers to operate efficiently. Such enabling environment should include a RWH policy, RWH standards, building code, financial incentives.

Several categories of barriers were identified in the demand-supply chain as illustrated by the Problem Tree (PT) in **Annex 1**. They are as follow:

- ✓ Economic and financial barriers
- ✓ Institutional, legal and policy barriers
- ✓ Market imperfections
- ✓ Lack of Information and Awareness

These barriers are discussed in more details below.

1.2.2.1 Economic and financial barriers

The cost of a complete RWH system will vary depending on the fittings required for the conveyance system and the storage capacity. For the example of a household of 4 persons, a simple gravity rooftop RWH system with a storage capacity of 500 litres would cost approximately 16,000 SCR[2] as indicated in **Table 5**.

[2] 1 US$ = 13.4 SCR

Table 5. Indicative cost of a gravity rooftop RWH system for a typical household in Seychelles.

Cost elements	Amount SCR
Collection system (gutter ,downpipe, fittings)	5,000
Outgoing Conveyance system(pipe, taps, fittings and overflow pipe)	1,000
Storage system (tanks 500 litres and fittings)	5,000
Filtration system	2,500
Transport and Installation cost	2,500
Total Cost	**16,000 SCR**

Source: TNA project

The mean monthly household income was around SCR 19,000 in 2013 (National Bureau of Statistics, 2013). In the same year, the average monthly household expenditure was SCR 10,899. Because of the relatively high upfront capital cost of a residential RWH system relative to disposable income, investment in RWH has remained a low priority for households. This financial barrier is compounded by a lack of understanding of the tangible benefits of a rooftop RWH system compared to others household spending priorities. Consequently, RWH is not perceived as an attractive investment by households and businesses.

Currently, the government is not providing any financial or economic incentives for promoting RWH, and an unsecured loan from commercial banks attracts a hefty interest rate of 27% per annum (Barclays Bank). A secured loan currently requires a minimum guarantee equivalent to 100 % of the value of the loan, and it typically attracts a minimum of 10% interest rate. There is therefore a lack of cheap capital available to households for purchasing a rooftop RWH system.

The Economic and financial category of barrier was deconvoluted (as shown in **Annex 1**), and the causes have been identified. The following lists the causes of the barrier with the root cause found at the bottom of the list:

- High capital cost of RWH systems;
- RWH is not an investment priority for households, especially in the context of high upfront capital cost;
- Lack of cheap capital available to households (high interest rates for unsecured loans);
- Lack of financial incentives for RWH.

1.2.2.2 Non Financial barriers

The main non-financial barriers identified by stakeholders are institutional, human capacity and technical (see PT in **Annex I**). These are discussed below:

Institutional, legal and policy barriers

Currently, there is no national water policy in the Seychelles to promote efficient, equitable and sustainable use of water resources. The PUC Act is mainly a water services Act (Government of Seychelles, 2017 – Section 4.3.1.2). In this context, there is no policy that promotes rainwater harvesting at the national level. Further, there is no institutional arrangement for supporting integrated water resources management (IWRM), including using rainwater harvesting for diversifying the supply of freshwater. There is also no building code for integrating RWH in building designs.

Standards and regulations related to RWH have not been developed. These are required to legally define the required technical specifications for RWH system (storage, piping, discharge, etc…), and for prescribing any treatment prior to rainwater usage.

The barriers identified in this category can be summarised into:

- No Supportive policy and regulatory instruments;
- There are no national rainwater harvesting standards and regulations;
- There is no overreaching institution for IWRM; and
- Rainwater harvesting is not integrated in building codes.

Market imperfections

There are three main local suppliers of rainwater storage tanks in Seychelles, all operating in the Providence Industrial Estate:

- AquaGlass (Pty) Ltd;
- Souris Glass (Pty) Ltd; and
- City Enterprise (Pty) Ltd.

The suppliers produce fibreglass and polyethylene water tanks of various volumes ranging from 500 litres to 8,000 litres.

There are three main suppliers of plumbing fixtures and fittings that are needed for the installation of rainwater storage tanks and the water supply system. These are:

- WaterMaster (Pty) Ltd in Providence Industrial Estate;
- Bestway Plumbing (Pty) Ltd Providence Industrial Estate; and
- Bodco (Pty) Ltd in Port Victoria.

The diversity of rainwater harvesting systems available on the market is limited. As mentioned earlier, market demand is small because of the high initial investment and due to the lack of public awareness of the multiple benefits of the adaptation technology. Few companies are engaged in such activities, resulting in a market that is not competitive. In addition, there are no reference projects to benchmark performance of RWH at the residential level.

The barriers identified under this category can be summarised into:

- Limited number of suppliers and limited technology choices
- Monopoly - underdeveloped competition;
- High costs; and
- Lack of reference projects in country.

Lack of Information and Awareness

There is a general lack of information and awareness in the general public of the adverse impact of climate change on water resources and how RWH systems could contribute to increase the resilience of households and businesses. The Non-Governmental Organisation (NGO) Sustainability for Seychelles has initiated an Education and Awareness campaign on this theme but it remains limited and needs to be scaled up.

The barriers identified under this category can be summarised as follows:

- Limited knowledge on RWH Technologies;
- Limited knowledge on how to install a RWH;
- Limited knowledge on long term benefit of RWH; and
- Lack of awareness about issues related to climate change and water.

The non-financial barriers are deconvoluted in the PT for rooftop RWH given in **Annex 1**.

1.2.3 Identified measures for rooftop RWH

An Objective Tree (OT) was developed (see Objective Tree Rainwater Harvesting in **Annex 1**) to identify main measures to support diffusion of RWH. This was done by identifying corresponding measures or interventions to address challenges and problems identified by the TNA project to scale up the diffusion of rooftop RWH systems. As shown in the OT for rooftop RWH systems, the proposed measures are articulated around the following components:

- Increasing the financial attractiveness of rooftop RWH;
- Strengthening the institutional, policy and legal framework for water management;
- Improving the awareness and knowledge on rooftop RWH of households; and
- Improving the availability of good quality RWH system on the market.

The measures proposed for each component are discussed below.

1.2.3.1 Economic and financial measures for RWH

First, the government should explore the possibility of establishing a subsidised loan scheme with an interest of 5% for households and Small and Medium Enterprises for RWH system similar to the scheme under the Seychelles Energy Efficiency and Renewable Energy Programme that provides subsidised loans for purchasing energy efficient appliances and renewable energy technologies. In this case, the Government provides an interest rate subsidy by paying the difference between the interest paid by the client and the average prime lending rates of banks which is currently around 10%. The period of loan repayment will be a maximum of 5 year and only installation and capital costs will be eligible.

Seychelles has a Value Added Tax (VAT) which is a broad-based tax on consumption. It applies to almost all goods and services that are imported, bought and sold for use or consumption in Seychelles. VAT is charged as a percentage of the price on the sale of goods and services and is borne ultimately by the final consumer. The standard rate is 15%.

As an additional financial incentive, the government could explore the possibility of exempting components of RWH system from VAT in order to make them more affordable to the general public and Small and Medium Enterprises. It is pointed out that similar VAT exemptions exist on renewable energy and energy efficient equipment.

1.2.3.2 Non-financial measures for RWH

Strengthening the institutional, policy and legal framework for water

The Ministry of Energy, Environment and Climate Change (MEECC) in collaboration with UNEP is currently developing a National Water Policy. This exercise aims to adopt and embed certain aspects and best practices of Integrated Water Resource Management (IWRM) namely; the development of a National IWRM Plan and Water Use Efficiency, National Water Policy and the formulation of a

National IWRM Indicator Monitoring Framework for Seychelles water sector. It is proposed that the institutional framework for water is strengthened with the establishment of an overreaching national water institution with water committees at the district level for promoting IWRM and rainwater harvesting. An estimated annual budget of 2 million rupees is being proposed of which 25% could be used to support diffusion of the rooftop rainwater harvesting technology.

Building code regulations should be revised to include regulations related to rainwater harvesting for new real estate development. Government could hire consultants to revise the building code regulations which could cost around 150,000 SCR.

Improving the awareness and knowledge on rooftop RWH of households

A national knowledge and awareness campaign is proposed to increase the awareness on climate change issues related to water, and to provide practical information on rainwater harvesting to households. The objectives of the campaign will be to explain how do install a RHW system, Explain the benefit of RWH, promote measures in place to support the adoption of RWH. The campaign will target the general public and could include:

- Setting up a website or webpages within another website with basic information about RWH, how it works, its benefits and its drawbacks, and contact details for loc al RWH suppliers
- Writing and publishing a series of articles about RWH for one of the local newspaper s focusing on the same content as the website.
- Creating and broadcasting an animated TV spot introducing RWH and its benefits.
- Holding a RWH exhibition in district with RWH Suppliers, PUC, and MEECC. Based on current practices such campaign costs around 360,000 SCR per year using the different media available.

Improving the access to RWH technology by supporting the establishment of a competitive market

It is proposed that rooftop RWH demonstration projects are established in each district in collaboration with importers and local manufacturers to showcase the different RWH technologies (and the different components of a RWH system), demonstrate and benchmark results, and to create market linkages between suppliers and potential users of rooftop RWH systems. The demonstration projects should be installed in high visibility areas such as in public institutions (schools, community centers, hospitals, etc.). Seychelles has 26 districts and it is foreseeable to have one demonstration project per district for an all-inclusive cost of 25,000 SCR per project.

1.2.3.3 Cost-benefit analysis of measures for RWH

A cost-benefit analysis (CBA) was carried out to investigate the financial attractiveness of the measures that are proposed to promote rooftop RWH systems in households. The cost elements relate to the cost of implementing the measures identified using barriers analysis, and in particular the Objective Tree (OT) that has been developed by mirroring the PT in **Annex 1**. The measures are public ones and their costs are born by the government. The costs of the measures are (**Table 6**):

- The cost of subsidised loans for capital and installation costs of the rooftop RWH system for a household;
- The cost of a VAT exemption on capital and installation costs;
- The cost for developing a building code integrating RWH;

- The cost for establishing an overreaching water institution which will support RWH among other activities;
- The cost of implementing RWH demonstration projects in each districts;
- The cost of developing and implementing a nationwide education and awareness campaign on RWH; and
- The overall incremental cost of RWH over dam extension capacity cost (the alternative technology in the absence of the TNA project).

Table 6. Summary costs of Rooftop Rainwater harvesting technology.

Costs	Number of households targeted	Cost of subsidised loans for RWH capital and installation costs[1]	Costs of VAT exemption on capital and installation costs[2]	Cost of integrating RWH in building code[3]	Costs of RWH in overreaching water institution[4]	Cost of demonstration projects[5]	Cost of Education and Awareness campaign[6]	The overall incremental cost of RWH over dam extension capacity cost[7]	Total costs (SCR)	Discount factor[8]	Present Value
year 1	5,000	4,000,000	12,000,000		500,000	325,000	360,000		17,185,000	1	17,185,000
year 2	5,000	4,000,000	12,000,000	150,000	500,000	325,000	360,000		17,335,000	0.9259	16,050,477
year 3	5,000	4,000,000	12,000,000		500,000		360,000		16,860,000	0.8573	14,454,078
year 4	5,000	4,000,000	12,000,000		500,000		360,000		16,860,000	0.7938	13,383,468
year 5	5,000	4,000,000	12,000,000		500,000		360,000		16,860,000	0.735	12,392,100
year 6					500,000		360,000		860,000	0.6806	585,316
year 7					500,000		360,000		860,000	0.6302	541,972
year 8					500,000		360,000		860,000	0.5835	501,810
year 9					500,000		360,000		860,000	0.5403	464,658
year 10					500,00		360,000	12,382,462	13,242,463	0.5002	6,623,880
TOTAL											**82,182,759**

Source: TNA project

1. RWH System capital and installation costs per household estimated at 16,000 SCR financed with loan of 1 year with a subsided interest rate of 5%compared to an average prime lending rate of 10%
2. Based on VAT of 15%
3. Based on a contract of services valued at 150,000 SCR
4. 25% of the total annual budget of the water overreaching institution estimated at 2,000,000 SCR
5. Based on the assumption of one demonstration project per districts with 26 districts at the cost of 25,000 SCR each
6. Based on the assumption of an annual cost of 360,000 SCR established from previous campaign.
7. Based on a cost of 270,000 million SCR as capital investment for a dam with an increased capacity of 670,000 m^3
8. Based on a discount rate of 8%

The large-scale diffusion of rooftop RWH systems in households is expected to yield multiple sustainable development benefits as shown by the ‘effects’ in the OT in **Annex 1**. The benefits that have been considered are:

- The potential savings in water bills by the 25,000 households targeted; and
- Potential jobs creation in the RWH value chain;

Table 7 summarises the value of benefits expected with the large scale diffusion of rooftop RWH systems.

Table 7. Summary Benefits of Rooftop Rainwater Technology.

Benefit	Volume of water saved for total household equipped (m^3 per year)[1]	Savings in water bills[2]	Value of Job creation for the RWH value chain[3]	Total benefit (SCR)	Discount factor	Present Value (SCR)
year 1	10,912,233	10,912,233	10,912,233	10,912,233	1	11,785,542
year 2	20,207,490	20,207,490	20,207,490	20,207,490	0.9259	21,824,467
year 3	28,066,090	28,066,090	28,066,090	28,066,090	0.8573	30,311,235
year 4	34,649,493	34,649,493	34,649,493	34,649,493	0.7938	37,421,453
year 5	41,797,560	41,797,560	41,797,560	41,797,560	0.735	45,138,417
year 6	38,702,354	38,702,354	38,702,354	38,702,354	0.6806	41,797,560
year 7	35,834,376	35,834,376	35,834,376	35,834,376	0.6302	38,702,354
year 8	33,181,343	33,181,343	33,181,343	33,181,343	0.5835	35,834,376
year 9	30,718,689	30,718,689	30,718,689	30,718,689	0.5403	33,181,343
year 10	28,446,415	28,446,415	28,446,415	28,446,415	0.5002	30,718,689
TOTAL						326,715,436

Source: TNA project

[1] Based on average daily consumption of 150 litres per capita, an average size of household of 3.4 and average saving of 30% of total household consumption
[2] Based on the average PUC water tariffs of 19.7SCR / m^3 until 2020 and 21.5 SCR/m^3 afterwards.
[3] Based on an average monthly salary of 10,000 SCR and 50 jobs created per 5000 RWH systems

A discount rate of 8% was applied corresponding to the return on investment (ROI) on long term treasury bonds issued by the central bank of Seychelles.

The benefit-cost ratio (BCR) is 4, implying that the measures recommended for scaling up the adoption of rooftop RWH among households should be implemented to bring sustainable development (economic, social and environmental) benefits to the Seychelles.

1.3 Barriers analysis and enabling measures for ground surface rainwater harvesting

1.3.1 General description of ground surface rainwater harvesting technology

Lack of adequate water supply during drought and seasonal dry periods can affect economic development and have a significant impact especially in the agricultural sector (Moustache, 2015). As explained above, most precipitation in the Seychelles runs off into rivers and eventually lost to the sea. Small-scale water runoff collection infrastructure can contribute greatly to the volume of freshwater available for human use mostly in the agriculture/livestock sector and landscaping. There are two main categories of technologies:

1. Collecting rainfall from ground surfaces utilising “micro-catchments” to divert or slow runoff; and
2. Collecting flows from a river, stream or other natural watercourse.

The technology with the most potential in the Seychelles is small reservoirs with earthen bunds or embankments (**Figure 3**) to contain runoff or river flow strengthened with gabions (**Figure 4**). This technology can help the agricultural sector to have a constant and regular water supply for agricultural production thereby minimising the impact of climate change on crop and livestock production, especially in the context of increasing water demand from all economic sectors (Government of Seychelles, 2017)

Source: Johan Mendez, hydrologist
Figure 3. Construction of embankments on Mahé.

Source: Johan Mendez, hydrologist
Figure 4. Embankment regulating water flow and increasing water storage on Mahé.

1.3.2 Identification of barriers to deployment of ground surface rainwater harvesting

Ground surface rainwater harvesting technology is classified as a capital good. There are a limited number of potential sites estimated at a maximum of 300 farms and investment is relatively large. A supply chain market analysis was carried out (see Market Map for Ground Surface Water Harvesting in Annex 1). The supply chain is composed of importers of gabion, local contractors, engineers for the design, and farmers. The diffusion of this technology is dominated by market decisions within the agriculture/livestock sector and requires an enabling environment that should include clear water rights, a ground surface rainwater harvesting policy, an overreaching institution for IWRM (same as for rooftop RWH), and appropriate financial incentives.

Several categories of barriers were identified in the demand-supply chain as illustrated by the Problem Tree (PT) in Annex 1. They are as follow:

- The technology is currently not financially viable;
- Weak Institutional, legal and policy framework;
- No site specific design available; and
- Lack of information and awareness on the potential sustainable development benefits of GWH.

These barriers are discussed in more details below.

1.3.2.1 Economic and financial barriers for ground surface rainwater harvesting

It is estimated that the total capital cost for a typical system with gabion of a total volume of 220m^3 is 720,000 SR as indicated in **Table 8**. Such a system could collect around 96,000m^3/year. The total maintenance cost is estimated at 120,000 SR per year.[3]

Table 8. Indicative Costs of Ground Surface Rainwater Harvesting.

Cost elements	**Costs SCR**
Foundation excavation, and backfill for 200 m^3 (500SCR /m^3)	100,000
Installation and filling of Gabions for 220 m^3 (2,840SCR/m^3)	620,000
Total (SCR)	**720,000**

Source: Adapted from UNDP-GEF Ecosystem based adaptation to climate change project (Mendez, 2017)

Most farmers are not paying for using the water directly from rivers and thus there is no motivation to adopt the technology. However, farmers are paying the normal water tariffs if they are using treated water from PUC. This occurs generally during the dry season where rivers are drying out. In this context, investment in surface water harvesting remains of high importance for farmers but benefits not clearly tangible compared to others spending priorities.

Currently, the government is providing other financial incentives to the agriculture sector, such as business tax exemptions, and loan access through the Development Bank of Seychelles at a subsidised interest rate of 5% but this technology is not eligible for subsidised loans. The following economic and financial barriers have been noted as indicated in problem tree for GWH in **Annex 1**:

- High initial capital cost of GWH technologies especially the installation and filling of gabions of which 50% of costs are for the rock filling;

[3] UNDP-GEF Ecosystem based adaptation to climate change project (Mendez, 2017)

- Ground surface water harvesting is not an investment priority for farmers; and
- Low water tariff for the agriculture sector acts as a deterrent for the adoption of the technology.

1.3.2.2 Non Financial barriers for ground surface rainwater harvesting

Institutional, legal and policy barriers

As indicated earlier, there is no existing national water policy in the Seychelles which promotes efficient, equitable and sustainable use of fresh water resources. An ecosystem based adaptation project funded by the climate change adaptation fund is looking at the possibly to establish river committees at the district level. The river committee will bring together the different water users and will be responsible for the water resource management and watershed management.

However, participation from stakeholders remains low and there is limited support from national institutions to the process. Similar to the case of rooftop RWH, there is also a lack of institutional arrangement supporting IWRM, including ground surface rainwater harvesting.

An additional barrier is that water rights are not clearly defined under the existing legislation, and this lead to conflicts between PUC and farmers on water usage rights. This situation will be exacerbated with climate change as the availability of fresh water resources becomes more constrained (Government of Seychelles, 2017).

The lack of adequate legislation, regulatory and institutional framework around GWH also makes the application process to obtain the necessary permits to construct GWH systems cumbersome. Rightly, in the absence of proper regulatory framework and guidelines, planning authorities are concerned about the potential adverse hydrological impacts of GWH systems on communities downstream should too much water be stored or diverted. The authorities must develop the technical ability to assess these impacts and prevent conflicts that could arise.

The barriers identified in this category can be summarized into:

- Lack of appropriate policy and legal framework for supporting GWH;
- Lack of overreaching institution for IWRM;
- Unclear water rights; and
- Unclear application process for obtaining permits to construct GWH systems.

Technical barriers

The design of GWH systems is not adapted to the available sites**.** There is a lack of hydrology and geomorphology data for most secondary rivers on Mahé, Praslin and La Digue, which makes it difficult to design the most cost effective, site-specific GWH systems. Moreover, national expertise to design such soft technology remains very limited, and, where available, most farmers do not have access to this expertise to make informed decisions. In general, there is a lack of expertise on IWRM at the national level.

The barriers identified in this category can be summarized into:

- Lack of data related to hydrology and geology for most secondary rivers; and
- Lack of technical expertise in IWRM and to design, install and maintain GWH systems.

Lack of Information and Awareness

There is a general lack of information and awareness in the agricultural sector of the adverse long-term impacts of climate change on agricultural production, especially concerning the availability of water resources. Also, according to Moustache (2015), small-scale farmers have little knowledge of options to improve their resilience against climate change including GWH. Sustainability for Seychelles has initiated and Education and Awareness campaign on this issue. The Ministry of Agriculture and the Seychelles Agriculture Agency are implementing a project funded by FAO and

IFAD, which aims to promote climate smart agriculture[4]. However, the focus is mainly on identifying crop species that are resistant to climate change, and little focus is given to water resources management. Some work is also being carried out under the project funded by the climate change Adaptation Fund that focuses on watershed management on selected agricultural sites, among others (Government of Seychelles, 2017). There is a need to scale up these initiatives based on lessons learned.

The following barriers have been identified in this category:

- Lack of practical information on the benefits of GWH systems in agricultural production;
- Lack of awareness about issues related to the impacts of climate change on agriculture; and
- Limited knowledge of technical options to deal with adaptation to climate change

1.3.3 Identified measures for ground surface rainwater harvesting

An OT was developed for GWH (see Objective Tree for Ground Surface Rainwater Harvesting in **Annex 1**) in order to identify measures to support the diffusion of GWH among farmers. The approach to identifying the measures by mirroring the root causes in the PT is the same as described above for rooftop RWH. The proposed measures are articulated around the following components:

- Increasing the financial viability of GWH;
- Improving the institutional, policy and legal framework for water management;
- Designing site-specific GWH systems; and
- Improving the awareness and knowledge on GWH among farmers.

These measures are discussed in the next sections.

1.3.3.1 Economic and financial measures for ground surface rainwater harvesting

It is proposed that the fiscal framework (Business Tax Act and Value Added Tax Act) for the agriculture sector is revised to ensure that GWH technology can be financed under the existing subsided loan scheme for the agriculture sector, and that the technology (and its components) is exempted from VAT (15%) to reduce capital and installation costs.

1.3.3.2 Non-financial measures for ground surface rainwater harvesting

Improving the institutional, policy and legal framework for water management

It is proposed that the institutional, policy and regulatory framework for water management is revised to ensure that water rights are clearly defined for promoting efficient, equitable and sustainable use of water resources across all sectors of the economy, and in particular the agriculture sector. An overreaching water management institution should be established to promote and monitor GWH among others activities. This institution will also regulate the promotion of rooftop RWH systems as discussed above. In order to make GWH systems financially competitive, water tariffs solutions for the agriculture sector should be explored. An estimated annual budget of 2 million rupees is being proposed of which 25% could be used to support diffusion of the ground surface rainwater harvesting technology.

Designing site-specific GWH systems

It is proposed that:

[4] Competitive Local Innovations for Small-Scale Agriculture Project (CLISSA)

- A data collection system on hydrology and geomorphology of rivers is established to support IWRM planning and decision-making; and
- National capacity in water management and water engineering is strengthened by integrating modules on sustainable water management practices and water engineering in the environmental degree proposed at the University of Seychelles.

Improving the awareness and knowledge on GWH among farmers
It is proposed that a national education and awareness campaign strategy is designed and implemented to increase awareness on climate change issues related to agriculture, and more specifically on the climate change impacts on water resources and climate change adaptation technologies options to increase the climate resilience of small-scale farmers.

The campaign will:

- Provide technical skills to build and maintain GWH system;
- Explain the benefit of GWH;
- Promote measures in place to support the adoption of GWH;
- Hold district consultation workshops with farmers through the Farmers Association;
- Work in close collaboration with the extension support provide by THE Seychelles Agricultural Agency; and
- Support writing and publishing a series of articles about GWH for one of the local newspapers.

The campaign will target the farmer community on Mahé, Praslin and La Digue. Based on previous experience, the cost of a typical campaign for around 700 farmers was estimated at 150,000 SCR per year.

1.3.3.3 Cost-benefit analysis of measures for ground surface rainwater harvesting

CBA was carried out to investigate the financial attractiveness of the measures that are proposed to promote Ground Surface Rainwater Harvesting Technology among farmers. The cost elements relate to the cost of implementing the measures identified using barriers analysis, and in particular the OT that has been developed by mirroring the PT in **Annex 1**. The measures are public ones and their costs are born by the government.

The costs of the measures are (**Table 9**):

- The cost of providing subsidised loans for capital expenses and installation costs of GWH systems;
- The cost of VAT exemption on capital and installation costs of GWH systems;
- The proportionated cost of establishing an overreaching water institution which will support GWH, among other activities; and
- The cost of developing and implementing a nationwide education and awareness campaign on GWH for farmers.

Table 9. Summary costs of Ground Surface Rainwater Harvesting technology.

Costs	Cost of subsidised loans for GWH capital and installation costs [1]	Cost of VAT exemption on capital and installation costs[2]	Costs of GWH in overreaching water institution [3]	Cost of Education and Awareness campaign[4]	Total costs	Discount factor	Present value
Year 1	180,000	54,000	500,000	150,000	936,500	1	884,000
year 2	180,000	54,000	500,000	150,000	936,500	0.9259	818,496
Year 3	180,000	54,000	500,000	150,000	936,500	0.8573	757,853
Year 4	180,000	54,000	500,000	150,000	936,500	0.7938	701,719
Year 5	180,000	54,000	500,000	150,000	936,500	0.735	649,740
Year 6	180,000	54,000	500,000	150,000	936,500	0.6806	601,650
Year 7	180,000	54,000	500,000	150,000	936,500	0.6302	557,097
Year 8	180,000	54,000	500,000	150,000	936,500	0.5835	515,814
Year 9	180,000	54,000	500,000	150,000	936,500	0.5403	477,625
Year 10	180,000	54,000	500,000	150,000	936,500	0.5002	442,177
Total							**6,406,171**

Source: TNA project

Notes: [1] Based on a subsidised loan of 1 year with an interest of 5% for an annual capital investment for the installation of 5 GWH at the cost of 720,000 SCR each

[2] Based on a VAT of 15% on total investment for 5 systems

[3] Based on 25% of the overall annual costs of an overreaching water institution

[4] Based on similar annual costs of targeted campaign for 700 registered farmers

The benefits that have been considered are (**Table 10**):

- The potential savings in water bills during the dry season when farmers are using PUC-treated water for farming purposes (when no other options are available);
- The value of job creation in the GWH value chain; and
- The overall avoided dam extension capacity cost.

Table 10. Summary of the benefits of Ground Surface Rainwater Harvesting technology.

Benefits	Total Volume of potential PUC water savings m3/year[1]	Value of Savings on PUC water bill per year[2]	Value of Job creation by the GWH value chain[3]	Overall avoided dam extension[4] capacity cost	Total benefit	Discount factor	Present value
Year 1	40,000	788,000	600,000		1,388,000	1	1,388,000
year 2	80,000	1,576,000	1,200,000		2,776,000	0.9259	2,570,298
Year 3	120,000	2,364,000	1,800,000		4,164,000	0.8573	3,569,797
Year 4	160,000	3,152,000	1,800,000		4,952,000	0.7938	3,930,898
Year 5	200,000	4,300,000	1,800,000		6,100,000	0.735	4,483,500
Year 6	240,000	5,160,000	1,800,000		6,960,000	0.6806	4,736,976
Year 7	280,000	6,020,000	1,800,000		7,820,000	0.6302	4,928,164
Year 8	320,000	6,880,000	1,800,000		8,680,000	0.5835	5,064,780
Year 9	360,000	7,740,000	1,800,000		9,540,000	0.5403	5,154,462
Year 10	400,000	8,600,000	1,800,000	107,194,029	117,594,029	0.5002	58,820,534
TOTAL							**94,647,409**

Source: TNA project

Notes: [1] Based on annual water saving per system of 96,000 m^3 divided by 12 representing the dry season

[2] Based on an average water tariff per m3 of 19.7 SCR up to 2020 and 21.5 SCR afterwards.
[3] Based on 15 jobs creation for the value chain of ground surface rainwater harvesting with an average monthly salary of 10,000 SCR over a 10 years period
[4] Based on a cost of 270,000 million SCR for a dam with an increased capacity of 670,000 m^3

A discount rate of 8% was applied corresponding to the ROI on long term treasury bonds issued by the Central Bank of Seychelles. A BCR of 14.8 was obtained. GWH is, therefore, a technology that is financially attractive and should be promoted among farmers.

1.4 Barriers analysis and enabling measures for water efficient fixtures

1.4.1 General description of water efficient fixtures

The most common water efficient fixtures and appliances include fixtures for toilets, showerheads and washing machine. They can simply use less water while yielding comparable performance (e.g. low-flow showerheads). There is a limited peer-reviewed literature based evidence for water saving. However, Mayer et al. (2004) reported a reduction of nearly 50% of water use per capita in Tampa, Florida with the installation of water-efficient devices. Similarly, Inman and Jeffrey (2006) reported that the comprehensive replacement of household appliances (showers, toilets, dishwashers) with highly efficient devices can reduce indoor consumption by 35% to 50%.

1.4.2 Identification of barriers to deployment of water efficient fixtures

Water efficient devices are classified as a consumer technology as it is intended for the mass market and purchased by private consumers, including households, businesses and institutions. There are a high number of potential consumers as shown by the high number of target beneficiaries in Section 1.1. As is typical of consumer goods, the demand for water efficient appliances depends on consumer awareness and preferences, and on commercial marketing and promotional efforts.

A market supply chain analysis was carried out and it is shown in **Annex 1** (Market Map for water efficient devices). The supply chain includes importers/retailers of water efficient devices, installers and maintenance contractors, and end users. The diffusion of water efficient devises requires an enabling environment for the demand-supply chain, and the services and inputs providers to operate efficiently. Such enabling environment should include water efficiency policy, water efficient standards for building, financial incentives, water efficiency labelling for water efficient products.

Several categories of barriers were identified in the demand-supply chain as illustrated by the PT in **Annex 1**. They are as follow:

- ✓ Economic and financial barriers
- ✓ Institutional, legal and policy barriers
- ✓ Market imperfections
- ✓ Lack of Information and Awareness

These barriers are discussed in more details below.

1.4.2.1 Economic and financial barriers for water efficient devices

The cost of water efficient devices (fixtures and appliances) will vary for each household depending of number of toilets and showers. For a household of 4 persons, with one toilet, one shower and one efficient washing machine, it would cost approximately 8,650 SCR as indicated in **Table 11**. Installation costs, mainly for the washing machine, was estimated at 1,500 SCR.

There are three suppliers of water-efficient fixtures and fittings in Seychelles. These are:

- WaterMaster (Pty) Ltd in Providence Industrial Estate.
- Bestway Plumbing (Pty) Ltd in Providence Industrial Estate.
- Bodco (Pty) Ltd in Port Victoria.

Estimated prices of water-efficient and fitting in Seychelles are presented in the table below.

Table 11. Prices of water-efficient fittings and fixtures in Seychelles.

Fixture / Fitting	**Description**	**Volume per use (litres)**	**Retail Price (SCR)**
Dual Flush (1)	Toilets	2.6 / 4.0	2,950
Dual Flush (2)		2.6 / 9.0	2,200
Low Flow	Showers	7	200
Efficient Front Loader	Washing Machines	9,240 per annum	5,500

Source: Resource Efficient programme in the Seychelles

Because of the relatively high upfront capital replacement cost of water efficiency appliances for the household relative to disposable income, investment in water efficient appliances has remained a low priority for households. This financial barrier is compounded by a lack of understanding of the tangible benefits of water efficiency compared to others household spending priorities.

The economic and financial category of barrier was deconvoluted (as shown in **Annex 1**), and the causes have been identified. The following lists the causes of the barrier with the root cause found at the bottom of the list:

- High capital cost of water efficient appliances for household
- Water efficient appliances is not an investment priority for households, especially in the context of high upfront capital cost
- Lack of cheap capital available to households (high interest rates for unsecured loans)
- Lack of financial incentives for water efficient appliances

1.4.2.2 Non Financial barriers for water efficient fixtures

Institutional, legal and policy barriers

Currently, there is no national water policy in the Seychelles to promote efficient, equitable and sustainable use of water resources. In this context, there is no policy that promotes water efficiency at the national level. Further, there is no institutional arrangement for supporting integrated water resources management (IWRM), including water efficiency measures. There is also no building code for integrating water efficiency in building designs.

Standards and labelling of water efficiency appliances have not been developed. These are required to legally define the required technical specifications for water efficiency appliances and the certification of volume of water saved by the water efficient appliances.

The barriers identified in this category can be summarised into:

- No supportive policy and regulatory instruments;
- There are no national standards and labelling for water efficient appliances;
- There is no overreaching institution for IWRM; and
- Water efficiency standards or guidelines have not been developed for the design of new buildings or for retrofitting existing buildings.

Market imperfections

There are three main suppliers of water efficient fittings. These are:

- WaterMaster (Pty) Ltd in Providence Industrial Estate;
- Bestway Plumbing (Pty) Ltd Providence Industrial Estate; and
- Bodco (Pty) Ltd in Port Victoria.

There are several suppliers of water efficient washing machine and other water efficient appliances, including:

- Samsung (Pty) Ltd in Orion Mall ,Eden Island
- OG Trading (Pty) Ltd in Providence Industrial Estate
- Home Makers (Pty) Ltd in Providence Industrial Estate and Victoria
- Lifestyle (Pty) Ltd in Victoria and Orion Mall
- Abhaye Valhabjee (Pty) Ltd in Victoria
- Good luck (Pty) Ltd in Victoria
- Sales point (Pty) Ltd in Victoria
- Kim Koon (Pty) Ltd in Plaisance

In Seychelles, there are 8 major importers/retailers of water efficient appliances and 3 suppliers of water efficient fitting which is enough for the local market. However, often the importers/retailers of water efficient appliances do not have any information about water consumption of the appliances that they can provide to customers. There are often no labels of water efficiency display on the appliances. The appliances are coming from a large variety of countries (Europe, China, Japan, Thailand, Dubai, etc) and often technical information on the appliances is in a foreign language not in use in Seychelles and the quality of the appliances is generally poor. The sales persons in the different shops are not knowledgeable about water efficiency. The choice of water efficient appliances is often very limited.

Market demand remains small because of the high initial investment and due to the lack of public awareness of the multiple benefits of the adaptation technology. In addition, there are no reference projects to benchmark performance of water efficiency at the residential level.

The following barriers have been identified under this category:

- Limited technology choices
- No standards in place to insure quality of water efficient appliances
- No national labelling system for water efficiency to benchmark performance of the appliance

Lack of Information and Awareness

There is a general lack of information and awareness in the general public of the adverse impact of climate change on water resources and how water efficiency could contribute to increase the resilience of households and businesses. Households lack knowledge on the long term water savings and water bill savings compared to the upfront investment costs. They may also lack knowledge on the technical performance of the devices to make a decision on investment.

The following barriers have been identified under this category:

- Limited knowledge on water efficiency technologies;
- Lack of project references; and
- Lack of awareness about issues related to water -climate change and water efficiency

The non-financial barriers are deconvoluted in the PT for water efficient fixtures given in **Annex 1**.

1.4.3 Identified measures for water efficient fixtures

An OT was developed (see Objective Tree Water Efficient Appliances in **Annex 1**) to identify main measures to support diffusion of water efficient appliances at residential level. This was done by identifying corresponding measures or interventions to address challenges and problems identified by the TNA project to scale up the diffusion of water efficient appliances. As shown in the OT, the proposed measures are articulated around the following components:

- Increasing the financial attractiveness of water efficient appliances;
- Strengthening the institutional, policy and legal framework for water efficiency;
- Improving the awareness and knowledge of households on water efficiency; and
- Improving the availability of good quality water efficient appliances on the market.

The measures proposed for each component are discussed below.

1.4.3.1 Economic and financial measures for water efficient fixtures

First, the government should explore the possibility of establishing a subsidised loan scheme with an interest of 5% for households for water efficient appliances similar to the scheme under the Seychelles Energy Efficiency and Renewable Energy Programme that provides subsidised loans for purchasing energy efficient appliances and renewable energy technologies. In this case, the Government provides an interest rate subsidy by paying the difference between the interest paid by the client and the average prime lending rates of banks which is currently around 10%. The period of loan repayment will be a maximum of 5 year and only installation and capital costs will be eligible.

Seychelles has a Value Added Tax (VAT) which is a broad-based tax on consumption. It applies to almost all goods and services that are imported, bought and sold for use or consumption in Seychelles. VAT is charged as a percentage of the price on the sale of goods and services and is borne ultimately by the final consumer. The standard rate is 15%.

As an additional financial incentive, the government could explore the possibility of exempting components of water efficient appliances from VAT in order to make them more affordable to the general public. It is pointed out that similar VAT exemptions exist on renewable energy and energy efficient equipment.

1.4.3.2 Non-financial measures for water efficient fixtures

Strengthening the institutional, policy and legal framework for water efficiency

The Ministry of Energy, Environment and Climate Change (MEECC) in collaboration with UNEP is currently developing a National Water Policy. This exercise aims to adopt and embed certain aspects and best practices of Integrated Water Resource Management (IWRM) namely; the development of a National IWRM Plan and Water Use Efficiency, National Water Policy and the formulation of a National IWRM Indicator Monitoring Framework for Seychelles water sector. It is proposed that the institutional framework for water is strengthened with the establishment of an overreaching national water institution with water committees at the district level for promoting IWRM. An estimated annual budget of 2 million rupees is being proposed of which 25% could be used to promote water efficiency.

Building code regulations should be revised to include regulations/guidelines related to water efficiency for new real estate development. Government could hire consultants to revise the building code regulations which could cost around 150,000 SCR.

Moreover, a standard and a labeling system could be introduced to ensure the quality of water efficiency imported and certified the volume of water saved by the water efficient appliances. The Seychelles Bureau of Standards will be responsible to develop such standards and labeling system in collaboration with the proposed overreaching national water institution. Government could hire consultants to develop standards and labeling system which is estimated to cost around 200,000 SCR.

Improving the awareness and knowledge on water efficiency of households

A national knowledge and awareness campaign is proposed to increase the awareness on climate change issues related to water, and to provide practical information on water efficiency to households. The objectives of the campaign will be to explain the benefits of water efficiency, to provide information of water efficiency technologies, and to promote measures in place to support the adoption of water efficiency appliances by households. The campaign will target the general public and could include:

- Setting up a website or webpages within another website with basic information about water efficiency, technical information on water efficiency technologies available, information on water efficiency standards and labelling system and contact details for local suppliers of water efficient fixtures;
- Writing and publishing a series of articles about water efficiency for local newspapers;
- Creating and broadcasting an animated TV spot introducing water efficiency and its benefits; and
- Holding exhibitions of water efficiency devices in districts.

Based on current practices[5] such campaigns cost around 360,000 SCR per year.

Improving the access to water efficient technology by supporting the establishment of a competitive market

It is proposed that water efficient demonstration projects (i.e. reference projects) are established in each district in collaboration with importers/retailers to showcase the different water efficiency technologies and to benchmark water saving results, and to create market linkages between suppliers and potential users of water efficient appliances. The demonstration projects should be installed in

[5] Sustainability for Seychelles (Michele Martin, 2016)

high visibility areas such as in community centres. Seychelles has 26 districts and it is foreseeable to have one demonstration project per district for an all-inclusive cost of 10,000 SCR per project.

1.4.3.3 Cost-benefit analysis of measures for water efficient fixtures

CBA was carried out to investigate the financial attractiveness of the measures that are proposed to promote water efficiency in households. The cost elements relate to the cost of implementing the measures identified using barriers analysis, and in particular the OT that has been developed by mirroring the PT in **Annex 1**. The measures are public ones and their costs are born by the government. The costs of the measures are (**Table 12**):

- The cost of subsidised loans for capital and installation costs of water efficient appliances for a household;
- The cost of a VAT exemption on capital and installation costs;
- The cost for developing a building code integrating water efficiency;
- The cost of developing a standards and a labelling system for water efficiency appliances
- The cost for establishing an overreaching water institution which will support water efficiency among other activities;
- The cost of implementing water efficiency demonstration projects in each districts; and
- The cost of developing and implementing a nationwide education and awareness campaign on water efficiency.

Table 12. Summary costs of water efficient appliances technology.

Costs	Number of households targeted	Cost of subsidised loans for water efficiency and installation costs[1]	Costs of VAT exemption on capital and installation costs[2]	Cost of integrating water efficiency in building code[3]	Costs of water efficiency in overreaching water institution[4]	Cost of demonstration projects[5]	Cost of Education and Awareness campaign[6]	Cost of developing standards and labelling system[7]	Total costs	Discount factor	Present Value
year 1	5,000	2,537,500	7,612,500		500,000	130,000	360,000		11,140,000	1	11,140,000
year 2	5,000	2,537,500	7,612,500	150,000	500,000	130,000	360,000	150,000	11,440,000	0.9259	10,592,296
year 3	5,000	2,537,500	7,612,500		500,000		360,000		11,010,000	0.8573	9,438,873
year 4	5,000	2,537,500	7,612,500		500,000		360,000		11,010,000	0.7938	8,739,738
year 5	5,000	2,537,500	7,612,500		500,000		360,000		11,010,000	0.735	8,092,350
year 6					500,000		360,000		860,000	0.6806	585,316
year 7					500,000		360,000		860,000	0.6302	541,972
year 8					500,000		360,000		860,000	0.5835	501,810
year 9					500,000		360,000		860,000	0.5403	464,658
year 10					500,000		360,000		860,000	0.5002	430,172
										TOTAL	**50,527,185**

Source: TNA project

Notes:

[1] Water efficient appliances capital and installation costs per household estimated at 10,150 SCR financed with loan of 1 year with a subsided interest rate of 5% compared to an average prime lending rate of 10%.

[2] Based on VAT of 15%.

3 Based on a contract of services valued at 150,000 SCR.

[4] 25% of the total annual budget of the water overreaching institution estimated at 2,000,000 SCR.

[5] Based on the assumption of one demonstration project per district with 26 districts at the cost of 10,000 SCR each. Reference projects are implemented over 2 years.

[6] Based on the assumption of an annual cost of 360,000 SCR established from previous campaign.

[7] Based on a contract of services valued at 150,000 SCR.

The large-scale diffusion of water efficient appliances in households is expected to yield multiple sustainable development benefits as shown by the ‘effects’ in the OT in **Annex 1**. The benefits that have been considered are:

- The potential savings in water bills by the 25,000 households targeted;
- Potential jobs creation in the water efficient appliances value chain;
- The overall avoided dam extension capacity cost

Table 13 summarises the value of benefits expected with the large scale diffusion of water efficient appliances.

Table 13. Summary benefits of water efficient appliances technology.

Benefits	Volume of water saved per household m3 per year(30 % Water savings)	Volume of water saved for total household equipped m3 per year[1]	Savings in water bills[2]	Value of Job creation for the water efficiency value chain[3]	Overall avoided cost for dam extension[4]	Total benefit	Discount factor[5]	Present Value
year 1	55.845	279,225	5,506,317	1,200,000		6,706,317	1	6,706,317
year 2	55.845	558,450	11,012,634	2,400,000		13,412,634	0.9259	12,418,758
year 3	55.845	837,675	16,518,951	3,600,000		20,118,951	0.8573	17,247,977
year 4	55.845	1,116,900	24,013,350	4,800,000		28,813,350	0.7938	22,872,037
year 5	55.845	1,396,125	30,016,688	6,000,000		36,016,688	0.735	26,472,265
year 6		1,396,125	30,016,688	6,000,000		36,016,688	0.6806	24,512,958
year 7		1,396,125	30,016,688	6,000,000		36,016,688	0.6302	22,697,716
year 8		1,396,125	30,016,688	6,000,000		36,016,688	0.5835	21,015,737
year 9		1,396,125	30,016,688	6,000,000		36,016,688	0.5403	19,459,816
year 10		1,396,125	30,016,688	6,000,000	118,867,537	154,884,225	0.5002	77,473,089
							Total	**250,876,671**

Source: TNA project

Notes:

[1] Based on average daily consumption of 150 litres per capita, an average size of household of 3.4, and average saving of 30% of total household consumption.

[2] Based on the average PUC water tariffs of 19.7SCR / m^3 until 2020 and 21.5 SCR/m^3 afterwards.

[3] Based on a monthly average salary of 10,000 SCR and 10 jobs created per 5000 households equipped with water efficient appliances.

[4] Based on a cost of 270,000 million SCR for a dam with an increased capacity of 670,000 m^3.

[5] A discount rate of 8% was applied corresponding to the return on investment (ROI) on long term treasury bonds issued by the central bank of Seychelles[6].

The benefit-cost ratio (BCR) is 5 implying that the measures recommended for scaling up the adoption of water efficient appliances among households should be implemented to bring sustainable development (economic, social and environmental) benefits to the Seychelles.

1.5 Linkages of barriers identified for the water sector

For the three adaptation technologies discussed above, it has been noted that there are common barriers. These are:

- Lack of an adequate institutional, policy, regulatory framework for the water sector;
- Limited awareness on climate issues related to water resources, and appropriate adaptation technologies;
- Limited technical expertise; and
- High costs of the adaptation technologies.

This creates synergies between the technologies related to the linked barriers. Therefore, these linkages provide an opportunity for scaling up climate adaptation through the promotion of water technologies in a cost effective way. For instance, the costs related to establishing an overreaching institution in the water sector, developing an integrated water and associated regulatory framework could be shared between the implementation of all technologies. The awareness campaign of climate issues related to the water sector can be done conjunctly for all the adaptation technologies, while bearing in mind the different target audiences. Subsidies needed for the adoption of climate change adaptation technologies for the water sector could be discussed jointly with the ministry of Finance and managed jointly by the Development Bank of Seychelles. Technical capacity building at vocational level required for these climate adaptation technologies could be a module within the curriculum of Seychelles Institute of Technology.

1.6 Enabling framework for overcoming the barriers in the water sector

In order to successfully implement RWH and water efficiency at the residential level, and GWH in the agricultural sector the following elements of an enabling framework will need consideration.

✓ **Institutional arrangements**

An overreaching water institution supporting integrated water management should be established. Amongst other activities, the water institution will support and promote the diffusion of rooftop rainwater harvesting technology and water efficiency at residential level and ground surface rainwater harvesting in the agricultural sector based on the policy and regulatory framework adopted.

✓ **Policy Framework**

- **Integrated water resources management policy framework**
  An integrated water resources management policy framework should be finalised based on a consultative approach of stakeholders and should integrate elements related to rooftop rainwater harvesting, water efficiency and ground surface rainwater harvesting technologies; and
- The agriculture policy should be updated to take into consideration and support the diffusion of ground surface water technology as a climate change adaptation measures for the agricultural sector.

✓ **Regulatory framework**

- Standards for rooftop rainwater harvesting system and water efficient appliances should be established to ensure quality of adaptation technologies available on the market;

- Building codes should be revised to integrate regulations/guidelines related to rooftop rainwater harvesting, adoption of water efficiency devices, and ground surface rainwater harvesting;
- Water rights should be revised and clearly defined to promote efficient, equitable and sustainable use of water resources across all sectors of the economy; and
- A labelling system for water efficiency appliances should introduced to inform and certify consumers of volume of water saved by technology type.

✓ **Tax and fiscal regimes**

- Regulations of the value Added Tax Act (2010) should be developed to ensure that the capital and installation costs of rooftop rainwater harvesting, water efficient appliances, and ground surface rainwater harvesting system are exempt of VAT.

✓ **Financial instruments**

Existing subsidies and loans schemes should be revised to integrate rooftop rainwater harvesting, water efficiency appliances, and ground surface rainwater system as eligible component.

Chapter 2 Coastal Zone sector

Since Seychelles is a small island developing states (SIDS), the Coastal Zone was another sector that was prioritised for technical assistance under the TNA project due to the sector vulnerability (Government of Seychelles, 2017). The choice of this sector is also aligned with the Seychelles Nationally Determined Contributions (NDC) that has been submitted to the UNFCCC (Government of Seychelles, 2015a). Three technologies were prioritised for further analysis regarding adaptation in the coastal zone during the first stage of the TNA project (Government of Seychelles, 2017):

1. **Mapping –** This technology includes flood mapping, mapping of coastal ecosystems (using LIDAR and drones), bathymetry and current mapping to better understand movement of waves and sand offshore in order to allow for better planning of coastal restoration and protection measures. Mapping is generally considered to be a basic necessity for the successful implementation of all other technologies for protection of the coastal zone. It can be implemented quite easily, given that several measures were put in place for overcoming the financial and human capacity barriers that the technology faces;

2. **Coastal wetland restoration –** Wetland restoration will help to address coastal flooding (precipitation, SLR, storm surges). In some places, wetland restoration would need to be implemented alongside other measures such as river outlet improvement and setbacks, as well as improving current laws and policies regarding wetland protection. There is great potential for working with private landowners and hotels and communities to restore and improve the natural functioning of coastal wetlands; and

3. **Dune Restoration –**Dune restoration has been tried to some extent by the government but needs further development. This technology has great interest due to the added social benefits of providing additional space for people to enjoy the beaches, as well as an opportunity for revegetation along coastal areas. There is need for more research to design dune restoration projects that are effective and tailored to the specific locations where they are needed, with input from an improved mapping and modelling capacity in the country. Furthermore, dune restoration can be combined with other soft and hard technologies, including river outlet improvement and low seawalls.

2.1 Preliminary targets for technology transfer and diffusion in the coastal zone sector

Coastal wetland restoration and dune rehabilitation are both natural ecosystem based technologies for protecting the coast. The first technology (mapping) is supportive of these ecosystem based technology. The prioritised adaptation technologies are thus in line with government policy and thinking to adopt natural methods of adaptation as far as practicable, thereby avoiding hard engineering solutions that are aesthetically displeasing and may undermine the natural beauty of the coastline that forms the basis for the tourism industry.

In contrast, a detailed study of coastal erosion and flooding in Seychelles published by JICA in 2014 recommends hard engineering solutions for the most vulnerable sites, such as construction of groynes and beach nourishment to address coastal erosion, and the construction of drainage ditches and widening of river mouths to prevent flooding of wetland areas in times of heavy rainfall.

Following discussions with the Coastal Zone TWG, it was agreed to use the TNA process to further investigate the potential of ecosystem-based adaptation (EBA) technologies to address protection of coastal areas from climate change impacts. Furthermore, it was noted that coastal habitats that naturally protect the coast in Seychelles are in extremely close proximity to one another due to the narrow width of the coastal strip surrounding the islands. There are numerous ecological interactions between coastal wetlands, adjacent beaches, river outlets and even the coral reefs just offshore protecting the coast. In fact, the other technologies which scored high in the MCA process included river outlet improvement and coral reef restoration (Government of Seychelles, 2017). The TNA can, therefore, while primarily focusing on wetland restoration and dune rehabilitation, incorporate those technologies as well within a broader EBA approach where relevant to the specific sites chosen for coastal protection measures.

Seychelles is already piloting several EBA projects (Government of Seychelles, 2017) which are addressing several of the target vulnerable sites for coastal erosion identified in recent studies (e.g. Mendez et al., 2013; JICA, 2013). However, most of them deal with only one aspect of the coastal ecosystem (e.g. restoring a beach, or a wetland or a reef, or a river outlet) and none of them have yet tried to adopt a holistic approach to coastal restoration from the coastal plateau to coral reef.

The Coastal Zone TWG has thus recommended that for the purposes of the TNA, the targets for technology transfer and diffusion to protect critical infrastructure in the coastal zone should include:

1) **Coastal Mapping and Monitoring** on all three main islands (Mahé, Praslin and La Digue) with a special emphasis on hotspots (see **Table 14** below for sites identified under several studies) that are already suffering from erosion and flooding, putting public and private critical infrastructure at risk. This will include bathymetry, studies of coastal processes including sand movement (i.e. near-shore dynamics), waves and currents, and sea level rise (SLR). High resolution satellite imagery will be required to carry out these analyses as well as ground truthing. This technology will also include housing the data, and processing it using mapping techniques, in a centralised location where the information can be made readily available to planners and developers undertaking coastal restoration and/or physical development work in the coastal zone.

Table 14. Summary of hotspots for coastal mapping and monitoring.

SITE	ISSUES TO MONITOR	REF
MAHÉ		
Bel Ombre	SLR and flooding	Mendez et al., 2013
Beau Vallon	SLR and erosion	JICA, 2013
Glacis	SLR and flooding	Mendez et al., 2013
North East Point	Beach erosion and impact of mitigation measures	JICA, 2013
Anse Etoile	SLR and flooding	Mendez et al., 2013
English River	SLR and flooding	Mendez et al., 2013
Victoria Town	Flooding	JICA, 2013
Mont Fleuri	SLR and flooding	Mendez et al., 2013
Les Mamelles	SLR and flooding	Mendez et al., 2013
Roche Caiman	SLR and flooding, mangrove restoration	Mendez et al., 2013
Cascade	SLR and flooding	Mendez et al., 2013
Pointe Larue	flooding and drainage	JICA, 2013; Mendez et al., 2013
Anse aux Pins	Erosion and flooding	JICA, 2013
Au Cap	flooding & drainage	JICA, 2013
Anse Royale	mangrove recovery, freshwater wetland and beach erosion	JICA, 2013; Ahmed, 2015; Mendez et al., 2013
Takamaka	SLR and flooding	Mendez et al., 2013
Baie Lazare	Beach erosion	JICA, 2013
Anse La Mouche	Beach erosion and impact of mitigation measures	JICA, 2013, CAMS
Anse Boileau	Impact of erosion control	Ahmed, 2015; Mendez et al., 2013
Grand Anse Mahé	SLR and flooding, wetland mitigation measures	Mendez et al., 2013

Port Glaud	SLR and flooding, mangrove restoration	Mendez et al., 2013; S4S, 2015
PRASLIN		
Praslin in general	Wetlands, dunes, benthic marine areas, coral reefs, SLR and flooding	EBA coastal, Ahmed, 2015;
Grand Anse district lowlands	Beach, sand accretion, flooding, movement of sediments	Mendez et al., 2013; SNA Oct.2016
Baie Ste Anne district lowlands	SLR and flooding	Mendez et al., 2013
Airport area	SLR and flooding	Mendez et al., 2013
Anse Kerlan	Erosion, wetland recovery, dunes, marine benthic coral reef recovery	JICA, 2013; SNA Oct. 2016
Nouvelles Decouvertes	monitor sediment flow and drainage patterns community stewardship pgm	Ahmed, 2015;
Anse St. Saveur – Anse Takamaka	Monitor wetland, beach, sand, currents, river outlet	Ahmed, 2015;
Au Cap Wetlands	monitoring sedimentation and drainage patterns mangrove regeneration.	Ahmed, 2015;
Anse Gouvernement	monitoring sedimentation and drainage patterns mangrove regeneration, beach	Ahmed, 2015;
Cap Samy	Monitor sediment patterns, beach and wetland	Ahmed, 2015;
Cote D'Or	Monitor beach, sediment, currents, river outlets, wetland, Water quality testing	Ahmed, 2015;
Anse La Blague,	Monitor beach and coastal area	SNA Oct. 2016
Anse Boudin,	Monitor beach and coastal area	SNA Oct. 2016
Anse Marie-Louise	Monitor beach and coastal area	SNA Oct. 2016
LA DIGUE		
La Passe	Monitor the whole coast for changes in beach profile, sedimentation, currents, sand accretion/erosion, changes to the wetland	JICA, 2013

Source: please see last column in table

2) **Restoration of coastal wetlands** based on EBA principles and intersecting with actions related to river outlet improvement, dune rehabilitation and coral reef restoration. The Coastal Zone TWG recommended that this technology be focused mainly on the island of Praslin for the purposes of the TNA, particularly in the area of the northwestern coast of Praslin, which is at risk to flooding due to poor drainage in the wetland area. Most of the coastal wetlands on Praslin are in close proximity to critical coastal infrastructure such as roads, the airport, and tourism developments. There is good potential for tangible improvement, as well as for gaining widespread participation in the process of restoration from different stakeholders including the community, civil society groups, government partners, the airport management, hotel operators, and private landowners. Because the distance between wetlands and beaches in the coastal plateau is very small, any wetland restoration work would be done in coordination with other coastal restoration works being done to protect the beach and improve the river outlet. This integrated EBA coastal restoration approach can then be scaled up to the other islands (i.e. Mahé and La Digue) since a similar situation exists in the narrow coastal plateau, where coastal habitats are closely interconnected. The recommended sites are:
   - Baie Ste Anne village
   - Grand Anse village
   - Anse Kerlan
   - Nouvelles Decouvertes
   - Anse St. Saveur – Anse Takamaka
   - Au Cap Wetlands
   - Anse Gouvernement

- Cap Samy
- Cote D'Or

3) **Dune rehabilitation** based on EBA principles and intersecting with actions where relevant related to wetland restoration, river outlet improvement, revegetation, and coral reef restoration in the same site. Dune rehabilitation is a technology for protecting the coast, which has been tried by the government in combination with construction of timber piling and even rock revetments in some places. This is a technology of great interest in the country due to the added social benefits of providing space for people to use the beaches as well as revegetation along coastal areas. In many places, the potential for dune restoration is restricted by the presence of a road along the top of the dune or just behind it, or building and other infrastructure in the dune area. Depending on the site, dune rehabilitation can be combined with other hard and soft technologies including river outlet improvement and low seawalls.

   The Coastal Zone TWG had recommended that the TNA focus primarily on Anse Kerlan and nearby beaches on the northwestern coast of Praslin. Anse Kerlan has been identified repeatedly in numerous studies (e.g. JICA, 2013; Ahmed, 2015; Mendez et al., 2013) as a site of critical erosion, putting local tourism developments, roads and private property at high risk. Several interventions involving hard engineering have already been attempted in this area, some earlier ones with deleterious effects, exacerbating the situation. However, at the time of writing it has emerged that a new hard engineering project involving the construction of groynes at Anse Kerlan has been approved, therefore the TNA project can focus on assisting with revegetation of the dune as sand accretes, and replanting further along the coast towards Grand Anse.

   The other targets for dune rehabilitation to be included in the TAP are **Baie Lazare**, **North East Point**, and possibly La Passe and La Digue, all of which were identified as highly vulnerable sites under the JICA study of coastal erosion (JICA, 2013). The criteria used in the JICA study to identify priority sites included: a) Historic events of flooding and/or erosion; b) Proximity to infrastructure and development; c) Potential new site for economic development and d) Degree of risk of damage. It should be noted that shoreline erosion at both North East Point and La Passe are also currently being addressed under other projects, partially through hard engineering strategies, but that these can be complemented by dune rehabilitation through planting native species. There is a Global Climate Change Alliance (GCCA+) project currently being planned for La Passe, which may already include rehabilitation and revegetation of the dune.

   It is recommended that the following hot spot sites be also included for dune rehabilitation work as these sites are already experiencing some erosion, no major projects are underway at these sites, and they are highly vulnerable to sea level rise due to tourism developments in the area (JICA, 2013; Mendez et al., 2013):
   - Cote D'Or, Praslin
   - Grand Anse, Praslin
   - Beau Vallon, Mahé

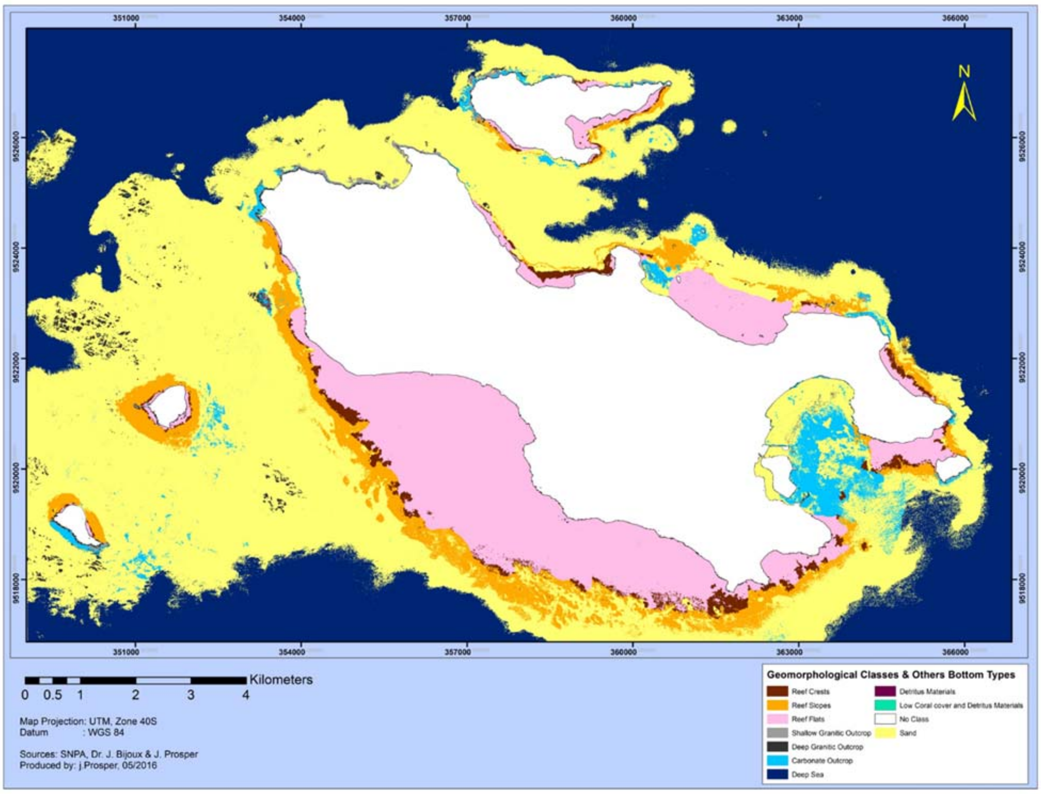
   The TNA project addresses the need for research to design dune rehabilitation projects that are effective and tailored to the specific locations where they are needed, with input from an improved mapping and modelling capacity in the country.

2.2 Barrier analysis and enabling measures for coastal mapping and monitoring

2.2.1 General description of coastal mapping and monitoring

This technology includes many different methods to map and monitor coastal areas, both onshore and offshore to just beyond the coral reefs. The geographic focus is on the main three islands (Mahé, Praslin and La Digue) where critical infrastructure is located. It is pointed out that the experience and expertise that will be developed will also be useful for informing developments on any of the other islands. Mapping and monitoring of coastal processes is generally considered to be a basic necessity for the successful implementation of all other technologies used to protect the coast from the impacts of climate change.

Some of the mapping methods included in this technology are mapping of coastal ecosystems (using high resolution satellite imagery mainly but also ground-proofing with field studies), bathymetry (**Figure 5**)**,** and risk maps identifying key areas susceptible to flooding, erosion and other impacts of climate change. In terms of monitoring, periodic data collection and analysis is required to gauge changes over time due to climate change impacts, developments on the coast, and impact of coastal restoration measures.



Source: Prosper, J. (2017)

Figure 5. Bathymetry map showing geomorphological features of benthic areas around Praslin Island.

The technology also includes ongoing studies of coastal dynamics to better understand movement of waves, currents and sand offshore and onshore in order to allow for better planning of coastal restoration and protection measures, as well as inform other development projects along the coast. By using up to date data, computer models can generate likely scenarios of how coastal developments and protection measures will affect wave action, sand movement and other coastal processes. Currents and waves can be monitored using acoustic Doppler current profilers (ADCPs) installed offshore near vulnerable beaches.

Beach profiling at vulnerable sites has been done in Seychelles for several years but sporadically. This is a simple technology that requires basic measuring equipment to estimate the beach slope and can be done once per year, given the availability of human resources to undertake the data collection, entry and analysis. Permanent beacons need to be installed as reference points.

While some mapping work (of all types) has been already carried out in Seychelles, it is sporadic, fragmented, and much of the data is not accessible because it is owned by private developers or international agencies who carry out bathymetric studies or commission high resolution satellite imagery. Overall, very little mapping has been done to date except for specific sites where a development has been planned. It could be implemented quite easily, since Seychelles already has reasonable technical and human resource capacity for centralised data storage and for producing maps. However, it would require several measures to be put in place for overcoming the financial and human capacity barriers (discussed below) that the technology faces.

At present, data, maps, models and other information about the coastal environment are not readily available in one centralised location, or coordinated by one central agency. There are many different stakeholders involved, including the Coast Guard, the MEECC, NGOs, private developers, MLUH, and the Meteorological Agency. There is a need for better institutional coordination to guide decision-making about how best to protect a public beach, or infrastructure such as roads from erosion, or how to restore a wetland or river outlet so as to avoid floods during times of heavy rainfall.

Table 15 outlines the priority sites and different proposed mapping and/or monitoring activities:

Table 15. Priority sites and proposed monitoring/mapping activities.

SITE	WORK NEEDED				
Method→	**Beach profile**	**Monitor tides, currents, waves, sand movement**	**Monitor sedimentation**	**Bathymetry**	**LIDAR maps of coastal area (satellite)**
Frequency →	2x / year	Once / 5 yrs	2x / year	Once / 5 yrs	1x / year
MAHÉ					
North East Point	x	x		x	x
Baie Lazare	x	x		x	x
Anse La Mouche	x				x
Victoria Town				x	x
Pointe Larue			x	x	x
Anse aux Pins	x	x	x	x	x
Au Cap	x	x	x	x	x
Anse Royale	x		x		x
Anse Boileau	x	x	x	x	x
Cascade					x
Grand Anse Mahé					x
Anse Forbans					x
Roche Caiman					x
Mont Fleuri					x
Glacis					x
Anse Etoile					x
Les Mamelles					x
Port Glaud					x
English River					x
Bel ombre		x			x
PRASLIN					
Praslin in general				x	x
Grand Anse district lowlands	x				
Baie Ste Anne lowlands					x
Airport area					x
Anse Kerlan	x	x		x	x
Nouvelles Decouvertes			x		x
Anse St. Saveur – Anse	x	x			

Takamaka					
Au Cap Wetlands			x		x
Anse Gouvernement			x		x
Cap Samy			x		x
Cote D'Or	x	x	x		x
Anse La Blague,	x				
Anse Boudin,	x				
Anse Marie-Louise	x				
LA DIGUE					
La Passe	x	x	x	x	x

Source: TNA project

This list of sites vulnerable to coastal erosion and flooding was derived from several recent reports (Khan, 2015; JICA, 2013 and Mendez et al., 2013). The sites for beach profiling include several beaches on Praslin where monitoring was initiated in 2016 by the MEECC.

2.2.2 Identification of barriers to deployment of coastal mapping and monitoring

A multi-stakeholder approach was used to identify the root causes of the barriers hampering the adoption of coastal mapping and monitoring using LPA. The resulting PT is given in **Annex II**. Coastal mapping and monitoring can be classified as a non-market good consisting of non-tradable technologies that do not use market conditions for diffusion (Nygaard and Hansen, 2015). It is expected that the bundle of technologies will be implemented by government using either public or multi-lateral (donor) funding.

The PT in **Annex II** shows that the central problem is the lack of an evidence-based approach grounded in sound science to inform decision-making about coastal development, protection and restoration. The problem arises from three adjoining factors:

- The unavailability of scientific information about coastal processes and dynamics;
- Inadequate EIA legislation mandating scientific studies to inform decision making in coast development; and
- Ignorance among decision makers about the value of scientific information to support evidence-based policy decision making.

There are a host of financial, regulatory, technical, institutional and human capacity barriers that underpin the three adjoining factors, and these are discussed below.

2.2.2.1 Economic and financial barriers for coastal mapping and monitoring

As mentioned earlier, mapping and monitoring is a non-market public good that incurs high upfront costs for setting up, and relatively high recurrent costs for maintenance and upgrading. The specialised equipment and expertise to carry out longitudinal studies of coastal dynamics, mapping of risk areas, and monitoring of changes to the coast are costly. Further, dedicated human expertise is required in modeling and analysing high resolution satellite imagery. The work is tedious, and although there are some very skilled people in this area in Seychelles, most working for government, there is very limited government budgeting at present to cover the costs of equipment and human resources needed to efficiently and effectively undertake coastal monitoring and mapping.

Little monitoring and mapping of the coast is funded through government budgeting. Currently, these are sporadically financed through project grants, private developments or in-kind support from overseas partners such as the Indian Navy. The end result is that because the Government of Seychelles (GoS) does not invest in coastal monitoring or mapping, it owns very little data, and the data are fragmented.

Some of the information, such as high-resolution satellite imagery can be purchased from international geospatial suppliers. At present the government relies on project grants to cover these costs and investments in the acquisition of images are sporadic. Ideally, the government should budget to invest in high resolution images for the three main islands at least twice per year (once for each monsoon season). These images can be used to track changes over time, both on land and in the shallow coastal seas.

Light Detection and Ranging (LIDAR) data can be purchased to compile updated high resolution bathymetry maps. Again, investment in human resources is needed to coordinate this mapping. Bathymetry mapping at specific sites (**Table 15**) to measure coral degradation or changes in the seafloor near the coast requires high resolution data (a recent project implemented on Praslin recommends 2m resolution (Prosper, 2017), and needs to be done twice per year (once in each season) to measure changes and anticipate the impact of developments on the coast. Investment in this research area is needed to provide the information needed for EIA's on coastal development or protection projects in the coastal area led by the government and/or other partners. Investment in mapping and monitoring is also required to provide information that complement those generated in an ad hoc manner for EIAs on development projects (mostly private) in coastal areas.

There would need to be an initial significant investment in specialised equipment, software and satellite imagery. A recurrent budget would be required for maintenance and upgrades. The costs would primarily include the following:

- Measuring currents and waves: Bottom mounted ADCP units are effective for monitoring ocean dynamics near vulnerable beaches (Pandiam et al., 2010);
- Purchase of high resolution satellite imagery covering hotspot coastal areas of all three main islands –once per year, to create bathymetry and topographic maps ;
- Bathymetry: Multibeam echosounder (MBES) for ground truthing satellite imagery and updating bathymetry maps of coastal areas around the three main islands;
- Beach profiling: basic measuring equipment and installation of permanent beacons at hotspot sites, purchase of drones and basic drone mounted LIDAR technology to monitor sand dynamics on vulnerable beaches; and
- Computer hardware and software for data storage, analysis, modeling and mapping

2.2.2.2 Non-financial barriers for coastal mapping and monitoring

Limited understanding of science-based decision-making

Although the GoS has been aiming towards becoming a knowledge-based economy since 2014 (State House, 2014), this is not yet the case. Like the general public, many politicians have had limited exposure to climate science in general, let alone climate change impacts on coastal processes and this is true of many countries in the Western Indian Ocean (Francis, et al., 2015). Consequently, policy makers may not understand the need for better information about how climate change is affecting the coastline. They also might not be aware that coastal protection measures can sometimes cause further problems if a systemic approach, including integrated planning and sound scientific knowledge, is not adopted.

Furthermore, short political cycles favour short-term decision making at the detriment of sustainable development planning, including planning for the impacts of climate change and variability in general, and more specifically regarding impacts on coastal zones. Consequently, there is a bias towards implementation of quick solutions to life and infrastructure threatening problems such as incidents of flooding or erosion, and mostly in a reactive way. Planning for the avoidance of potential future problems, and undertaking the scientific monitoring required for putting in place measures that will minimise damage from climate change impacts in coastal areas, is not the norm, and not even a priority. There is an urgent need to increase policy-makers' understanding of the importance of science-based decision making for more effective long-term planning for climate change adaptation.

Civil servants making decisions about developments in the coast do have access to scientific advice, but may be prejudiced by other factors such as political influence or the need for urgent response to a critical situation of flooding or erosion. Without political commitment to science-based decision-making, it is unlikely that government will allocate more resources toward the expertise and equipment needed for long term and longitudinal studies of coastal processes. As discussed below, the focus of the TNA project will be on increasing awareness of the need for integrated, long-term planning as a means of galvanising political support for science-based decision-making. This is especially important since the long timeframe involved in anticipating future changes to the coast caused by climate change are not in sync with the short political cycles.

Weak legal framework for science-based decision-making

Private sector developments on the coast require Environmental Impact Assessments (EIAs) under the current laws of Seychelles (Government of Seychelles, 2016), including in some cases studies of coastal processes and modeling to show how wave action, currents, sand movement, sedimentation or other natural processes might change as a result of a development. However, in cases where coastal protection measures are being planned by government and take place in areas under multiple ownerships or on government property, or are a response to an urgent issue of flooding or erosion, decisions can be made in the absence of any scientific data to show the most effective course of action.

In a small country like Seychelles where many non-state actors are involved in coastal developments and implementation of coastal protection measures, pooling resources by sharing data can help reduce costs, avoid duplication and contribute to better understanding of coastal processes around Seychelles main inhabited islands. However, currently Seychelles has no legislation or guidelines in place that require or motivate non-state actors such as the private sector and civil society organisations to share data they have gathered regarding coastal processes. Frequently, civil society organisations who undertake research in the coastal sector do share their data and reports, but studies done by the private sector as part of the EIA process commissioned by developers are not shared, let alone the raw data. The EIA legislation does not require sharing of data with the government. MOU's, data sharing agreements, and incentives for data sharing can be explored by government to encourage data sharing for better decision making by policy makers and developers alike (NOAA, 2009).

Similarly, coastal research partners such as the Indian Navy (who undertook bathymetry studies in Seychelles waters in collaboration with the Seychelles Coast Guard) typically share reports and maps but not the raw data. There is currently no legal framework that requires the raw data regarding Seychelles coastal features to be made available to GoS by research partners, and collaboration agreements have not required sharing of data for coastal monitoring purposes. This could be resolved by the establishment of a simple protocol or data sharing agreement between the government of Seychelles and other parties, once the need is recognized.

Resistance to change

It is difficult for a government to justify investments in mapping and monitoring of the coast when the norm is to focus on short term, quick fix approaches. The methods used to calculate the return on investment ignore the high cost of potential future damage caused to the coast and coastal infrastructures due to poorly planned coastal protection measures that are not based on science. On the other hand, climate change requires long-term, systemic thinking.

The issue is compounded by the fact that uncertainties are inherent to climate change and climate variability, implying that their impacts also come with uncertainties. The lack of understanding or avoidance of the complexities associated with climate change and climate variability and short political cycles drive short-term decision-making that is characterised by investment in hard engineering solutions with tangible and quick results. However, these types of approaches often undermine the aesthetics of Seychelles' natural coastline, and can themselves cause further problems of coastal degradation if they are not well designed and do not take into account changing coastal dynamics.

In order to understand the future impacts of climate change and climate variability, there is a need to have sound analyses of the likely changes in climate and its variability. Given the relatively small geographical scale of the Seychelles, there is a pressing need to enhance human and institutional capacity to carry out downscaling of Global Circulation Models (GCMs) as discussed in the TNA Report – Adaptation (Government of Seychelles, 2017).

Network failures and limited institutional capacity

In Seychelles, there are several government institutions and programs that are responsible for different aspects of monitoring, mapping and modeling coastal processes and other information such as climate variability, with implications for addressing coastal degradation due to climate change. These are:

- Seychelles Coast Guard – has undertaken some bathymetry work and mapping in collaboration with international partners such as the Indian Navy;
- Ministry of Environment, Energy and Climate Change GIS Unit – has technical expertise for analysing coastal data, coordinating data sharing, generating maps, and some expertise for modelling of coastal processes (but overstretched human resources);
- Ministry of Environment, Energy and Climate Change Climate Adaptation and Management Section (CAMS) – has technical expertise for beach profiling, and a mandate (but limited human resources) for monitoring coastal degradation, leading coastal restoration projects addressing flooding and erosion, and advising on potential impacts of development projects along the coast;
- Seychelles Fishing Authority – has technical expertise for modelling currents, waves and other coastal processes; and
- Seychelles National Meteorological Authority (SMA) – has the mandate for monitoring SLR, rainfall, sea and air temperature, waves, and other meteorological parameters, and for modeling future climate change and climate variability. The SMA is also responsible to issue early warnings related to intense rainfall that can lead to flash flooding and landslides, intense winds (that can also produce high waves threatening the coastal areas) and cyclone warnings.

In addition, there are several projects underway, funded by the Global Climate Change Alliance (GCCA), the Adaptation Fund, UNEP, the Nature Conservancy, GEF and other donors, all of which include studies of coastal processes, and are generating data, maps and reports. Most of these projects, but not all, are being implemented by the Ministry of Environment, Energy and Climate Change and its various agencies.

In terms of non-state actors, several NGOs are also involved in studies of coastal processes and ecosystems, and while many are willing to share data, there is no clear focal point to manage and compile the data to get a more complete picture of how the coast is changing or might respond to changes whether they be from climate change or human developments.

Some studies are being undertaken by the private sector as part of the EIA process, but there is no institution with the mandate to request or compile copies of their studies on coastal processes or advocate for legislation requiring data sharing.

There seems to be a proliferation of organisations with some capacity for coastal mapping and monitoring. However, no one government institution is recognised or designated as the hub to coordinate all projects, information, and data, to analyse the information and generate reports on changing coastal processes that can be used by decision-makers to plan how best to protect the coast.

Limited human capacity
Over the past ten years, Seychelles has greatly increased the number of nationals with technical expertise in coastal mapping, monitoring and modeling. These individuals are generally interspersed among a wide range of institutions (as listed above) and some work as freelance consultants or for private companies. Generally, most of these experts are overstretched and none are focused exclusively on coastal monitoring and mapping, or compiling data from different sources, or generating models. The work is done on a case by case basis in response to developments or available funding for studies of a particular area of coastline.

As a result, while there is some technical expertise, it is not enough. There is a need for more training of local expertise, and also for building partnerships with overseas universities and research institutions that can bring in expertise and help train more Seychellois in the field of coastal mapping and monitoring. In some cases, it may be more feasible and economical for the government to hire international consultants for specialised areas of research that may be beyond the scope of local technical expertise.

At the same time, there should be some committed technical experts housed in one centralised location, devoted entirely to the task of compiling and collating information about coastal processes so that it is readily available for decision makers when planning coastal developments and measures for coastal protection.

Insufficient knowledge of climate science and coastal protection measures
In Seychelles, the public have a general understanding of the importance of climate change and how it will affect our islands. Individual cases of flooding and coastal erosion are often attributed directly to climate change in the media and in conversation, but with limited understanding of climate science and the time frames involved in climate change. In order to make informed decisions about tourism developments or infrastructure investments in the coastal zone, it is critical that decision-makers and planners have a very solid understanding of how our coasts are changing as a result of climate change, and how they will change in the future, thereby affecting any developments or infrastructure built today.

There is an ongoing need for more in-depth and targeted climate change education programs to help decision-makers understand climate change impacts, and how they can be measured and modeled to inform effective long-term planning. At the same time, improved media programs and climate information via websites can also provide a valuable source of information for the general public, potential developers, contractors and others to learn about how climate change and climate variability are changing coastal areas.

2.2.3 Identified measures for coastal mapping and monitoring

An OT that mirrors the PT was developed to identify possible measures to overcome the root causes shown in the PT for coastal mapping and monitoring (Nygaard and Hansen, 2015, Chapters 4 and 6). The OT is also shown in **Annex II**.

2.2.3.1 Economic and financial measures for coastal mapping and monitoring

There is need to provide funding to invest in coastal monitoring equipment, as well as computer hardware and software for storing and processing data. The equipment will be owned by whichever institution is designated by the Government of Seychelles to serve as the hub for monitoring and mapping (see section 1.2.3.2.1).

The recommended strategy is for the Government of Seychelles to apply for grant funding from the Green Climate Fund (GCF) to support initial investment into equipment needed. A GCF project proposal focused on climate change adaptation on the coastal zone has already been initiated and can integrate the recommendations from the TNA process. The Government of Seychelles will have to allocate budgetary funds to support the recruitment of a full-time coordinator and maintenance and storage costs of the equipment beyond the lifetime of the grant.

2.2.3.2 Non-financial measures for coastal mapping and monitoring

Build institutional capacity to map and monitor coastal processes

It is proposed that one national authority with existing capacity should be specifically designated as the hub for monitoring and mapping coastal processes, and generating reports to guide decision-making. This could be either the SMA, or the GIS unit of the MEECC. There would be a need for budget allocation and possible amendments to legislation regarding the mandate of the institution. The authority would be responsible for coordinating and harmonizing data between the different government and non-government stakeholders engaged in studies of coastal dynamics and ecosystems.

Improve legal framework to support science-based decision making

Two measures are proposed to improve the legal framework to support an evidence-based approach to policy decision-making, including:

- Revising the EPA in order to mandate sharing of data and reports generated by non-state actors with the national authority designated as the hub. It is understood that data generated for EIAs may be confidential, and it is proposed that such data are made available to government for the public good, and not necessarily for broad public access; and
- Revising the Town and Country Planning Act with respect to planning and/or building permit approval requiring scientific evidence that proposed developments on the coast and coastal protection measures will not have a negative impact on the coast, and that the measures are suitable for long-term protection.

Build human capacity and local technical expertise in mapping and monitoring

The measure to enhance human capacity in coastal mapping and monitoring contains several elements as follows:

- Allocate government funding for staffing and other operational costs to coordinate mapping and monitoring of coastal processes on a national basis with all of the stakeholders
- Employing at least one full time person to coordinate data management related to coastal processes and coordinate regular liaison and data sharing with all relevant stakeholders;
- Providing opportunities for student internships in government institutions and private sector organisations undertaking studies of coastal processes;
- Enhancing UniSey environmental science and IT curricula related to GIS, mapping, data management, modeling, etc.;
- Providing opportunities for Seychellois experts to work alongside international consultants undertaking studies of coastal processes at equivalent and fair pay rates; and
- Developing partnerships with overseas universities and research institutions engaged in data collection, mapping, monitoring and modeling related to coastal processes.

Provide training in climate science for decision-makers

In order to generate political commitment for supporting an evidence-based approach to climate change adaptation, it is proposed that policy decision-makers should be trained to understand the basics of climate science. Hence, it is proposed to develop short term training programs to help decision-makers (e.g. politicians, government planners, investment and finance advisors) understand the long term impacts of climate change and climate variability on the coast, and appreciate the need for science-based decision making to protect the coast over the long term.

Enhance Science & Technology education on a national level
In conjunction with enhancing the capacity of decision-makers to understand and deal with climate change and variability, it is necessary to also enhance the level of understanding of climate change impacts at all levels. Consequently, the following accompanying measures are proposed:

- Building capacity in the National Institute of Science, Technology and Innovation (NISTI) to further develop STEM (science, technology, engineering and math) education in schools at all levels;
- Developing and disseminating support materials and conduct teacher training to enhance climate change education in the curriculum, particularly in the science and geography programs for secondary and post-secondary schools; and
- Developing media programs to make climate science understandable and relevant to the general public.

2.2.3.3 Cost-benefit analysis of measures for coastal mapping and monitoring

The proposed measures are incremental relative to the baseline scenario – i.e. in the absence of TNA project implementation. It is also assumed that the absence of the measures will result in the status quo with none of the benefits calculated below in the case of measures being implemented. It is cautioned that there is no residual damage from extreme events when the measures are implemented.

Cost of measures
An indication of costs is provided below:

- Bathymetry and Lidar equipment for ground truthing (including maintenance and replacement costs) initial investment 2MSR, then SR 150,000 per year x 15= 2.25 MSR (prices online and estimates by Marc D'Offay). The total is therefore 4.25 MSR;
- Local expertise to undertake bathymetry surveys SR2 million per survey, every 5 yrs (x3) – i.e. total of 6 MSR (estimate by Marc D'Offay, and assuming coastline of 200km to be covered for 3 main islands);
- LIDAR surveys – SR800,000/yr x 15 yrs SR = 12MSR (based on 2000SR/km, twice per year x 200km – including rocky coastline to get a complete picture;
- Purchase of high resolution satellite imagery, once per year for 15 years @ US$9000/image covering 150 km^2, assume about 5 needed per year to cover 3 main islands US$ 45,000 per year = 9.2 MSR (exchange rate of SR 13.6 = US$ 1);
- Current and wave mapping – 1 sensor = SR 240,000 x 25 = 6 MSR x replacement every 5 ys x 3 = 18MSR;
- Local expertise to process data and produce maps SR 150K per year x 15 yrs = 2.25MSR;
- Training of local experts – 2.5 MSR (2 Masters degrees plus local workshops); and
- External expertise on numerical modelling of maps brought in from academic institutions or commercial organisations 5msr initial assistance, and repeated every 5 years to update maps = 15MSR.

The total cost for a 15-year period is, therefore, estimated at 69.2 MSR.

The value of benefits

The benefits to implementing this technology can be approximated in terms of avoided damages due to coastal flooding and erosion up until the year 2030. With better mapping and monitoring systems in place, the government and development partners will be in a better position to design and build coastal developments and protective measures that are effective in helping Seychelles adapt to the eventuality of heavy rains, sea level rise and storm surges caused by climate change, and will not accidentally exacerbate the problems as a result of poor design.

Estimated avoided damages for flooding incidents:

- Estimated cost per event of damages, based on Pointe Larue example SR 100 million, (GOS, 2013) – assuming one severe event every 3 years (5 events) total 500 MSR

Estimated Avoided damages for coastal erosion:

- Cost estimate based on damage to 100m stretch of road at Mare Anglaise: SR2.5 million x 15 sites = 30 million, also loss of tourism revenues for degraded beaches – estimate 100 MSR over 15 years (conservative), total 130 MSR

Over a 15-year period, the total benefit in terms of avoided damage is estimated to be 630 MSR. Also included under benefits are the advantages of the purchase of satellite imagery which can also be used for land use planning and other applications, if the images are shared among different government departments and other stakeholders.

Benefit-Cost Ratio (BCR)

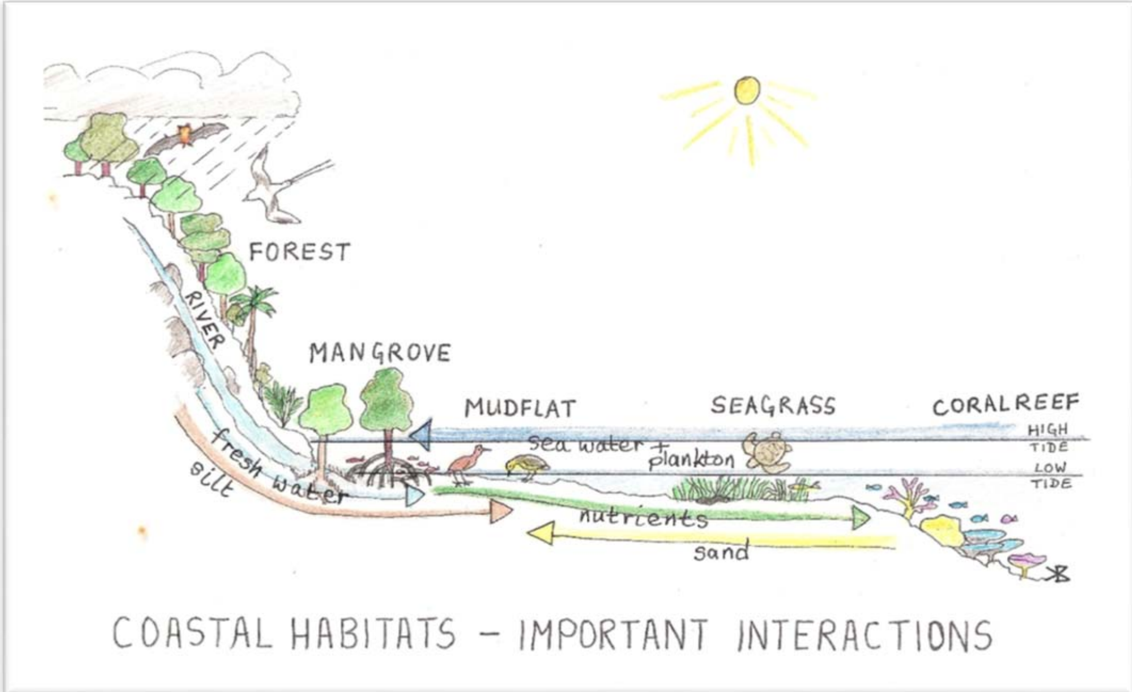
Using the above assumptions, the BCR = 9.1. However, two things should be noted to qualify this analysis. The costs do not include the cost of hard infrastructure to avoid damages, and the benefits assume that there are no residual damages once adaptation measures have been implemented. Consequently, the calculation of BCR for coastal mapping and monitoring should be carried out in conjunction with the implementation of other coastal adaptation technologies

2.3 Barrier analysis and enabling measures for Wetland Restoration

2.3.1 General description of wetland restoration

As described above, the Technology Working Group has recommended an EBA approach to wetland restoration that takes into account a more integrated approach to coastal rehabilitation that intersects with other ecosystems in close proximity such as dunes, beaches, rivers and river outlets. EBA refers to the conservation, sustainable management, and restoration of ecosystems to help people adapt to the impacts of climate change. This approach to adaptation has been endorsed by the Convention on Biological Diversity and widely promoted now by many international organisations working on climate change adaptation in the coastal zone, e.g. the IUCN, UNEP, the UNFCCC, the Nature Conservancy, the Indian Ocean Commission, as well as GoS.

The coastal zone of Seychelles (the narrow strip between the mountains and the reefs), includes diverse interrelated habitats including freshwater and brackish coastal marshes, mangrove swamps, rivers and river outlets, beaches, seagrass beds and coral reefs. In many instances, these habitats are all located within close proximity to each other, e.g. less than 1km apart, and the interactions between them are well documented (MFF, 2009). The diagram below (**Figure 6**) illustrates the interrelationships between these ecosystems in Seychelles.



Source: Courtesy of Katy Beaver, Plant Conservation Action Group
Figure 6. Illustration of interacting coastal habitats.

The principle underlying the EBA approach is the use of nature-based solutions to provide long term adaptation results (Andrade et al., 2011) that will benefit communities, rather than relying on hard engineering technologies. However, there are cases where ecosystems are degraded to the point where there is a need for a hybrid approach whereby nature-based adaptation structures (green infrastructure) are enhanced to some degree with hard engineering technologies (grey infrastructure) (Hale et al., 2009; Nature Conservancy, 2015; Sutton-Grier et al., 2015).

In the case of coastal wetlands, two main types can be found in Seychelles: freshwater marshes, and mangrove swamps. Freshwater marshes are formed when the river meanders and the water pools in low points at the back of the plateau. The vegetation in these freshwater marshes can include grasses, sedges, ferns as well as several tree species (including mangroves) that are water tolerant. As the river gets closer to the outlet to the sea, salt water enters and mixes with the fresh water at high tide, forming a brackish wetland characterized mainly by various species of mangrove. In times of heavy rainfall, these wetlands function as a sponge, absorbing water and slowly releasing it to the sea. Prior to human settlement, much of the coastal plateau would have been partially wet or flooded at times. However, to make use of this land, most of the freshwater marshes on the three main islands have been backfilled, drained, and fragmented by human activity including agriculture and more recently, the construction of roads and housing developments. As a result, their functionality as a means of absorbing heavy rains has been undermined and flooding incidents have occurred on occasion (see **Figure 7** and **Figure 8**).

Source: Seychelles News Agency
Figure 7. Flooding of streets on La Digue Island due to heavy rains.

Source: Seychelles News Agency
Figure 8. Flooding at Pointe Larue in 2013 cost the government an estimated SCR 100 million to repair damages.

Additionally, in some areas along the coast, there are scattered remains of mangrove forest as well as new mangroves which have formed in the lagoons created between the old shoreline and reclaimed islands just offshore. Coastal mangrove forests provide natural protection against flooding from storm surges and high tides, as well as sea level rise. Many of these forests were cleared to make way for human settlement as well, leaving some areas of the coast exposed to wave and tidal action, expected to worsen as a result of climate change.

Source: Courtesy of Sustainability for Seychelles
Figure 9. Community mangrove replanting at Port Launay.

In a recent study undertaken by Khan (2015) as part of the EBA South project funded by UNEP and China, several coastal wetlands were identified as potential areas for works to restore their functionality as defenses against climate change. Under this same project, a few pilot sites were chosen to initiate restoration works, but several others are still degraded. Similarly, the research undertaken by JICA (2013) identified sites prone to flooding and implemented some actions (using hard engineering solutions) to improve wetland drainage in 2012-13. Although wetlands have some measure of protection under Seychelles laws, conserving and restoring them is a challenge due to pressures for further coastal development, and having to coordinate multiple land ownership. There are some examples of coordination between different stakeholders: in an excellent example of private-public partnership, a local hotel at Port Glaud has been collaborating with the government, local community and an NGO to undertake mangrove conservation and restoration activities in the Port Launay Ramsar site (**Figure 9**).

In most cases, urgent problems of coastal flooding are addressed using hard engineering approaches, such as the reconstruction of river outlets in concrete, concrete drainage structures to guide run off of heavy rains from roads or housing estates, and walls along river banks to control flooding. In addition, heavy machinery is regularly used to desilt wetlands and river outlets that are still in a semi-natural state, to drain water that collects in the plateau after a heavy rainfall. In addition to blockage at the outlet by sand movement closing off the mouth of the river, wetland drainage is impeded naturally by branches, vegetation, but also significantly, rubbish of all sorts.

Wetland restoration in the context of Seychelles must be specific to each site (Henriette, 2016). However, generally, to restore freshwater wetlands often involves reconnecting the fragmented sections (to benefit biodiversity and improve drainage) through the installation and maintenance of culverts. Other actions required on many sites involve replanting and naturalizing the banks of the wetland areas to create a buffer zone, as well as regular removal of invasive species and rubbish. These actions are best done through a participatory planning approach involving the local community, property owners and other local stakeholders who are at risk from flooding and will benefit from the presence of a more functional wetland.

Although wetland restoration is much more challenging than other coastal adaptation technologies, it will help to address coastal flooding (precipitation, SLR, storm surges). In many places, coastal wetland restoration needs to be implemented alongside other measures such as river outlet improvement and setbacks, dune restoration, as well as improving current laws and policies regarding wetland protection.

While there is limited coastal land for restoring lost wetlands, there is great potential for working with private landowners and hotels to restore and improve the natural functioning of wetlands. This approach is already being tested on a small scale at Cap Samy on Praslin, whereby culverts are being put in place to restore hydrological flow through 300 hectares of mangroves fragmented by physical development (Henriette, 2016). However, there is a need for restoration works in wetlands at other sites, particularly those listed in **Table 16**, all of which are located on Praslin island, and can be considered as target sites for the TNA.

Table 16. Vulnerable coastal wetland sites for action under the TNA.

SITE					
Method→	Remove rubbish and invasives	Replant	Improve banks	Improve flow & drainage	coordinate property owners
Frequency →	Site specific	Site specific	Site specific	Site specific	Site specific
PRASLIN ONLY					
Baie Ste Anne village	x	x		x	x
Grand Anse village	x			x	x
Anse Kerlan				x	x
Nouvelles Decouvertes			x	x	x
Anse St. Saveur – Anse Takamaka		x	x	x	x
Au Cap Wetlands		x.		x	x
Anse Gouvernement		x	x	x	x
Cap Samy	x	x		x	x
Cote D'Or	x	x		x	x

Source: TNA project

2.3.2 Identification of barriers to deployment of wetland restoration

The PT for Wetland Restoration shown in **Annex I** was obtained using LPA and a multi-stakeholder process. Similar to coastal mapping and monitoring, wetland restoration based on EBA can be classified as a non-market good, as it employs non-tradable technologies that do not use market conditions for diffusion (Nygaard and Hansen, 2015). It is expected that wetland restoration will be implemented by government using either public or multi-lateral (donor) funding.

The PT in **Annex II** shows that the central problem is that coastal wetlands are degraded and not functioning as coastal defences against flooding and other climate change impacts. This problem is caused by three main factors:

- The lack of information about wetland hydrology, functions and restoration methods;
- Poor planning at present and historically; and
- Lack of coordination between multiple landowners and stakeholders.

The combination of these three factors gives rise to a situation where short-term planning and a lack of information favour the adoption of hard engineering solutions for coastal adaptation as opposed to wetland restoration. There are a host of financial, regulatory, technical, institutional and human capacity barriers that underpin the three factors mentioned above, and these are discussed below.

2.3.2.1 Economic and financial barriers for wetland restoration

Value of coastal land

Coastal land is very limited in Seychelles, which is why wetlands have been backfilled and drained in the first place. Even coastal properties that are prone to occasional flooding may have high value. Many of these properties are already occupied by infrastructure and tourism developments, and some are on government land, particularly where wetlands form part of riverways. There are currently no financial incentives in place to encourage property owners to either sell their land to government at a fair compensation for wetland restoration for the public good, or be compensated for wetland restoration works (or wetland conservation) at their own cost.

Limited investment in wetland restoration

Currently most wetland restoration projects are donor-funded and being implemented by the government or NGOs. The government budget for wetland restoration and conservation is non-existent, with any funds available being spent on dredging of wetlands and river mouths rather than wetland ecosystem restoration. There is a need for a commitment to government investment in wetland protection and restoration as a long-term strategy for flood proofing in the coastal zone. There is also a need to identify funds that can be used by NGOs and community groups to plan and implement coastal wetland restoration and maintenance project in collaboration with government. The new fund established by the government to support NGO projects has no clear commitment to climate change funding for civil society adaptation projects, and the other trust funds e.g. SEYCATT (Seychelles Conservation and Climate Adaptation Fund) and the ETF (Environment Trust Fund) both seem to be dysfunctional.

2.3.2.2 Non-financial barriers for wetland restoration

Lack of coordination between stakeholders

Most of the coastal wetlands that are currently being degraded, particularly on the island of Praslin, span properties that are owned and/or used by many different groups, including government, private residents, and hotel proprietors. Planning wetland restoration projects will involve multiple stakeholders, each having their own agendas, concerns and priorities. Bringing the stakeholders together to plan restoration projects, to contribute towards adaptation financing and participating in project implementation and monitoring and evaluation are examples of the many challenges facing the implementation of restoration projects.

Inadequate government policies and legislation regarding restoration of coastal wetland ecosystems

Seychelles' policies and laws regarding wetland protection and restoration are confusing and vague. The Wetland Policy (2011) is under revision but has no legal clout. The newly revised Environment Protection Act (2016) mentions that wetlands are important coastal ecosystems but has no specific wording related to their protection. The EPA does refer to the State Lands and River Reserves Act (1991) which defines a setback of 30 feet on each side of the river bank, within which no construction is permitted, but it is common to see construction within that zone alongside rivers and wetlands. The Town and Country Planning Act (1992), which guides all planning and building in the coastal zone, makes no reference at all to wetlands. Where legislation exists to protect natural ecosystems, there is a shortcoming in relation to its enforcement.

In short, although the wetland policy (2011) is under revision, and the legal framework guiding wetland protection and management is unclear, making it complicated to plan for acquisition of such lands or restoration projects connecting wetlands that are owned and/or shared by multiple users. Generally, the planning authority obtains input from many stakeholders including the Ministry of Environment when developments are planned adjacent to rivers, wetlands and dunes, but the legal framework is weak, meaning that exceptions are often made and coastal ecosystems become further compromised.

Lack of awareness among planners and policy makers of the need for long-term planning and natural coastal rehabilitation measures

Seychelles Climate Change Policy (2009) calls for the development and implementation of pilot projects on coastal ecosystem restoration to enhance coastal protection, but these have been very small scale and are still not the norm. Hard engineering measures are the most commonly adopted approach to deal with drainage and flooding mitigation, but these are not usually planned for future climate impacts – rather for dealing with immediate crises. Strategies are needed to change the mindset of planners, engineers and technicians, mainly employed in government posts that design and build coastal restoration projects. They are not familiar with or confident in the advantages of natural and ecosystem based approaches to protect the coast over the long term.

Limited literature and information on wetland restoration in island ecosystems using an EBA approach

Contributing to the above is the absence of good projects that showcase integrated restoration of coastal wetland ecosystems in conjunction with other nearby ecosystems. For small island states with limited land area, the physical topography of the coastal lands may be different from large mainland countries where wetlands are distinct ecosystems spatially separated from dunes for example. This is not only a problem locally but also globally, where the literature and even resource materials provided through the TNA process do not sufficiently address this integrated approach. Without information and evidence, it is difficult to convince decision-makers, planners and landowners of the need to use valuable coastal land for ecosystem restoration projects that will yield benefits over the long term rather than the short term. This underlines the importance of documenting and publishing the results of EBA coastal projects in small islands.

Limited Technical Expertise

There are several local experts in wetland conservation or policy but very few who have experience in wetland ecosystem restoration. There are no formal training courses focused on wetland restoration but there have been several short workshops offered through Mangroves for the Future projects and the IUCN international program, as well as the EBA South project in Seychelles (Henriette, 2016). Several people have taken part in wetland and mangrove restoration projects implemented under the EBA South project (Henriette, 2016) and another project implemented by Sustainability for Seychelles (www.s4seychelles.com). Most of the local technical staff working in coastal protection and infrastructure planning for the government are more familiar with hard engineering methods for dealing with drainage, flooding and silt removal.

Limited information on climate change and the importance of wetlands

From the level of schools up until the level of policy-makers, there continues to be a general lack of understanding of the importance of wetlands to the functioning of coastal ecosystems, and as a protection measure against flooding caused by climate change. In terms of schools, several resources have been produced and some children and teachers participate in wetland education activities, but this is largely as extra-curricular work. There is limited information about wetlands in the curriculum, and few opportunities, particularly in secondary and post-secondary education, to get students actively learning about wetlands. Adults, particularly landowners, decision-makers, planners and other stakeholders have generally not been exposed to education programs about wetlands except on television, where several good local documentaries have been aired by the Seychelles Broadcasting Corporation (SBC).

Weak institutional set up

Many of the most degraded wetlands with the greatest potential for restoration are located on Praslin Island. While the MEECC has a special unit designated for coastal adaptation including wetlands based on Mahé, this unit is short of staff with expertise specifically in wetland restoration and EBA and has a poor track record for managing or coordinating donor funded projects related to wetland conservation and restoration due to their staffing issues. The problem is compounded on Praslin where there are no specialists in coastal ecosystem conservation or restoration permanently based on that island. The upshot is that any works being implemented on Praslin have to be overseen by staff from the main island of Mahé, which can lead to delays and poor implementation, and make community and stakeholder engagement challenging. There are several reputable NGOs based on Praslin specialising in ecosystem restoration and there could be some agreement whereby the government provides funding for these organisations to carry out restoration works and formalises a working agreement through an MOU or contract.

2.3.3 Identified measures for wetland restoration

An OT or solutions tree that mirrors the PT was developed to identify possible measures to overcome the root causes shown in the PT for wetland restoration (Nygaard and Hansen, 2015, Chapters 4 and 6). The OT is also shown in **Annex II**.

Most of the identified measures would be coordinated and led by the government, with the Ministry of Environment, Energy and Climate Change (MEECC) taking the lead. However, there is a need for a multi-stakeholder approach, in recognition that already several civil society organisations are involved in wetland conservation and restoration projects along the coast.

2.3.3.1 Economic and financial measures for wetland restoration

Introduce financial incentives for property owners to promote wetland protection and restoration

Because many key coastal wetlands are partly or even fully located on private property, the government can explore financial incentives such as grants schemes, CSR or other tax breaks for businesses / hotels to pay for conservation and restoration of coastal wetlands on their property, particularly in vulnerable or hotspot sites. Another option to consider is for government to acquire such properties at fair compensation to the owners, in order to set them aside for the public good. In the case of the latter, the government would have to provide an assurance to the owners that the lands are being acquired in order to become protected areas. There would be a need for consultation with stakeholders to determine the most appropriate and attractive financial incentives, and to consider various options for financing such schemes, including public and donor funds.

Explore strategies to invest in wetland protection and fund coastal wetland restoration projects

Coastal wetland restoration can involve a number of cost items depending on the site, but these may include any of the following:

- Land acquisition (coastal land is valued at approximately SR4000/m^2 in Seychelles);
- Equipment and materials, including plants & nurseries, basic gardening equipment, contractors with machinery for unblocking debris and desilting, installation of culverts, geotextiles for rehabilitation of wetland banks or river outlets, in some cases may also need rock revetments to redesign river outlet (in cases where hybrid technologies are required);
- Community wetland clean up and removal of invasive species;
- Technical expertise in wetland restoration as well as engineering/hydrology in the case where improvements to hydrological networks is required; and
- Labour in the case of major works involving machinery and hydrology.

In order to cover the costs of the investments needed to restore key wetland areas targeted under the TNA, the Government of Seychelles will need to:

- Explore strategies for cost-sharing among stakeholders (different government agencies as well as landowners). This is related to the above measure involving financial incentives for private property owners, including the Corporate Social Responsibility Tax;
- apply to international donors and lending institutions for financial support (grants/loans) to cover costs of technical expertise and restoration works or equipment;
- Consider allocating more public funds to support wetland maintenance and technical support for restoration projects;

- Provide grant support for coastal ecosystem restoration projects initiated by NGOs and community groups; and
- Partner with universities and research institutions overseas to share costs of coastal EBA pilot projects and studies

2.3.3.2 Non-financial measures for wetland restoration

Improve institutional set up and coordination among stakeholders

EBA and wetland restoration, as has been mentioned above, is a multi-stakeholder venture and can only be successful if there is good coordination among stakeholders. Ideally, one institution is designated to act as a hub for planning and action, and a clearinghouse for the sharing of information. At present, this institution is the Wetlands Unit of the Ministry of Environment, Energy and Climate Change, based in the Coastal Adaptation and Management Section (CAMS).

There is an urgent need to improve the set up and functioning of this critical section of government for climate change adaptation in the coastal zone by ensuring that the staff have the technical expertise, knowledge and skills to guide coastal EBA works, to coordinate and communicate effectively with multiple stakeholders from within and outside of government, and to carry out work in enforcement of laws protecting wetlands. For works that are undertaken on Praslin Island, the MEECC could appoint a technical officer or consultant based full time on that island who can work with the existing stakeholders already engaged in wetland and coastal restoration works to provide technical support, coordination, and oversight of works being implemented.

Policy and legal reform

Three measures are proposed regarding policy and legal reforms to promote wetland restoration and protection:

1. Providing support for the strengthening of the national wetland policy and its integration into existing environmental laws and regulations concerning developments in or near wetlands and favouring EBA methods for wetland restoration;
2. Using EBA as a catalyst for new policy measures that adopt a multi-sectoral holistic approach and synergise with ongoing Integrated Coastal Zone Management (ICZM) initiatives (UNEP, 2010, 2016);
3. Defining and enacting laws for clear setbacks for construction next to wetlands and their associated rivers and river outlets; and
4. Strengthening institutional capacity for enforcement of coastal setbacks for construction near beaches.

Build technical expertise in wetland restoration and EBA and share knowledge with other SIDS

Several measures are proposed to enhance human capacity for coastal wetland rehabilitation using EBA. These are:

- Enhancing University of Seychelles (UniSey) environmental science curriculum on climate change and coastal ecosystem restoration;
- Providing internship opportunities for students to participate in all phases of wetland restoration projects planning and implementation;
- Bringing international expertise to work alongside and train local experts/staff;
- Providing funding support for Seychellois to undertake research, publish and share findings related to coastal wetland restoration projects at relevant regional and international conferences;
- organisation of an international conference on EBA in SIDS in Seychelles;
- Outsourcing ecosystem restoration projects to local consultants, companies and NGOs where capacity exists; and

- Enhancing coastal mapping, modeling and monitoring through their integration into coastal EBA restoration projects. This measure is supportive of (or supported by) the Coastal Mapping and Monitoring technology discussed above.

Improve awareness of climate change and EBA methods to protect the coast

The measures being proposed here are targeted at different audiences, from decision-makers and policy-makers and planners, to school children and community members. Communication is an integral part of enhancing capacity at all levels. The following measures are proposed to increase awareness on the interactions between climate change and coastal ecosystems, and EBA interventions that can be deployed to protect the coast:

- Training sessions specifically targeting policy makers and planners to help them understand the impacts of climate change, and the benefits of EBA approaches to protecting the coast, in comparison with hard engineering approaches;
- Climate change education is currently being integrated into the national curriculum albeit at a slow pace. Wetland conservation and/or restoration is taught mostly through extra-curricular activities. There is a need to do an inventory of the national curriculum to see where and how climate change adaptation, including EBA, can be integrated into core programs. This kind of learning must be complimented by opportunities for students and teachers to be engaged in real-life wetland restoration projects to protect the coast;
- Schools as well as communities and local businesses are key stakeholders in EBA projects and the process by which they are consulted and invited to participate is essentially an opportunity to learn wetland restoration by doing it;
- Media coverage and the creation of documentaries that can be shared through television and/or the web are also important tools for awareness raising that can be implemented alongside physical restoration works to enhance the public's understanding of how wetlands contribute to flood mitigation in the coastal environment;
- Developing media campaigns for the general public in order to promote greater understanding of climate change impacts on coastal areas, and how coastal ecosystems can help protect the coast;
- Developing posters and other teaching resources for schools and communities to promote greater understanding of coastal ecosystems;
- Developing and implementing a training program targeting decision-makers to help them understand ecosystem-based approaches to protecting the coast; and
- Offering site visits and open days to pilot project sites using coastal ecosystem-based restoration.

2.3.3.3 Cost-benefit analysis of measures for wetland restoration

CBA has been carried for the restoration of 10 wetlands over a 15-year period. Each site is expected to cover an area of 1 ha.

Cost of measures

The estimated costs of a wetland restoration project are as follows, based on information provided by TWG members:

- Mapping and modeling costs – about SR 50,000/site (i.e. SR 500,000 for 10 sites);
- Dredging / silt removal or other engineering works like culverts to connect fragmented sites – about 2 MSR /site (i.e. total of 20 MSR);
- Purchase of seedlings and plants at about SR50,000 per site (i.e. SR 500,000 for 10 sites);
- Replanting works SR 50,000 per site (i.e. SR 500,000 for 10 sites); and
- Post-implementation monitoring operations – SR 300,000/yr x 15 yrs = 4.5 MSR.

Total cost of about 26 MSR.

Benefits accruing from measures

The benefits of implementing this technology can be approximated based on avoided costs of dealing with a flooding incident. Based on the Pointe Larue wetland flooding damages that occurred in January 2013 (GoS, 2013) as a result of very heavy rains, the total damages to property and infrastructure were estimated by the Government of Seychelles to be about 100 MSR, although this figure does not include all ecosystem services given that many are difficult to monetise. The area where the flooding occurred was historically a coastal wetland but which is now populated by houses, schools, a sewage treatment plant and has thus been largely infilled, fragmented and compromised. Furthermore, the wetland/river outlet was altered in the 1970s during the construction of reclaimed land for the airport and road in the same area.

For the purposes of the TNA, it can be assumed that 3 such flooding events are likely to occur over 15 years. These events will carry a total cost of damage equal to 300 MSR.

Benefit-Cost Ratio (BCR)

The BCR (without discounting) for the proposed measures is estimated at 11.5 revealing that the benefits accruing from measures far outweigh their implementation costs. It assumed here that there is no residual damage arising from flooding events once wetlands have been restored. As an example, if residual damage were 25% with wetland restoration, then the BCR would be 8.7. It has not been possible in the TNA project to estimate the value of residual damage. A generic BCR can be written as:

$$BCR_{residual\ damage} = BCR_0 \times (1 - fraction\ of\ residual\ damage) \qquad \text{Eq(1)}$$

Where, BCR_0 = 11.5, and

fraction of residual damage = residual damage as a fraction of total damage.

2.4 Barrier analysis and enabling measures for integrated coastal rehabilitation, including dune restoration

2.4.1 General description of integrated coastal rehabilitation

Coastal degradation due to erosion of beaches and dunes is taking place on all three of the main populated islands of Seychelles (Mahé, Praslin and La Digue), and the damage to infrastructure, particularly property and roads but also buildings, is already evident (**Figure 10**). As has been already discussed, urgent problems are addressed predominantly using hard engineering approaches, (such as the reconstruction of river outlets in concrete, seawalls, groynes, and rock revetments) to reclaim lost land and halt destruction of roads due to beach erosion. Such measures are costly, and at times have unintended effects including the exacerbation of erosion, and/or sand accretion in another area. These measures also undermine the aesthetic beauty of Seychelles’ beaches and limit access and use of the beaches by tourists and residents alike.

Source: Courtesy of Sustainability for Seychelles
Figure 10. Erosion on Mahé at Bel Ombre.

Dune restoration has been tried by the government in combination with the construction of timber piling and even rock revetments in some places. This technology has great interest due to the added social benefits of providing additional space for people to enjoy the beaches, as well as an opportunity for revegetation along coastal areas. In many places, the potential for dune restoration is restricted by the presence of a road along the top of or just behind the dune. There is need for more research to design dune restoration projects that are effective and tailored to the specific locations where they are needed, with input from an improved mapping and modelling capacity in the country. Furthermore, dune restoration can be combined with other soft and hard technologies, including wetland restoration, river outlet improvement and coral reef restoration. Along the entire west coast of Praslin starting from Anse Kerlan down to the junction with the Vallee de Mai road is severely eroded, as are many sections of the Cote d'Or/ Anse Volbert road. In the case of the latter, work on river outlet improvement and wetland restoration can be planned hand in hand with some dune restoration works for a more integrated approach.

Over the last several years, there have been a number of attempts to use a softer engineering approach to protecting and rehabilitating beaches. For example, the government has used timber piling (**Figure** 11 and **Figure 12**) and a combination of rock revetment and dune replanting to control beach erosion in a more natural and aesthetically pleasing way (JICA, 2013) at several sites including Anse Royale, Anse Boileau and Anse La Mouche on Mahé, and Cote d'Or on Praslin. Several community groups in collaboration with local NGOs, businesses, hotels and the government have participated in mangrove and coastal replanting measures (S4S, 2016) and the installation of bollards (**Figure 13**) to prevent parking along the dunes, e.g. at Anse Royale, Mahé. Coral reef restoration projects near Praslin Island have been implemented by NGOs and government, and are showing signs of success (Reef Resilience, 2016).

Source: Seychelles MEEC (http://www.gcca.eu/national-programmes/africa/gcca-seychelles-climate-change-support-programme)

Figure 11. Timber piling to control coastal erosion at Anse Boileau on Mahé.

Source: https://id.pinterest.com/pin/410390584776215345/?lp=true

Figure 12. Timber pilings at Cote D’Or, Praslin.

Source: Courtesy MEECC

Figure 13. Bollards installed to protect dune at Anse Royale beach.

There are several pilot projects currently being implemented by GoS using an EBA approach to coastal protection (Government of Seychelles, 2017), and these are being implemented in various sites on all three main islands as shown in **Table 17**. These projects cover a range of strategies including replanting of mangroves, connecting and restoring fragmented coastal wetlands, coral reef restoration, dune restoration and river outlet improvement. However, each EBA action is taking place in isolation and although the dunes, wetlands and coral are in close proximity, none of the actions currently implemented is taking an integrated approach. Local experts in the field recognise that this is a shortcoming in the approach taken so far, and there is consensus that Seychelles needs to start addressing EBA more holistically (Technology Working Group, Coastal Zone). There is an urgent need for pilot projects that can serve as a case study to convince decision-makers to adopt integrated EBA measures as an effective long-term strategy to protect the coasts, and maintain the integrity and aesthetic beauty of Seychelles' coastal areas.

Table 17. List of EBA projects in the coastal zone.

EBA South (UNEP/GEF/ China) "Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries"	Mahé Island: Anse Royale, East Coast lagoons – Cascade to Roche Caiman and Petit Barbarons Praslin Island: Cap Samy, Cote D'Or, Kot D'Hauban (Anse Gouvernement), La Pointe (Anse St. Sauveur to Anse Takamaka), Mare du Ranteau (Au Cap), Nouvelle Decouverte	This project is ongoing and focuses on wetland EBA in the coastal zone. Some of these wetlands are in areas near eroded beaches as well.
EBA Watersheds (UNDP/Adaptation Fund) "Ecosystem Based Adaptation to Climate Change in Seychelles"	North East Point	Ongoing: Integrated shoreline management plan being developed. Submerged breakwater and possibly coral reef rehabilitation planned, bathymetry and other coastal dynamics studies underway, also some studies done on adjacent wetland and outlet.
EBA Coastal (UNEP) "Building Capacity for Coastal EBA in SIDS"	Anse Kerlan, Praslin	Bathymetry maps completed of entire Praslin, coral reef rehabilitation planned
Anse Kerlan Avangard	Anse Kerlan, Praslin	Ongoing/stalled but detailed studies completed

Community Group (GEF/SGP)		(bathymetry, currents)
La Digue GCCA+ coastal adaptation project	La Passe, La Digue	Ongoing - integrated shoreline management plan being developed, drainage redesigned, and beach berms redesigned and coastal planting to be done to protect beach.

Source: TNA project

Bearing in mind some of the EBA projects already taking place on some vulnerable beaches in Seychelles, it is proposed that the TNA project focus on the sites listed in the **Table 18**. The physical locations of these sites are shown in **Figure 14** and **Figure 15**.

Table 18. Dune rehabilitation works proposed as target sites under the TNA project.

SITE					
Method→	Timber piling or other soft engineering work	Planting & Install bollards	River outlet improvement	Coral reef restoration	coordinate property owners
Cote D'Or, Praslin	x	x			
Grand Anse Praslin	x	x			x
Baie Lazare, Mahé	x	x	x	x	x
Beau Vallon, Mahé		x	x		x

Source: TNA project

The JICA study (2013) identified the four most vulnerable beaches on the three main islands: Anse Kerlan (Praslin), North East Point and Baie Lazare (Mahé) and La Passe (La Digue). La Passe on La Digue and North East Point on Mahé are both being sufficiently addressed under the EBA projects listed above. The severe erosion problem at Anse Kerlan is currently being addressed through hard engineering solutions (the construction of new groynes) as well as a coral reef restoration project being undertaken under a UNEP funded EBA project (mentioned above) and rock revetments have been put in place under a community group project.

The remaining vulnerable sites recommended for action under various reports (JICA, 2013, Mendez et al., 2013, Khan, 2015) but not being sufficiently addressed under any existing project include Cote d'Or and Grand Anse on Praslin, as well as Baie Lazare and Beau Vallon on Mahé. Of these, the Baie Lazare site is rated the most critical (JICA, 2013) as shown in **Table 18**.

One of the EBA projects being implemented by government has already generated maps and data about coastal processes around Praslin Island, which can provide key information for any dune rehabilitation projects planned for beaches on Praslin.

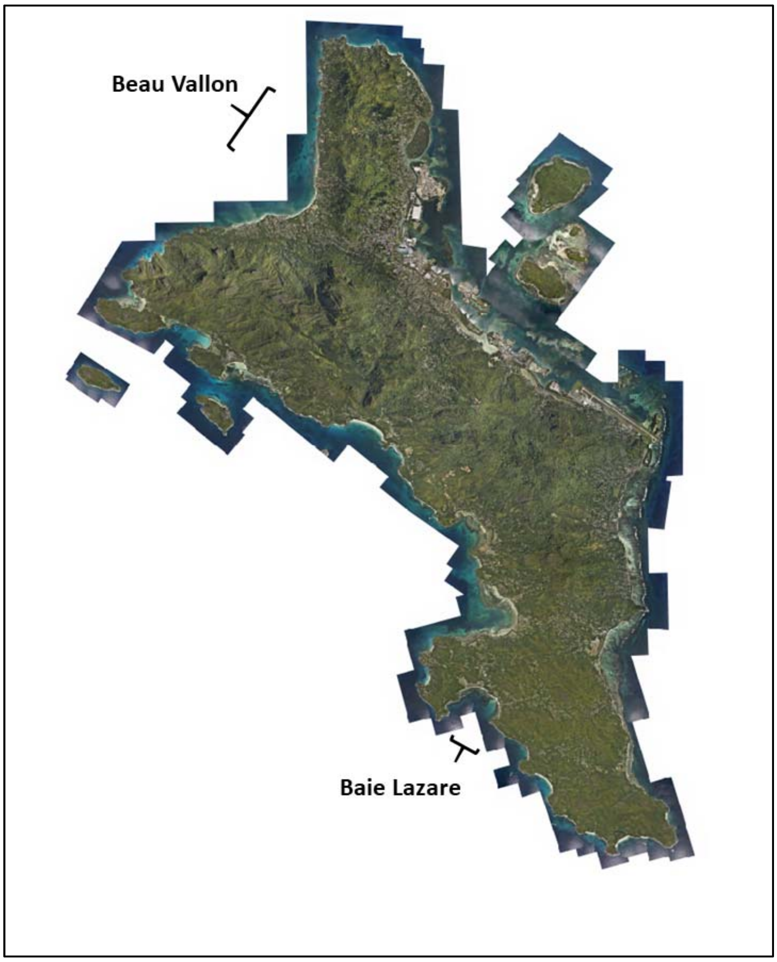


Figure 14. Map of Mahé island showing the location of the proposed sites**.**

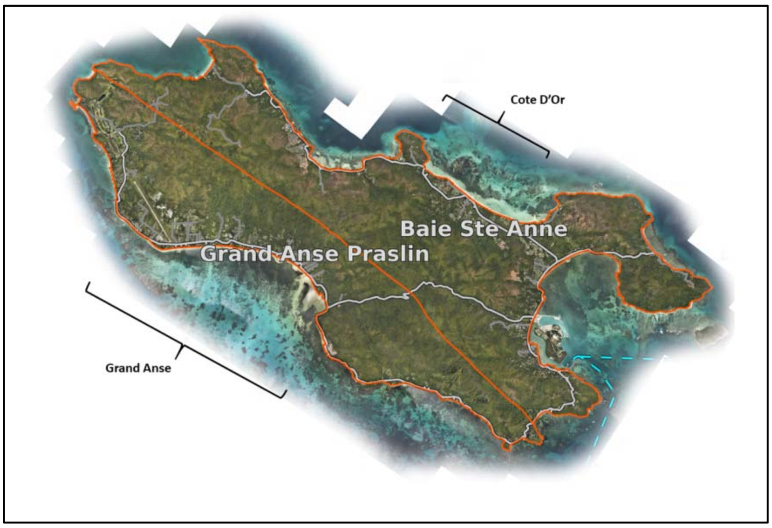


Figure 15. Map of Praslin Island showing the proposed sites.

In addition to undertaking dune rehabilitation work on the beach itself, it is advisable to also consider the stresses that lead to beach degradation, including increased wave action caused by coral reef dieback. Coral reef rehabilitation is the act of partially or, more rarely, fully replacing structural or functional characteristics of a coral reef ecosystem that has been diminished or lost, or the substitution of alternative qualities or characteristics than those originally present with the proviso that they have more social, economic or ecological value than existed in the disturbed or degraded state (Edwards & Gomez, 2007).

The main objective is to build up the height of the reefs to enhance their ability to reduce wave energy reaching the shore under current climate change, and in anticipation of future sea level rise (SLR). This technology combines the application of physical structures such as boulders on top of an existing coral reef, with enhancement of natural coral restoration efforts.

Usually coral reef rehabilitation takes two forms (Edwards & Gomez, 2009):

1. *Physical restoration of reef structures* – This is done in instances of damage to reefs and the need to restore their physical structure to enhance protection of the coastline against erosion. In certain circumstances, completely artificial reefs are created offshore to enhance coastal protection and to provide habitat for marine life. Physical restoration can be done using large boulders (usually limestone), or designed concrete modules. Large boulders can be used on rubble beds to diminish further damage to existing coral. These physical rehabilitation methods are hard engineering responses, which require the involvement of experienced coastal engineers with excellent technical expertise regarding wave action, sand movement and currents; and
2. *Natural rehabilitation* - In this case, coral recruits are grown and planted on structures made of metal, cement or other materials, to help speed up recovery of coral reefs in areas where they have been damaged by storms, bleached, blasted, broken by anchors or other events. Coral species are specially selected for their resilience in terms of rapid growth and also resistance to bleaching.

Generally, coral reef rehabilitation by natural means is a very long-term process and needs to be coupled with efforts to resolve the human-made problems that caused the coral reef damage in the first place. In many cases, coral reef rehabilitation is done by combining physical and natural reef rehabilitation methods. In Seychelles, currently there are several examples of coral reef restoration being undertaken as a climate change adaptation exercise to protect the coast, one being the Reef Rescuers project being implemented by Nature Seychelles (). Additionally, at North East Point a submerged breakwater is planned under an EBA project in order to encourage coral growth and slow down erosion on the beach, and a similar initiative is now being planned for Anse Kerlan on Praslin Island under a different EBA project.

On one of the sites proposed for action under the TNA, at Baie Lazare, it is proposed to combine dune restoration methods onshore with coral reef restoration offshore.

Source: www.natureseychelles.org

Figure 16. Illustration of coral reef restoration in Seychelles**.**

2.4.2 Identification of barriers to deployment of integrated coastal rehabilitation

The PT for Integrated Coastal Rehabilitation shown in **Annex II** was obtained using LPA and a multi-stakeholder process. Similar to the other technologies being proposed for the coastal zone sector, dune rehabilitation can be classified as a non-market good, consisting of a bundle of non-tradable technologies that do not use market conditions for diffusion (Nygaard and Hansen, 2015). It is expected that the bundle of technologies will be implemented by government using either public or multi-lateral (donor) funding.

The PT in **Annex II** shows that the central problem is that beach protection measures are over-reliant on hard engineering solutions. The problem is given rise by two main factors:

- The lack of information about soft engineering alternatives and EBA approaches; and
- Poor planning and emphasis of short term impact of coastal protection measures.

The combination of these two factors gives rise to a situation where short-term planning favours the adoption of hard engineering solutions for coastal adaptation, and this is particularly evident when it comes to protecting beaches. There are a host of financial, regulatory, technical, institutional and human capacity barriers that underpin the two adjoining factors, and these are discussed below. These barriers have multiple overlaps with those discussed in the previous section which focused on wetland restoration.

2.4.2.1 Economic and financial barriers for integrated coastal rehabilitation

Value of beaches

As previously mentioned, coastal land is in high demand in Seychelles, and many of the vulnerable beaches are vulnerable because they are both prone to erosion and located on sites of intense economic development and infrastructure such as roads. While the area of the beach up to the high tide water mark is technically public property, the dune which is located above the high tide water mark is subject to private ownership, and in the case of many beaches, multiple ownership along its length. Although beaches are all vulnerable to future SLR, these properties continue to be of very high value, at approximately SR4000/m^2. There are currently no financial incentives in place to encourage property owners to either sell their land to government at a fair compensation for rehabilitation of the dune and surrounding area for the public good, or be compensated for dune rehabilitation works implemented at their own cost.

Limited public investment in dune rehabilitation through EBA methods

Currently most dune rehabilitation projects using an EBA approach are donor-funded, while hard engineering approaches (such as rock revetments and groynes) are paid out of the government budget or with donor funding. Most of the projects are being implemented by the government who contract private companies to do the engineering and construction work. The government budget for EBA approaches to dune rehabilitation and maintenance is very limited, with no commitment to natural methods or to consistent monitoring and mapping of beach dynamics in vulnerable areas. While some of this work can be implemented in collaboration with NGOs and community groups there is no reliable fund to support this work, although the proposed SEYCATT program may soon provide some funds.

2.4.2.2 Non-financial barriers for integrated coastal rehabilitation

Many of the barriers that dune restoration faces within the larger ambit of EBA are similar to those faced by integrated wetland restoration. The similarities imply that there are synergies between these soft adaptation technologies.

Lack of coordination between stakeholders

As discussed earlier, beaches in Seychelles are used and/or owned by multiple land stakeholders, including government, private owners, the community, and hotel proprietors. Planning dune rehabilitation projects will have to involve these multiple stakeholders, each having their own agendas, concerns and priorities. At present there is no one agency with the experience or mandate to bring stakeholders together to plan restoration projects, to secure financing and to implement and monitor restoration activities and their impact.

Uncertain government policies and legislation regarding coastal ecosystems

The policy framework guiding dune rehabilitation is non-existent, and the legal framework (Environment Protection Act, 2016, Town & Country Planning Act, 1992) regarding restoration works in coastal areas is confusing and vague. There is a policy guideline for a 25m setback from the high tide water mark for all new builds along beaches, but this is not a law, and in some cases insufficient. There is no written policy to guide planners towards the use of soft engineering methods over hard engineering, although the MEECC has in recent years begun to explore some of these methods in public sites. Where the legislation exists to protect natural ecosystems, there is a shortcoming in relation to its enforcement.

Generally, the planning authority obtains input from many stakeholders including the Ministry of Environment when major developments are planned adjacent to beaches and dunes, but the legal framework is weak, meaning that exceptions are often made and coastal ecosystems become further compromised.

Lack of knowledge and confidence in natural coastal rehabilitation measures

Seychelles Climate Change Policy (2009) calls for the development and implementation of pilot projects on coastal ecosystem restoration to enhance coastal protection, but these have been very small scale and are still not the norm. Hard engineering measures are the most commonly adopted approach to deal with urgent beach erosion issues caused by storms and wave action, but these are not usually planned for future climate impacts. EBA or hybrid methods that have been attempted have been designed to deal with an existing problem, not to prepare and adapt in anticipation of problems that will likely arise within the next 15 years. Strategies are needed to change the mindset of planners, engineers and technicians, mainly employed in government, who design and build coastal restoration projects. They are not familiar with or confident in the advantages of natural and ecosystem based approaches to protect the coast over the long term, nor with the need to monitor and understand coastal dynamics to inform coastal restoration planning. Part of the problem is that they may also not even be familiar with climate change, its impacts, and the specific projections that have been made for Seychelles regarding erosion due to sea level rise and storm surges such as outlined by Mendez et al. (2013).

Contributing to the above is the absence of good projects that showcase successful integrated restoration of coastal ecosystems. This is not only a problem locally but also globally, where the literature and even resource materials provided through the TNA process do not address this integrated approach needed for small island developing states. Without information and evidence, it is difficult to convince decision-makers, planners and landowners of the need to use valuable coastal land for ecosystem restoration projects that will yield benefits over the long term rather than the short term.

Limited Technical Expertise

There are a few local experts in ecosystem restoration but few if any who have had the opportunity to plan and implement integrated approaches to rehabilitating dunes. There are no local training courses focused on integrated coastal ecosystem restoration but there are several informal and formal programs on specific ecosystems such as coral reef restoration (www.natureseychelles.org), and some stakeholders have had the opportunity to participate in coastal replanting measures at Anse Royale such as school wildlife clubs. Most of the local technical staff working in coastal protection and infrastructure planning are more familiar with hard engineering methods for dealing with urgent problems of beach erosion due to wave action, but even so there are currently no government staff qualified in coastal engineering, and there are only two individuals in the country (in the private sector) who have expertise in this area.

Limited information on climate change and the importance of coastal ecosystems
Despite many efforts at climate change education through school extracurricular programs and media programs for the public, people are still not sufficiently aware of how urgently Seychelles needs to start planning for future impacts of climate change. The public are not making the link between healthy coastal ecosystems and future protection against sea level rise and storm surges. As discussed earlier under wetland restoration, there is a need to upgrade climate change education at all levels, from primary education to post-secondary, as well as develop programs for different stakeholder groups, including policy makers and landowners or coastal hotel managers and owners.

Weak institutional set up
The CAMS unit in the MEECC has the mandate to plan and implement coastal protection measures but the unit has limited staff with expertise and experience, and they are generally understaffed. When it comes to implementing projects on Praslin or La Digue the issue of institutional support is even more challenging with no permanent staff with coastal restoration expertise based on these islands. The upshot is that any works being implemented on Praslin have to be overseen by staff from the main island of Mahé, which can lead to delays and implementation problems, and make community and stakeholder engagement challenging. There is no permanent formal structure for coordinating stakeholders and working in partnership with civil society groups and the private sector, or even other government agencies. Existing staff for monitoring beaches and data analysis are overstretched and as a result there is a lack of consistency and follow up when dealing with erosion problems or projects.

2.4.3 Identified measures for integrated coastal rehabilitation
An OT that mirrors the PT was developed to identify possible measures to overcome the fundamental challenges shown in the PT of over reliance on hard engineering methods to safeguard beaches and dunes (Nygaard and Hansen, 2015, Chapters 4 and 6). The OT is shown in **Annex II**.

Most of the identified measures would be coordinated and led by the government, with the Ministry of Environment, Energy and Climate Change (MEECC), particularly the Climate Adaptation and Management Unit, taking the lead. However, actions taken at specific sites would involve multiple stakeholders to participate in all aspects of planning, implementation, monitoring and evaluation.

The measures listed in this section are very much aligned with those discussed for the previous section for wetland restoration. This is because these coastal ecosystems are located in close proximity to one another, and the reasons for their degradation and over reliance on hard engineering vs ecosystem based adaptation solutions to protect the coast, are very similar in both cases.

2.4.3.1 Economic and financial measures for integrated coastal rehabilitation
Introducing financial incentives for property owners to promote dune rehabilitation and conservation and restoration
In cases where degraded beaches are partly or even fully located on private property, the government can explore financial incentives such as grants schemes, CSR or other tax breaks for businesses / hotels to pay for conservation and restoration of dunes on or adjacent to their property, particularly in vulnerable or hotspot sites. Another option to consider is for government to acquire such properties if they are not yet developed, at fair compensation to the owners, in order to set them aside for the public good. In the case of the latter, the government would have to provide an assurance to the owners that the lands are being acquired in order to become protected or public areas permanently. Before deciding on the best financial incentives, there would be a need for consultation with stakeholders to

determine the most appropriate and attractive options, and to consider various options for financing such schemes, including public and donor funds.

Exploring strategies to invest in coastal conservation and dune rehabilitation projects
Coastal ecosystem conservation and rehabilitation can involve a number of costs depending on the site, but these may include any of the following:

- Land acquisition (beach front land is valued at approximately SR4000/m^2 in Seychelles);
- Equipment and materials, including plants & nurseries, basic gardening equipment, in some cases may also need rock revetments or timber piling to redesign river outlet (in cases where hybrid technologies are required), contractors with machinery for digging and installing timber piling and or rocks, geotextiles for rehabilitation of dunes;
- stakeholder engagement events and planting/volunteer actions;
- Education and awareness program on climate change, coastal ecosystems and how to protect the dunes;
- Technical expertise in dune rehabilitation design /engineering and ecological expertise related to both dune ecology and offshore ecosystems that protect the coast such as coral reefs /restoration;
- Labour for reconstruction of dunes, diving for coral reef restoration, planting, etc.

The strategies to cover the costs of the investments in dune restoration are the same as those proposed for integrated wetland restoration.

2.4.3.2 Non-financial measures for integrated coastal rehabilitation

Improving institutional set up and coordination among stakeholders
Please see discussions in section 2.3.3.2.

Policy and legal reform
Three measures are proposed regarding policy and legal reforms to promote the protection of beaches using dune rehabilitation:

- Providing support for the strengthening of the Environment Protection Act and its enforcement in terms of protection and rehabilitation of dune vegetation, and favouring EBA methods for coastal protection along beaches.
- Using EBA as a catalyst for new policy measures that adopt a multi-sectoral holistic approach and synergise with ongoing Integrated Coastal Zone Management (ICZM) initiatives (UNEP, 2010, 2016) and the soon to be revised National Climate Change Strategy; and
- Enact the existing planning guideline for construction set back at 25m or greater (upgrade from its current status as planning guideline to law).

Build technical expertise in integrated EBA and dune rehabilitation and share knowledge with other SIDS
Several measures are proposed to enhance human capacity for coastal rehabilitation using EBA. These are identical to the measures suggested for wetland restoration in the previous section.

Improve policy and decision-makers understanding of EBA and soft engineering methods to protect the coast
To help policy and decision makers understand the long-term impacts of climate change, and the multiple benefits of protecting and restoring coastal ecosystems as an adaptive measure, it will be necessary to invest some resources into training programs targeting this group specifically. These include:

- Training sessions specifically targeting policy makers, senior engineers and planners to help them understand the impacts of climate change, and the benefits of EBA approaches to protecting the coast, in comparison with hard engineering approaches; and
- Workshop and site visits for politicians focused on climate change, impacts on the coast, predictions for Seychelles, and measures to protect the coast

Improve awareness of climate change and EBA methods to protect the coast
As mentioned above (section 2.3.3.2), the EBA approach favours multi-stakeholder engagement. Hence, there is a need to enhance human capacity in EBA for coastal protection and restoration among all the stakeholders. Communication is an integral part of enhancing capacity at all levels. As a complement to the previous set of measures that seek to build technical expertise and policy-makers understanding, the following set of measures will promote learning among other stakeholders. The measures being proposed here are targeted at different audiences, from children to adults and range from dissemination of information to engagement in actual projects:

- Climate change education is currently being integrated into the national curriculum albeit at a slow pace. Many schools have been involved in extracurricular projects and initiatives focused on climate change and the coast (e.g. the Sandwatch program www.sandwatch.ca) but these only target a small number of individuals. There is a need to redo an inventory of the national curriculum to see where and how climate change adaptation, including EBA, can be integrated into core programs. This kind of learning must be complemented by opportunities for students and teachers to be engaged in real-life dune rehabilitation projects to protect the coast;
- Holding information sessions to keep stakeholders involved in and aware of restoration plans. These work sessions will also provide opportunities for stakeholders to give inputs in participatory and collaborative approaches to designing, planning, implementation, and monitoring and evaluation of coastal restoration projects;
- Holding training sessions on current and future climate change and variability, the impacts of coastal areas, and integrated coastal adaptation, including hands on training in restoration methods grounded in EBA;
- Creating public spaces for sustainable use and enjoyment of restored coastal habitats as a means of demonstrating to the general public of the benefits of integrated approaches to coastal protection and restoration.
- Conducting coastal restoration work by engaging schools, communities and other stakeholders. This measure is a no cost approach that is already practiced in Seychelles. It is a cost-effective means to enhancing community understanding and capacity in EBA;
- Media coverage and the creation of documentaries that can be shared through television and/or the web are also important tools for awareness raising that can be implemented alongside physical restoration works to enhance the public's understanding of dune dynamics and how they contribute to protecting the coast;
- Developing media campaigns for the general public in order to promote greater understanding of climate change impacts on coastal areas, and how coastal ecosystems can help protect the coast;
- Developing posters and other teaching resources for schools and communities to promote greater understanding of coastal ecosystems; and
- Offering site visits and open days to pilot project sites using coastal ecosystem based restoration.

2.4.3.3 Cost-benefit analysis of measures for integrated coastal rehabilitation

The economic analysis has been carried out for the rehabilitation of dunes at 10 different sites each of average length of 100 m, and one site with area 10 ha at Baie Lazare for coral reef rehabilitation.

Cost of measures

The costs of implementing dune rehabilitation projects will vary from site to site depending on the scale of the project, actions needed as well as its location (site conditions). However, an approximation of the costs of rehabilitation works can be estimated as follows, based on estimates from the TWG and available literature:

Costs

The cost elements for dune restoration work are:

- Timber piling and geotextiles to stabilize dune – SR 5,000/m –(ref. JICA and CAMS);
- planting new dunes with vegetation – SR 1000/m;
- Installation of bollards to restrict vehicle access – SR 1000/m;
- Construction of boardwalks for pedestrian access SR 50,000 per boardwalk (CAMS);
- Construction of alternative parking areas for vehicles – SR 50, 000 per site;
- Public awareness and engagement SR100,000 per site;

Assuming that each typical site for rehabilitation has an average length of 100m, the total cost using the above estimates is ~ SR 900,000 per site. If one such site is rehabilitated every year over a period of 15 years, the total cost is expected to be ~SR 13,500,000 or 13.5 MSR.

Additional cost of sand recharge will likely be needed. At an average of SR100/tonne, and 3000 tonne per year for all the sites, the total sand recharge cost over 15 years is ~ 4.5 MSR.

Regarding coral reef rehabilitation, the following costs are expected:

- Major physical restoration of reefs costs in the order of US$100,000 –1,000,000's per hectare
- Low-cost transplantation appears to cost about US$2000 –13,000 per hectare. With more ambitious goals this rises to about $40,000 per hectare (Edwards & Gomez, 2007)
- For Seychelles, natural coral reef restoration is estimated at US$ 10,000/ha (Reference: N. Shah, Nature Seychelles), but for a combination of natural restoration and physical restoration using local boulders or other structures the internationally standard cost of US$ 60,000 (SR 780,000) per hectare (Edwards & Gomez, 2007)

The total cost of coral reef restoration over an area of 10 ha at Baie Lazare is estimated at 7.8 MSR.

Consequently, the total costs estimated for integrated coastal rehabilitation that covers dune restoration and coral reef rehabilitation is around 25.8 MSR.

Benefits accruing from measures

The benefits of dune and beach rehabilitation projects can be mainly approximated in terms of avoided damages.

- Cost to repair of 100 m of road in 2011: SR2.5 million, assume about 1000m to be addressed under TNA at different hotspots = 25 MSR (based on costs incurred to repair damages caused to a 100m stretch of road at Mare Anglaise, damaged in 2011 during an incident where high tide coincided with high winds and storm surge);
- Cost to repair buildings and infrastructure at the site (not including roads) estimated at SR300,000/m length of dune x 1000 m = 300 MSR;
- Loss of tourism revenues for degraded beaches or beaches with diminished aesthetic and recreational value due to use of hard engineering solutions: – estimated ~100 MSR over 15 years (conservative).

- Potential revenue from coral reefs including tourism and fisheries is estimated at US$6,075 (SR 78,000) per hectare per year (Edwards & Gomez, 2007) x 10 ha=SR 780,000 x 15 years=11.7 MSR.

The total benefits over a 15 year period are estimated at ~436.7 MSR.

Benefit-Cost Ratio (BCR)

The BCR is calculated at 16.9 revealing the cost effectiveness of the proposed coastal adaptation technology. Here again, it is assumed that residual damage after technology implementation will be zero. A modified version of Eq(1) can be used to calculate the BCR with residual damage when the technology is implemented, which in this case will be:

$$BCR_{residual\ damage} = \frac{(total\ avoided\ damage_0 \times (1 - fraction\ of\ residual\ damage)) + avoided\ loss\ in\ tourism\ revenue + revenue\ from\ coral\ reefs}{total\ cost\ of\ implememting\ technology} \quad \text{Eq(2)}$$

Where,

total avoided damage$_0$ =436.7 MSR;
fraction of residual damage = residual damage as a fraction of total damage without technology;
avoided loss in tourism revenue = ~100 MSR;
revenue from coral reefs = 11.7 MSR; and
total cost of implementing technology = ~25.8 MSR.

2.5 Linkages of barriers identified in the coastal zone sector

The technologies for coastal adaptation (mapping and monitoring, and integrated coastal restoration – covering both wetland and dune restoration) are closely interrelated because they both involve long time scales for gathering information and simulating future climate change and impacts, and putting in place measures that will prevent or minimise coastal degradation over the long term. Many of the barriers to the implementation of these technologies are closely interlinked, such as:

Funding and budget support

In all cases, there is very limited government funding available for long term sustained coastal adaptation projects, whether it be for monitoring coastal processes, or planning and implementing long term coastal EBA projects. Available funding is almost exclusively from project grants to government, and in some cases, civil society.

Focus on short-term decision making

Decisions made about measures to tackle climate change impacts in the coastal zone are usually focused on short term impacts, because the process for decision-making is reactive rather than preventive. Planning ahead for the impacts that climate change will continue to have on coastal ecosystems and infrastructures over the long term – over decades - is very challenging given the current policy and legal framework, lack of political will (coupled with short political cycles of 5 years), limited knowledge of decision-makers about climate change, and the importance of science based decision-making, which is further discussed below.

Lack of awareness about climate science, coastal processes

While there is general awareness in Seychelles of climate change and how it will impact the islands, there is limited in-depth understanding of climate science, the importance of monitoring changes to the coast and studying the potential impacts of developments on coastal ecosystems and infrastructure. There is a need to generally enhance science and technology education in Seychelles to mainstream decision-making based on sound scientific understanding, rather than options that are short term, easy and familiar.

Limited technical expertise

For all the prioritised technologies, there is limited technical expertise in the country, and particularly in the government sector. Many of the experts in coastal monitoring mapping and modeling are the same people who also have some experience in coastal EBA restoration. These individuals are overstretched and often underpaid compared to international consultants. There is an urgent need to both expand local technical expertise, and seek strategies to compensate them fairly for their work.

2.6 Enabling framework for overcoming the barriers in the coastal zone sector

The market maps in **Annex II** that have been developed for each technology indicate a similar set of factors that would, if implemented, provide a more enabling framework for the use of soft engineering coastal protection measures. Many of them are interrelated. These can be summarized as follows:

Financing

In the case of all three technologies, the present government budgetary support for soft engineering coastal protection measures is insufficient. Allocating a budget to cover the costs of staffing, equipment maintenance, monitoring, site maintenance and coordination of stakeholders is necessary to ensure continuity and availability of information to guide planning. Additionally, there is great potential for the exploration of financial incentives that might encourage more private landowners or businesses to contribute to the costs of coastal protection. And finally, there is likely to be a continued need for donor funded projects that can cover the high capital expenses of project implementation such as equipment and large-scale initial restoration works.

Ease of access to information about coastal processes

While one of the technologies is directly concerned with increasing available scientific information to guide sound planning and decision-making about coastal processes, the availability of this information over the long term is a critical enabling factor for the success of all coastal EBA measures. Although there are currently a few donor-funded projects being implemented that will provide some information about coastal processes in some locations, there is an urgent need to have an effective system in place to carry on with monitoring over the long term. The existing GIS unit at the MEECC would be the ideal hub for the coordination of information gathering, storage, analysis and dissemination, if their capacity were increased.

Institutional set up

There is a need to improve the current institutional set up to enable better dissemination and use of all three technologies. Being such a small country with limited resources is a challenge, but the predicted impacts of climate change on the economy and ecology of Seychelles justify the investment in establishing efficient, well-funded government institutions with a mandate for coastal protection, staffed by individuals with sufficient knowledge and experience to undertake the work needed. There is an opportunity under the proposed Climate Change Strategy revision (through the EU-funded GCCA+ project) to make provision for improvements to the current institutional set up for climate adaptation in the coastal zone. The Coastal Adaptation and Management Section (CAMS) of the MEECC would be the focus for improving this enabling factor.

Partnerships and coordination

Integrated Coastal Zone Management (ICZM) is not new to Seychelles and has itself been integrated into some national plans and policies such as the SSDS (2011-2020). Engaging with multiple stakeholders is an absolutely essential component of ICZM and as can be seen from each of the technologies discussed above, having a system and process for coordinating between multiple stakeholders and project partners is critical to their success. This issue is closely tied in with the above mentioned issue of institutional set up – a strong institution will be able to function effectively as a coordinating hub between the different stakeholders, communicating information about issues, projects, monitoring, and facilitating stakeholders' participation in projects.

Policy and legislation

The National Climate Change Strategy is Seychelles policy regarding climate change. However, it does not presently have any clout. With the upcoming revision, there is an opportunity to ensure that climate change adaptation is sufficiently integrated into existing laws and policies, with special attention paid to EBA methods.

Enforcement of existing laws protecting the coast falls under the mandate of the Coastal Adaptation Unit. There is a need to increase their capacity for undertaking this enforcement work, and to engage with other law enforcement partners including the Police and the Tourism Police for support.

Technical expertise

In the case of all three technologies, there are already a few very knowledgeable and experienced individuals who are already engaged in coastal adaptation projects. The problem is that there are too few of them and they are engaged in many other projects at the same time. With the University of Seychelles already offering courses on coastal management, there is an opportunity to increase the number of people in Seychelles who can be involved in coastal studies and protection / restoration projects. Helping UniSey to exploring partnerships and collaboration with overseas Universities and other research institutions will give Seychellois opportunities to improve their knowledge and skills, and potentially pursue post-graduate studies in the sector.

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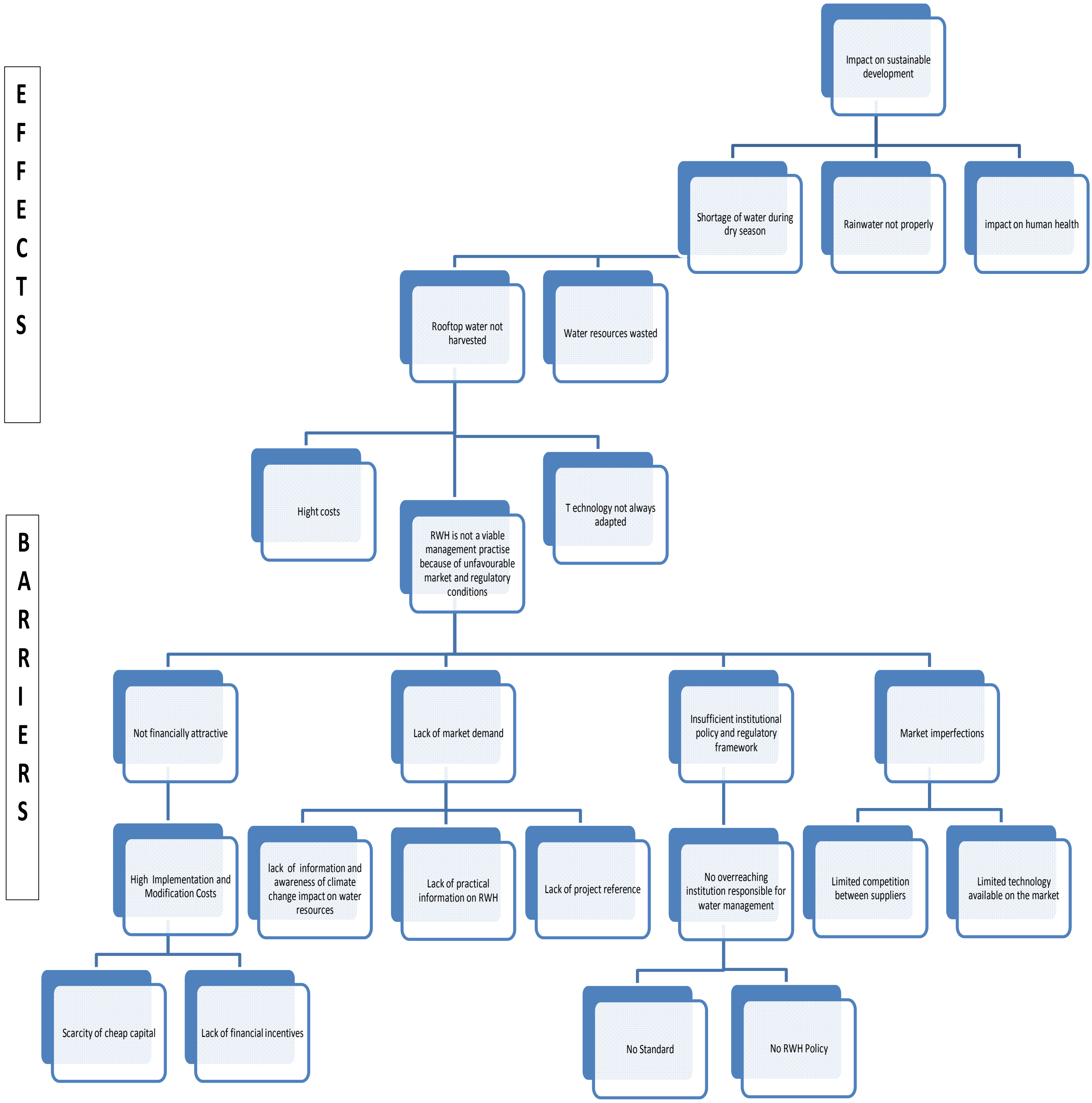
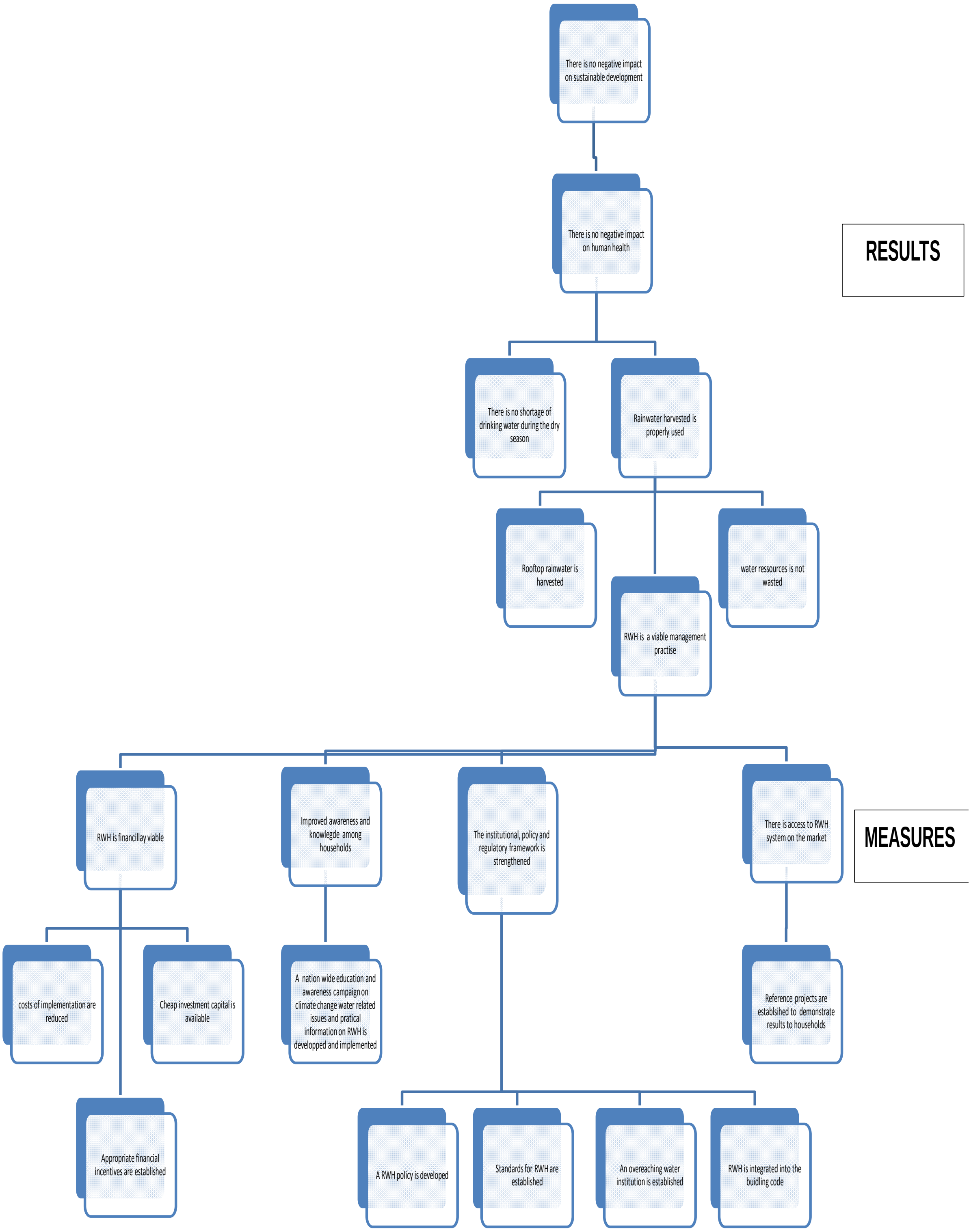
Annex I: Logical Problem Analysis and Market Mapping for Water Sector Adaptation Technologies

Rooftop rainwater harvesting (RWH)

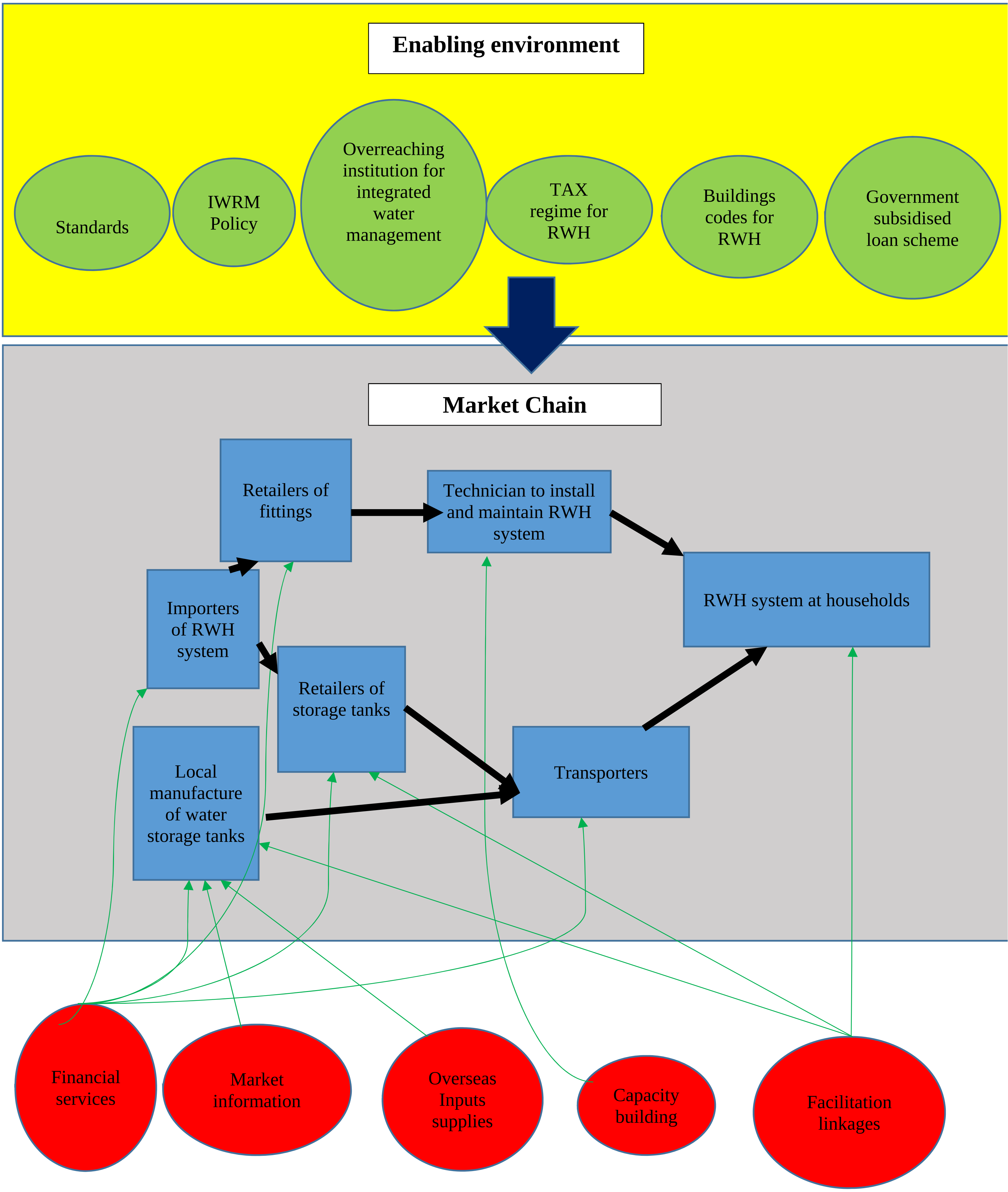
Problem Tree (PT)



Rooftop rainwater harvesting (RWH)
Objective Tree (OT)

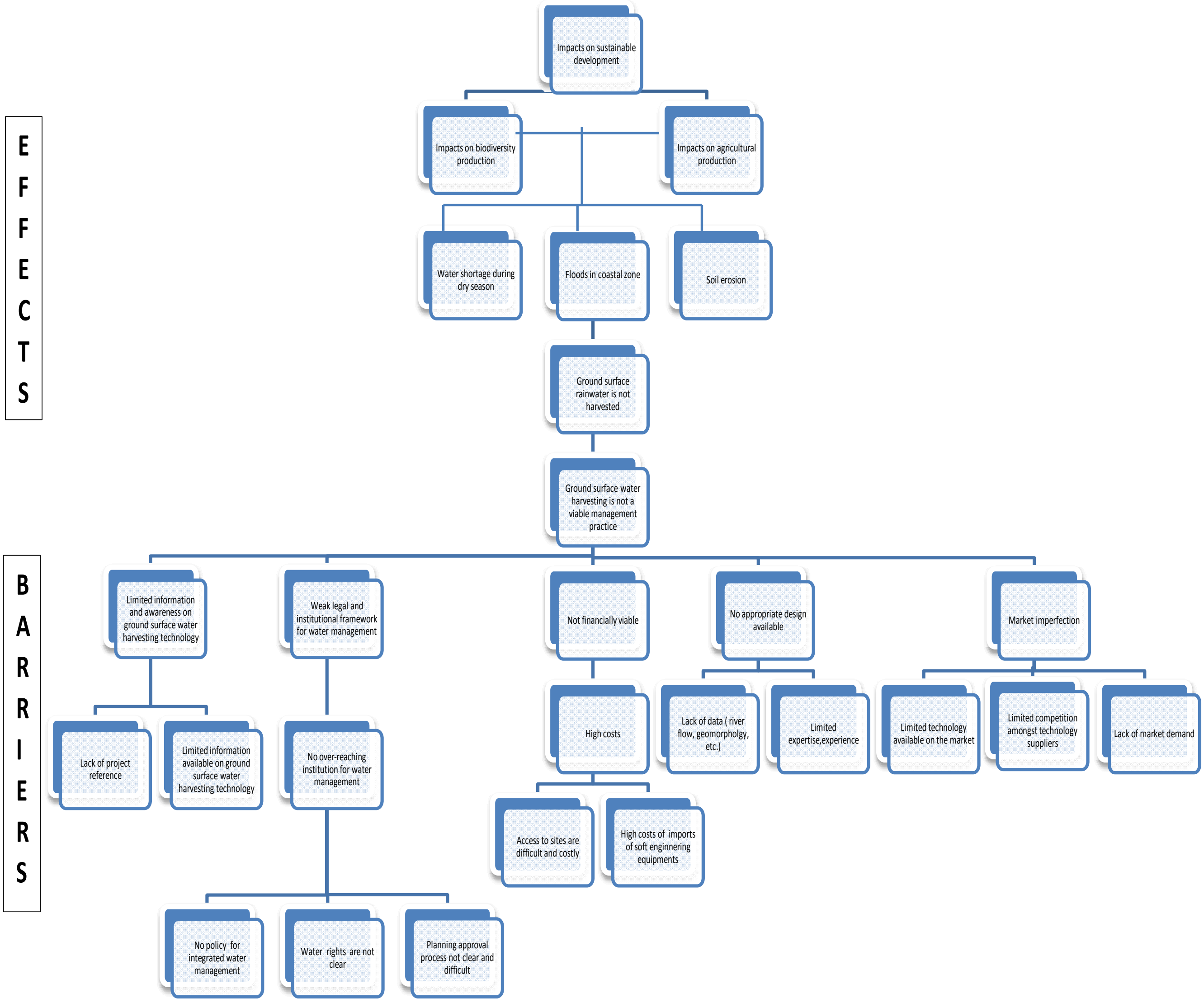


Rooftop rainwater harvesting (RWH) Market Map



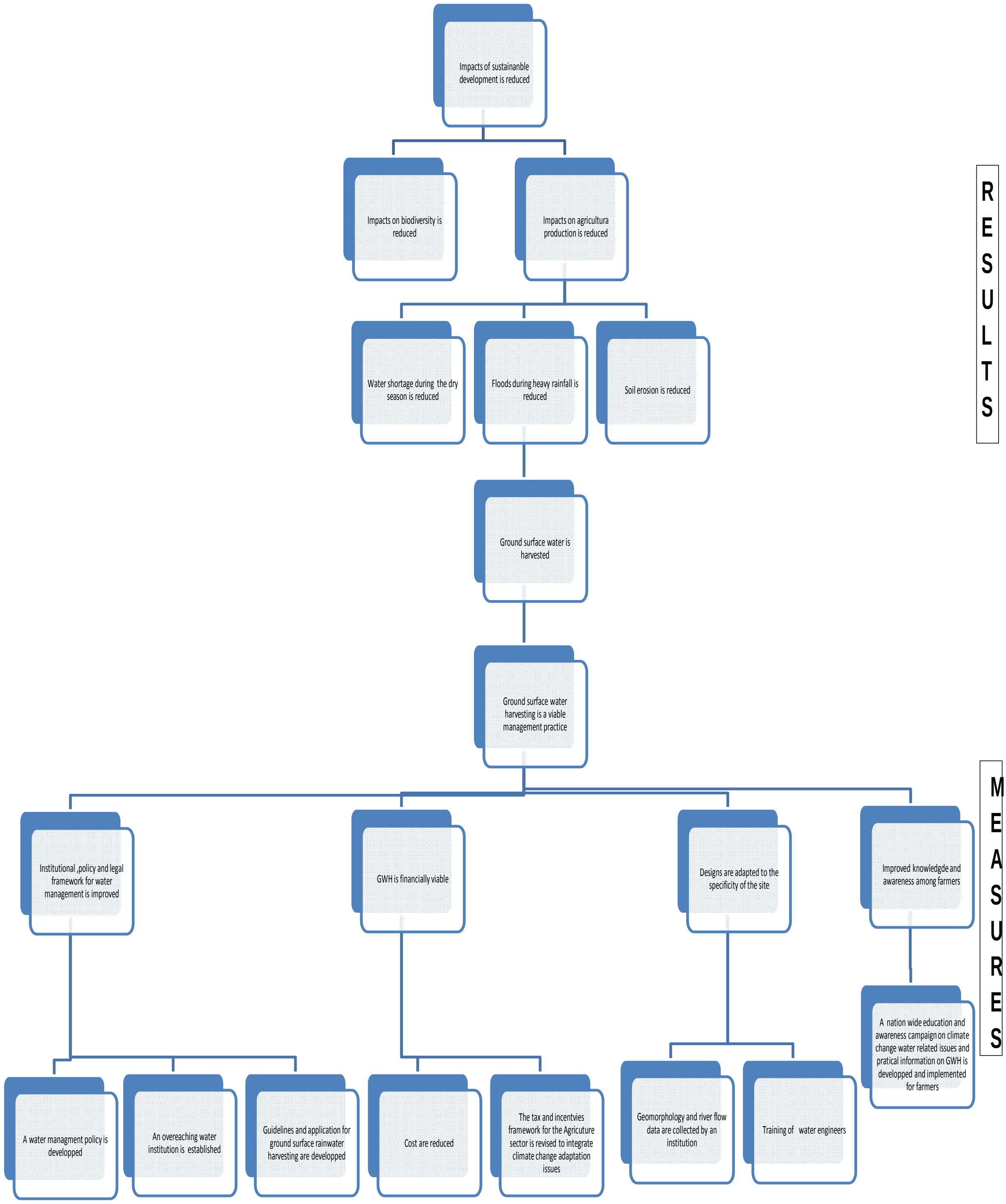
Ground surface rainwater harvesting (GWH)

Problem Tree (PT)

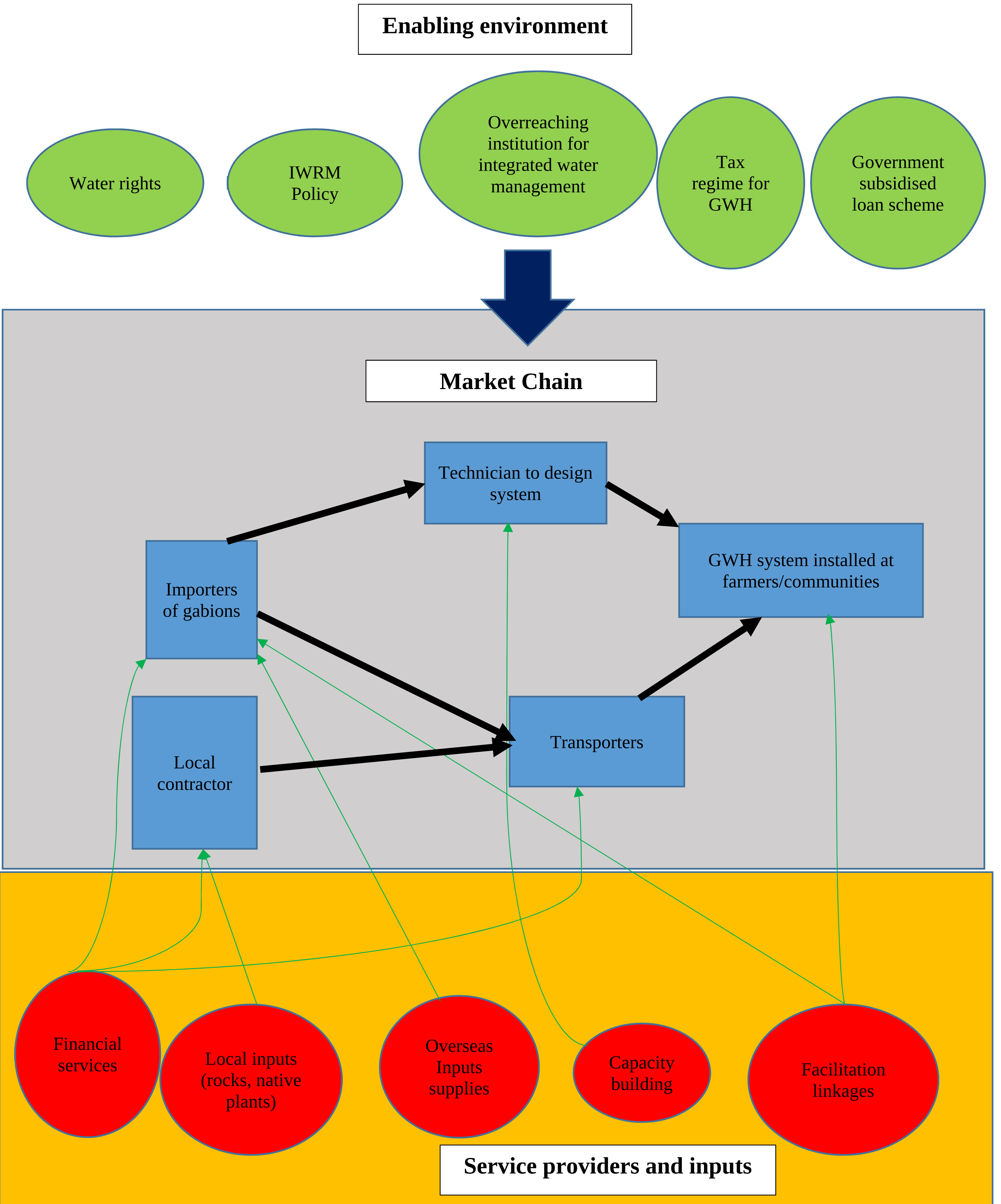


Ground surface rainwater harvesting (GWH)

Objective Tree (OT)

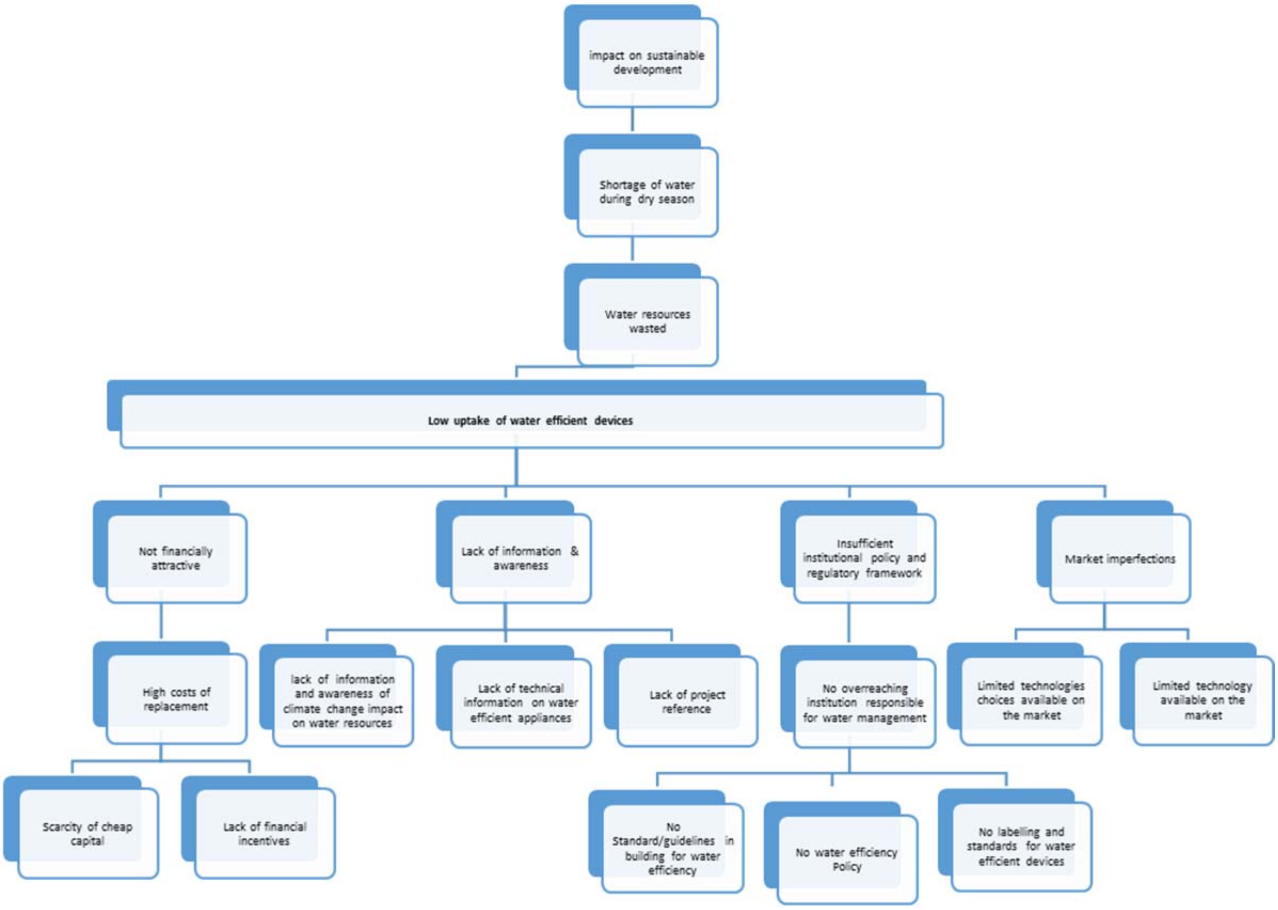


Ground surface rainwater harvesting (GWH) Market Map



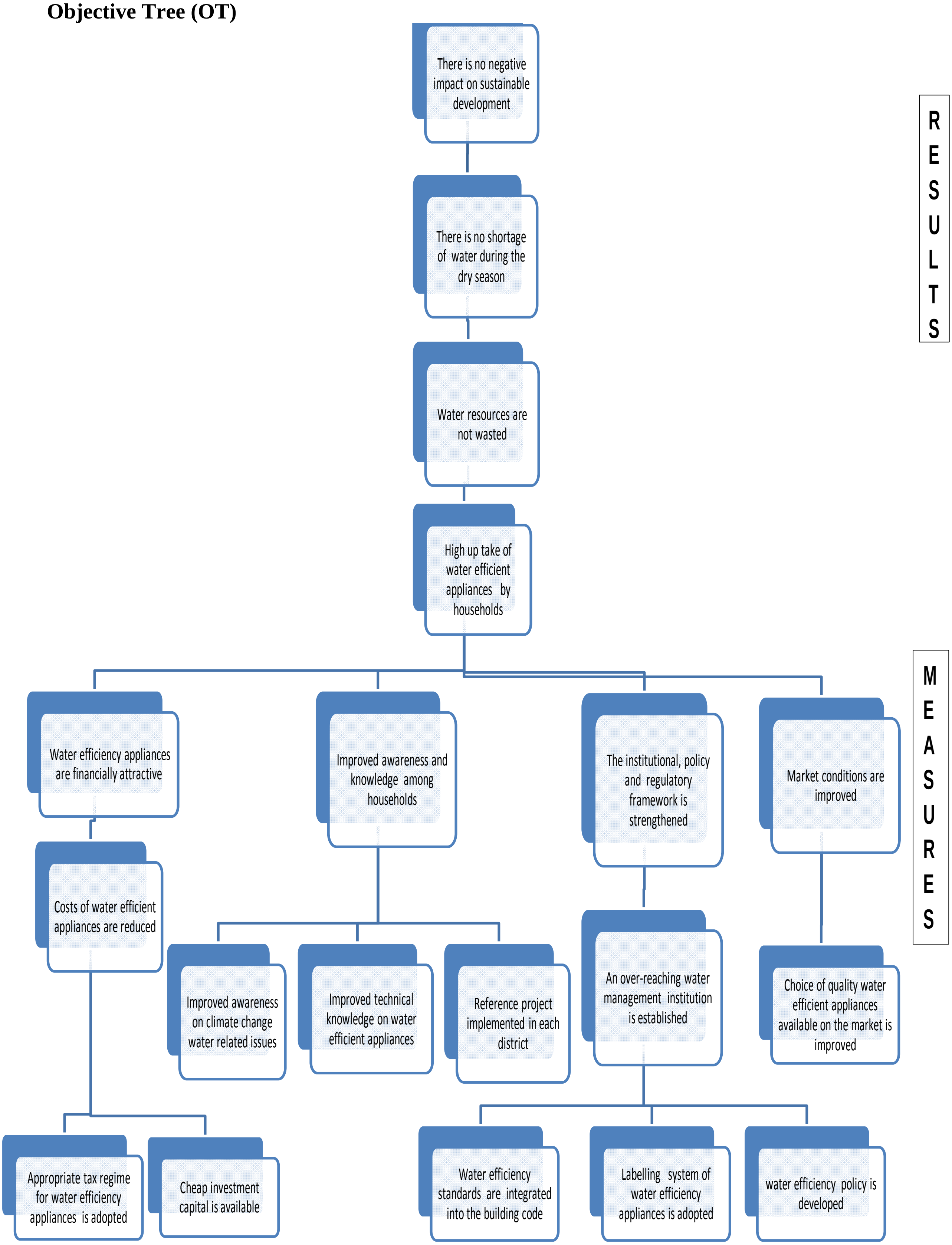
Water Efficient Fixture

Problem Tree (PT)



Water Efficient Fixtures

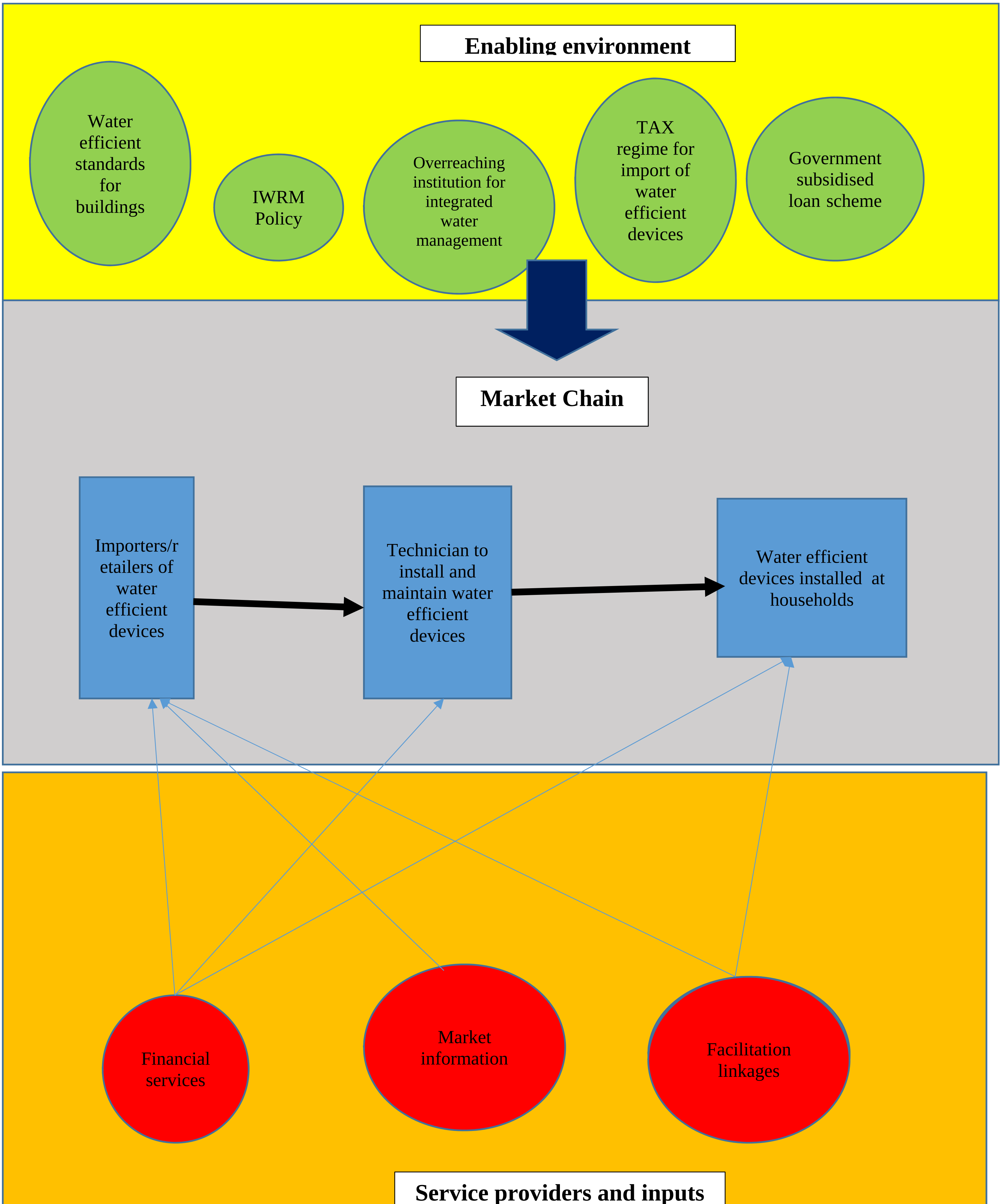
Objective Tree (OT)



Water Efficient Fixtures

Market Map

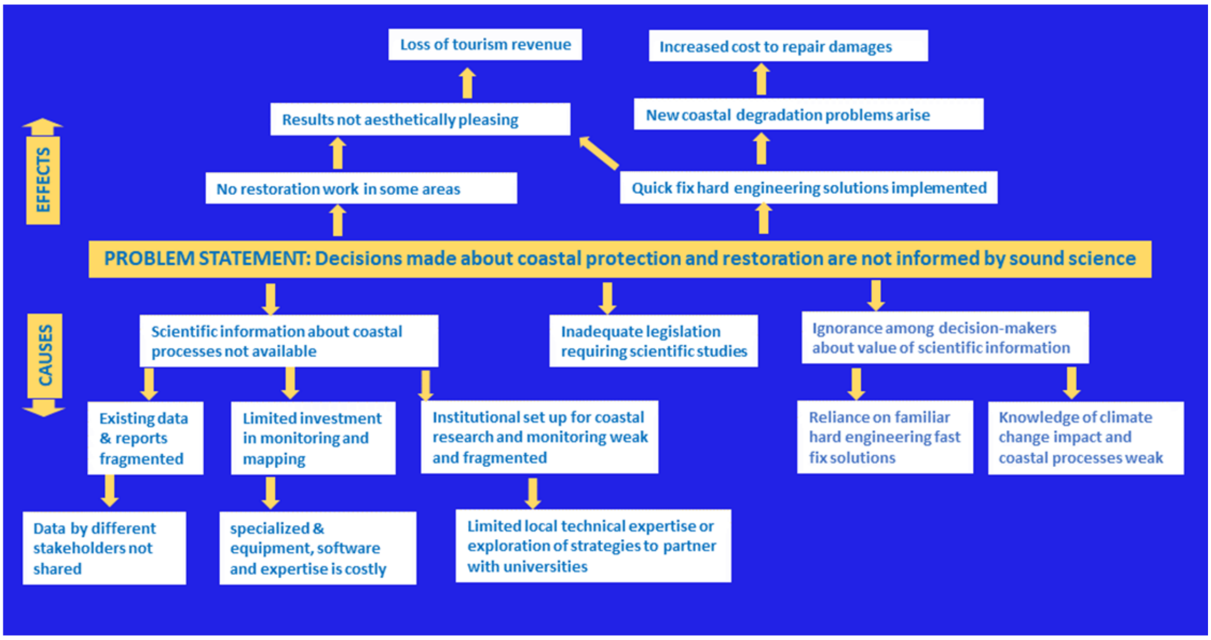
MARKET MAP FOR WATER EFFICIENT APPLIANCES



Annex II: Logical Problem Analysis and Market Mapping for Coastal Zone Adaptation Technologies

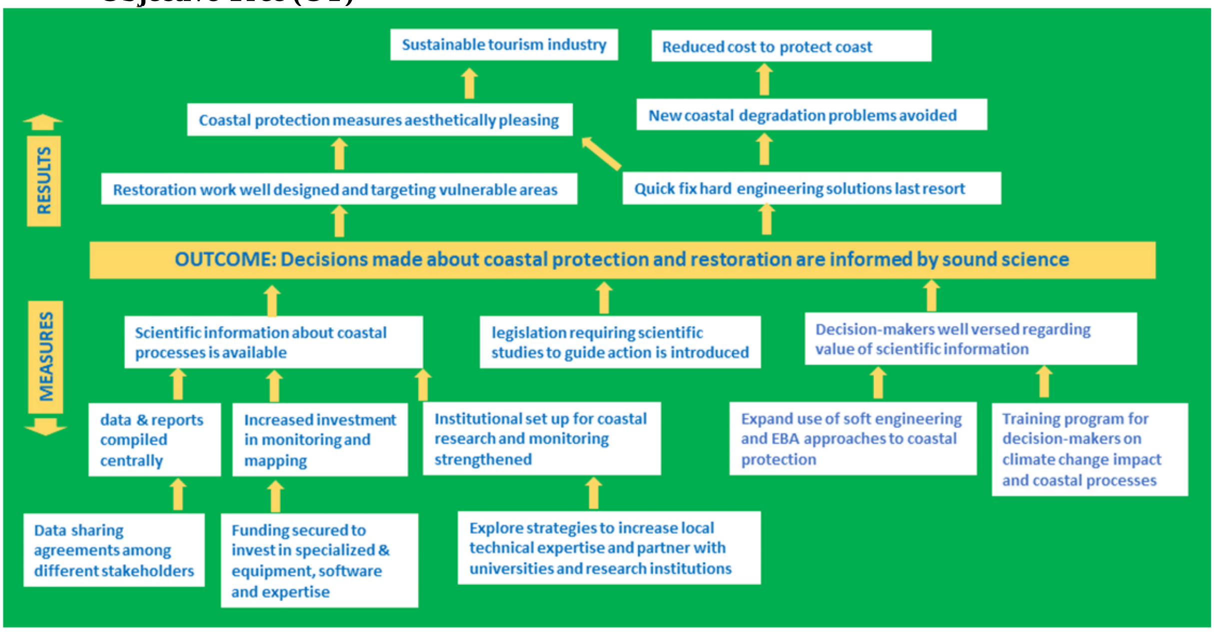
Coastal Mapping and Monitoring

Problem Tree (PT)



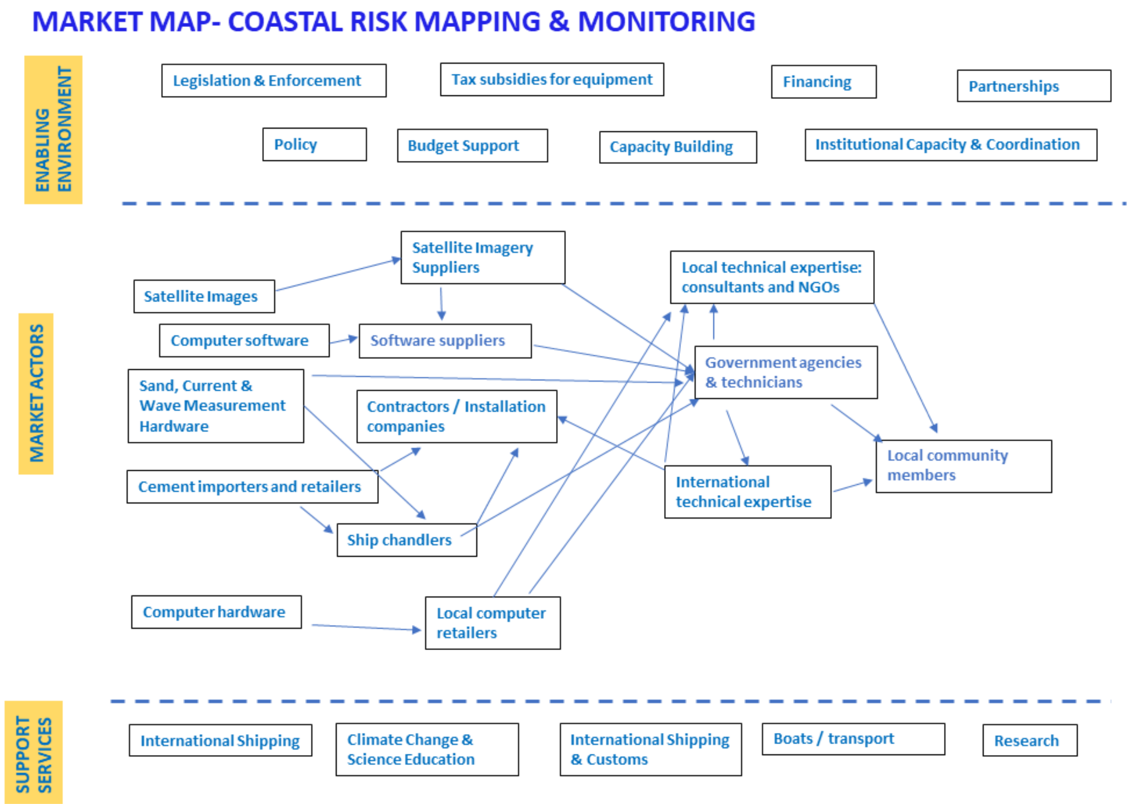
Coastal Mapping and Monitoring

Objective Tree (OT)



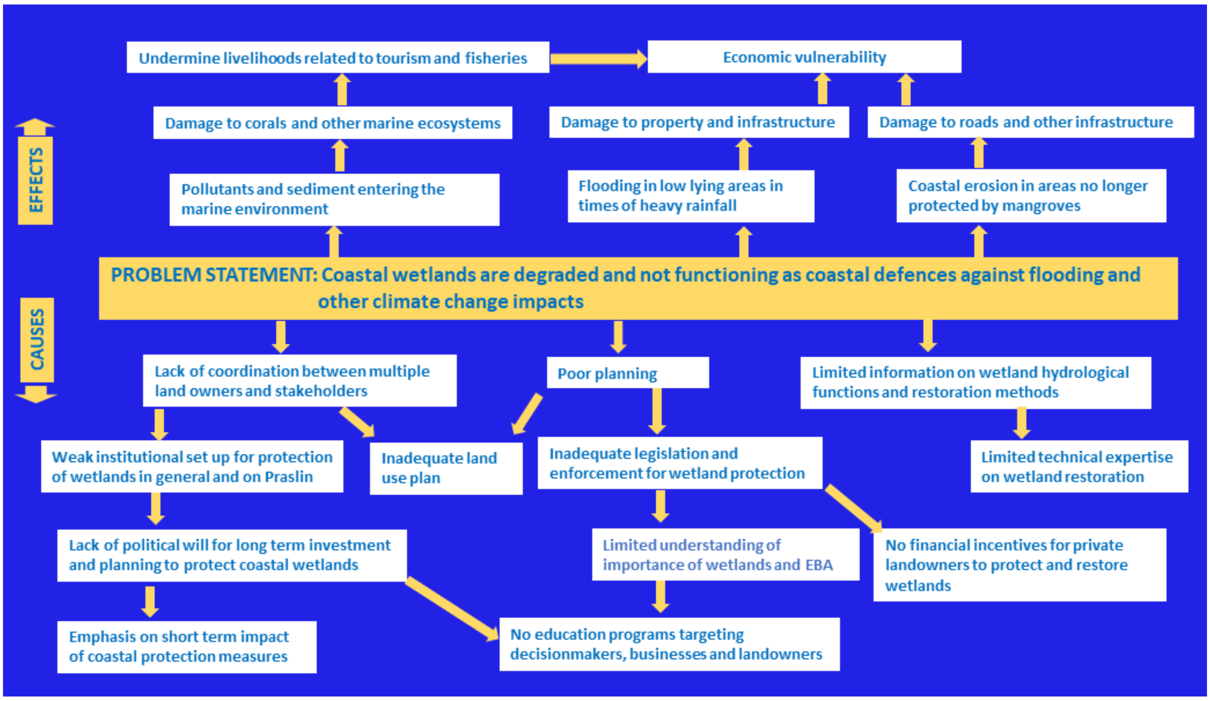
Coastal Mapping and Monitoring

Market Map



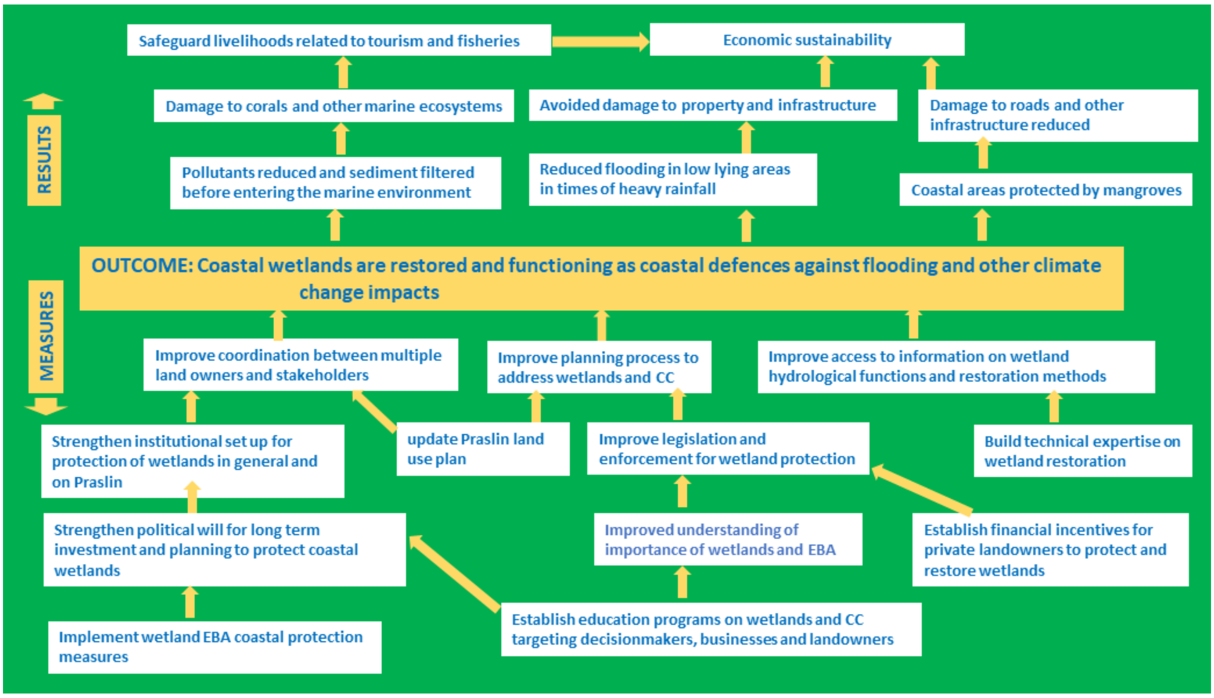
Wetland Restoration

Problem Tree (PT)

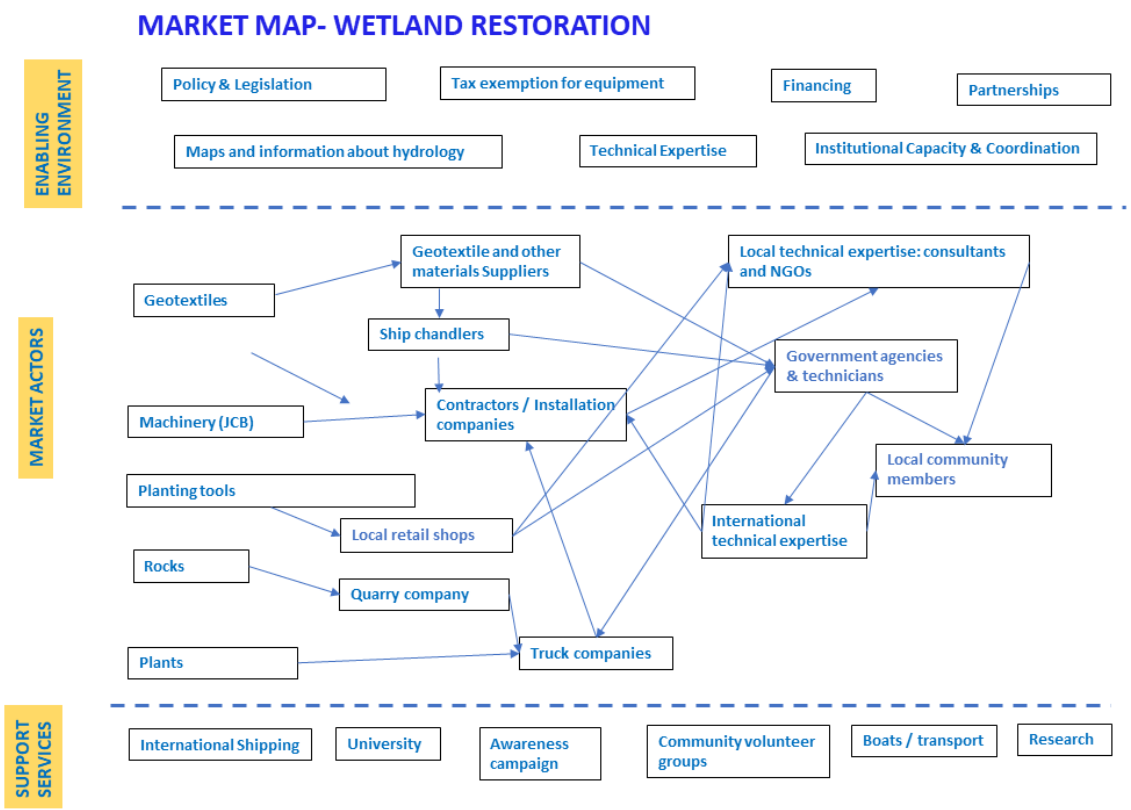


Wetland Restoration

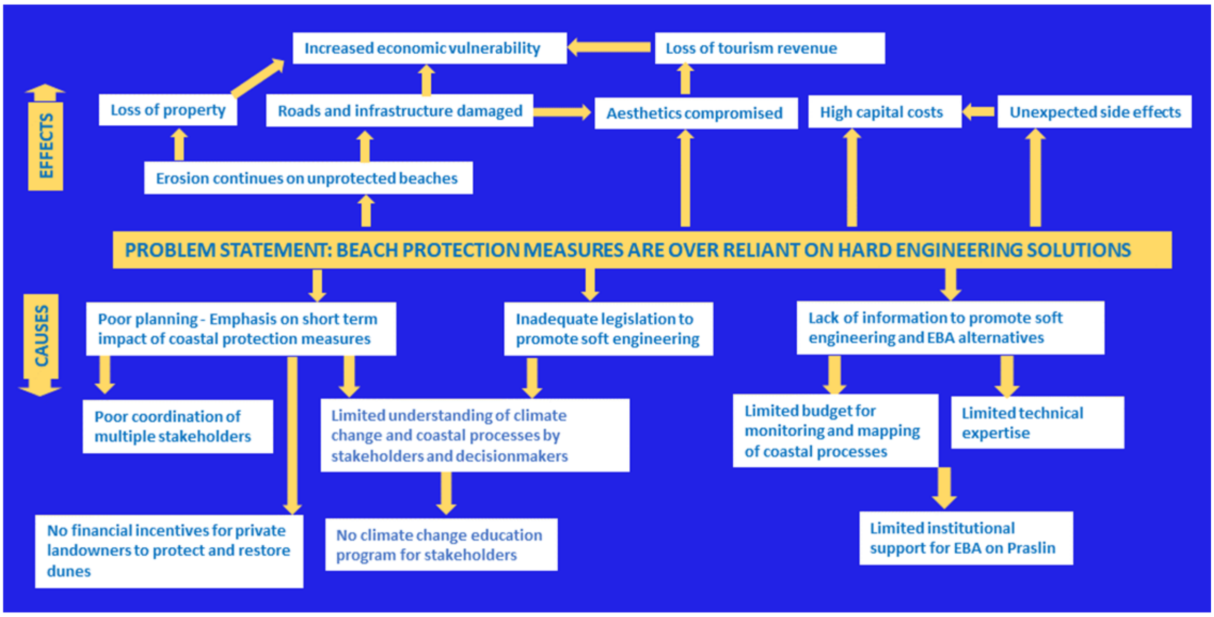
Objective Tree (OT)



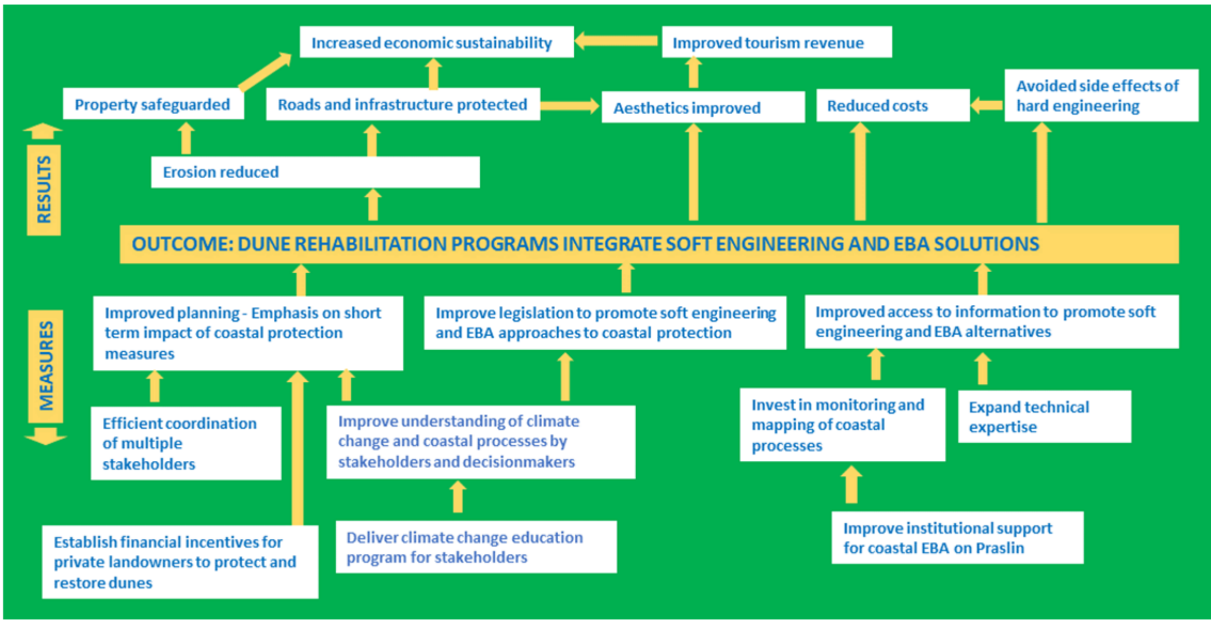
Wetland Restoration
Market Map



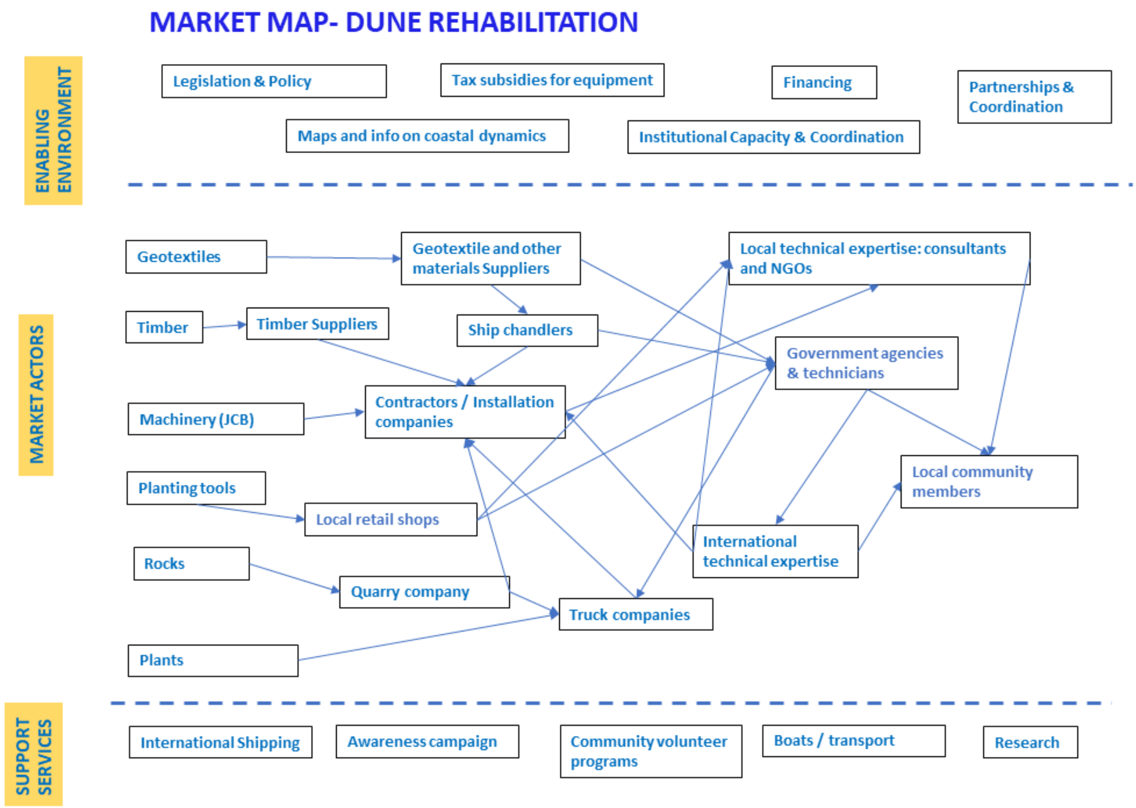
Integrated Coastal Rehabilitation (including Dune Rehabilitation)
Problem Tree (PT)



Integrated Coastal Rehabilitation (including Dune Rehabilitation)
Objective Tree (OT)



Integrated Coastal Rehabilitation (including dune rehabilitation)
Market Map



Annex III: List of stakeholders involved and their contacts

WATER SECTOR

Name	Contact details	Affiliation	Approach of consultation	Topics
Steve Mussard	smussard@puc.sc	Director, Water Section, Public Utility Corporation	Meeting	Technology barriers and CBA
Franky Dupres	fdupres@puc.sc	Senior Engineer, Water Section, Public Utility Corporation	Meeting	Technology barriers and CBA
Johan Mendez	j.mendez@pcusey.sc	Hydrologist, Ecosystem based Adaption project	Meeting	Technology barriers and CBA
Betty Seraphine	b.seraphine@pcusey.sc	Project Manager Ecosystem based Adaptation project	Workshop	Technology barriers and CBA
Betty Mondon	b.mondon@pcusey.sc	Community Engagement Specialist, Ecosystem based Adaptation project	Workshop	Technology barriers and CBA
Michele Martin	martinzanli@gmail.com	CEO, Sustainability for Seychelles	Meeting/ workshop	Technology barriers and CBA
Vanessa Zialor	zialorvz@gmail.com	Project Manager, Sustainability for Seychelles	Workshop	Technology barriers and CBA

COASTAL ZONE

NAME	ORGANISATION	METHOD OF CONSULTATION	DATE	TOPICS DISCUSSED
Ed Atkin	Consultant, eCoast (New Zealand company involved in EBA project)	Bilateral meeting	March 20/2017	eCoast study of NE point coast, coastal monitoring methods, strategies to develop tech capacity in Seychelles
Cliff Zelia	Seychelles Coast Guard	TWG meeting	April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping
Samuel King	Seychelles Coast Guard	TWG meeting	April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping
Rodney Quatre	UNDP/MEECC project coordinating unit	TWG meeting	April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects

		informal discussion	March	Mapping and monitoring
Jude Bijoux	UNDP/MEECC project coordinating unit	TWG meeting	April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
		informal discussion	March	Mapping and monitoring
Helena Sims	The Nature Conservancy (Seychelles Marine Spatial Planning Project)	TWG meeting	April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
		informal discussion at MSP workshop	March, 2017	Coastal mapping under MSP project
David Rowat	Marine Conservation Society of Seychelles	TWG meetings	March 17 April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
		TWG meeting		
Justin Prosper	GIS UNIT	TWG meetings	March 17 April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
Ashton Berry	UniSey BERI	Email exchange	Feb 2017	Invitation to discuss barriers to coastal adaptation technologies
Vanessa Zialor	Sustainability for Seychelles	Informal discussion	ongoing	EBA technologies, synergy with GCF project
Elvina Henriette	Independent consultant	Bilateral meeting	March 8	EBA project proposal for GCF, Integrated EBA strategies for coastal protection
		TWG meeting	March 17 April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
Nimhan Senaratne	Civil Engineer - EcoSol	TWG meetings	March 17 April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
Marc D’Offay	Civil Engineer	TWG meeting	March 17	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
		Informal discussion		Coastal technology barriers, technical capacity, hybrid approaches
Selvan Pillay	CAMS		March 17 April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, existing EBA projects
Andre Labiche	MEECC – Climate Change Adaptation section CAMS	TWG meetings	March 17 April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, integrating EBA approaches
Nigel Simeon	MEECC – Climate Change Adaptation section CAMS	TWG meetings	March 17, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, integrating EBA approaches
Mersiah Rose	GIS unit	TWG meetings	March 17, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, integrating EBA approaches
Annie Simeon	MEECC – Climate Change Adaptation section CAMS	TWG meetings	April 7, 2017	Barriers and technical capacity for coastal monitoring and risk mapping, integrating EBA approaches
Marcel Belmont	Seychelles Meteorological Authority	TWG meetings	March 17	Barriers and technical capacity for coastal monitoring and risk mapping, integrating EBA approaches