# TECHNOLOGY NEEDS ASSESSMENT FOR ADAPTATION TO CLIMATE CHANGE – GRENADA

BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR THE DIFFUSION OF ADAPTATION TECHNOLOGIES IN THE WATER SECTOR

## EXECUTIVE SUMMARY

This Barrier Analysis and Enabling Framework Report is the second of three main reports prepared for the Technology Needs Assessment project.

Report II identifies the barriers to the diffusion of the technologies prioritized for the water sector in report I and proposes an enabling framework to overcome those barriers. It also sets targets for those technologies in keeping with the national targets for the Sustainable Development Goals (SDG6) set for Grenada. Technologies were prioritized for the agriculture, domestic water supply and the tourism sub sectors. All of the technologies exist in Grenada but none of them have been diffused.

Chapter I identifies the barriers to the diffusion of the micro dam and micro irrigation technologies into the agriculture sub sector and proposes an enabling framework for overcoming those barriers. It sets a target to construct micro dams on appropriate locations on the eastern side of the island and to equip vegetable farmers island wide with micro irrigation technology by 2030.

The barriers to diffusion of micro dam and micro irrigation technologies and measures to address the barriers were identified using problem trees methodology during focus group meetings with key stakeholders and through the review of literature.

A micro dam is a structure built for impounding water whether in or off stream. The dam creates a water reservoir. It can be constructed off stream on hilly areas to capture run-off from catchments, which will allow the water to be taken down by gravity for irrigation.

The micro irrigation technologies were drip and micro spray. Drip irrigation is a low-pressure irrigation system in which water is delivered through an emission device (emitter) in drip mode. The drip mode delivers the water, which is either applied as droplets or trickles. Micro sprinkler is a low-pressure irrigation system in which water is delivered through an emission device (emitter) in micro-sprinkler mode. In micro sprinkler mode the water is sprayed, sprinkled or misted. The emitters operate by throwing water through the air, usually in predetermined patterns.

The report examines the causes for the limited diffusion of these technologies that are critical if the agriculture sector in Grenada is to adapt to reduced rainfall.

Most of the barriers were common to the micro dam and the micro irrigation technologies. The barriers include:

- high cost of the technology
- lack of access to credit
- small farm size
- insecure land tenure
- Inadequate data for design
- Inadequate capacity

Among the measures proposed to address the barriers are:

- Capacity building
- Establishment of a credit scheme
- Improve data collection of agro-metrological data
- Implementation of the Grenada National Land Bank

The report shows that there is a link between access to credit, the small size of the farm and insecure land tenure. It proposes an enabling framework which includes the establishment of a water resources management authority, capacity building to design micro dams and micro irrigation systems, a revised National Water Policy to include Rainwater Harvesting for agriculture irrigation and

Chapter 2 focuses on the use of Saltwater Reverse Osmosis technology to produce potable water to augment the freshwater supply. The target for the installation desalination plant in the south of the island is 2030.

Saltwater Reverse Osmosis technology is not new to Grenada. The National Water and Sewerage Authority (NAWASA) operated three plants before including one on Grenada. Two new plants are currently operated by NAWASA in Carriacou and Petit Martnique. Private sector entities were also given incentives to operate desalination plants but most have ceased operations.

Saltwater Reverse Osmosis is a process where water from a pressurized saline solution is separated fm the dissolved salts by flowing through a water-permeable membrane. The permeate (the liquid flowing through the membrane) is encouraged to flow through the membrane by the pressure differential created between the pressurized feed water and the product water which is at near atmospheric pressure. The remaining feed water continues through the pressurized side of the reactor as brine (UNEP)

A focus group meeting was held with staff of NAWASA and an interview was done with an officer of the Caribbean Community Climate Change Centre to determine what are the barriers to NAWASA installing a desalination plant in Grenada.

A review of the literature found that the financial barriers to the use of desalination is well documented and are generally high investment costs, high operational and maintenance cost and high energy costs.

The location site of the feedwater intake was the main non-financial barrier and the SWRO plant in Carriacou is currently experiencing challenges with the feed water. NAWASA identified the availability of freshwater as a barrier pointed out that desalinated water would only be considered during a water crisis.

Two case studies of an SWRO plant operating in Bequia were reviewed. One was a Benefit and Cost Analysis, which concluded that the investment in the SWRO plant was feasible and the other used the Levelised Water Cost (LWC) methodology and found the price of production of desalinated water was competitive with cost of production from surface water.

It would be necessary to conduct a Benefit and Cost Analysis to determine the feasibility of an SWRO plant for Grenada and to utilize PV to address the issue of high energy costs.

An enabling framework to overcome the barriers to SWRO technology is included in the report and it includes the revision of the National Water and Sewerage Act to give NAWASA the mandate to produce desalinated water, and the revision of the National Water Policy to also include desalinated water.

Chapter 3 presents the technology for wastewater reclamation and reuse. The target for that technology is for all existing and new onsite wastewater systems to reuse the wastewater for landscape irrigation.

Before wastewater can be reused it must be treated. The stages of treatment of wastewater covered in the report are preliminary, primary, secondary, tertiary and disinfection. It describes the two systems, which have been recommended for Grenada. They are the slow sand filter and the packaged plant.

There are many barriers to the wastewater reuse and interviews were done with hotel operators and discussions were held with staff of the Grenada Tourism Authority and the ministry of tourism to find out what they saw as the barriers to wastewater reuse. A focus group meeting was held with the staff of government institutions with responsibility for wastewater systems. The Coconut Bay Resort and Spa in St. Lucia was contacted for their views on their experience with wastewater reuse. A review of the literature was conducted and the analysis done for the Coconut Bay Resort and Spa (CABRAS) was reviewed. Other literature reviewed highlighted the challenges in finding an appropriate methodology for conducting the analysis of wastewater reuse.

Although the CABRAS study concluded that wastewater reuse is feasible it pointed out that it was only feasible when the environmental benefits are taken into consideration. The CABRAS study cited the lack of credible and sufficient data, which may have indicated greater feasibility of the intervention.

The interviews revealed that key stakeholders in Grenada had limited knowledge of wastewater reclamation and reuse and that there was a negative perception of reuse of wastewater.

Another barrier highlighted was the inadequate capacity among the government departments responsible for monitoring the effluent discharge from these wastewater treatment systems. In addition the roles of the various government departments were unclear.

Many of the hotels are operating on small spaces had to opt for the packaged plant which had a high investment and operations costs and it required a skilled technician to maintain it.

Hotel operators proposed an incentive regime, which will allow hotel operators to access a loan through a special fund and to repay only part of the loan. Hotel operators also receive tax concession through the Grenada Industrial Development

Corporation and it was prosed that equipment for wastewater be given concession.

The enabling framework for wastewater reuse included legislative reform, clarification of the roles and responsibilities of the government institutions and capacity building.

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# CHAPTER ONE AGRICULTURE SECTOR

## 1.1 PRELIMINARY TARGETS FOR TECHNOLOGY TRANSFER AND DIFFUSION IRRIGATION TECHNOLOGIES

The National Sustainable Development Goals 6.4, which addresses the issue of the use of water efficient technologies, guided the development of the target for the diffusion of efficient irrigation technologies in the Agriculture sector.

Irrigation technology is not new to Grenada because many of the large estates were equipped with irrigation systems with water being sourced from either river diversion canals or in-stream dams. Irrigation practices flourished particularly in the production of bananas with the use of overhead boom sprinklers. In the 1970's these large-scale irrigation systems were taken out of operation when the estates were subdivided into small farmer holdings. Since then there have been the implementation of several irrigation technology programmes including micro and drip irrigation but the success of the irrigation programmes has been low (UNDESA 2012).

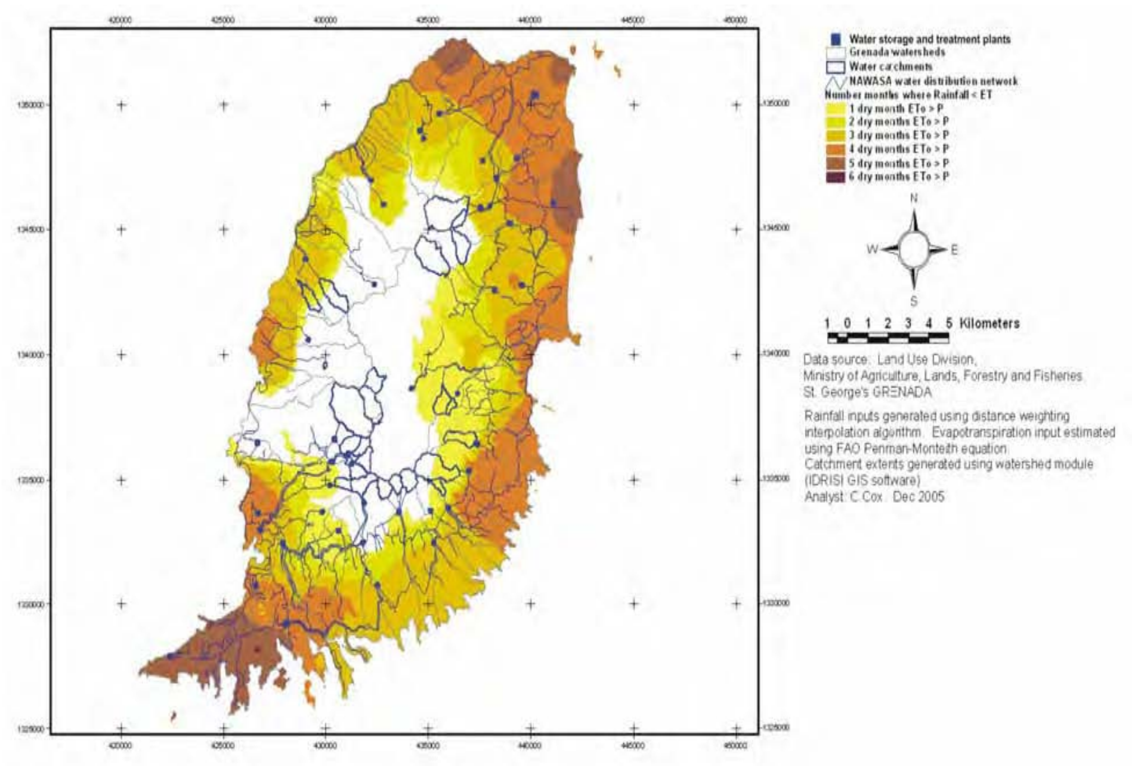
According to the 2012 Agricultural Census only 25% of farmers use some form of irrigation and in some instances only on a portion of the land. The Land Use Division estimates that about 2, 500 acres are under irrigation but the exact amount was not known because farmers were unsure about the exact amount of land under irrigation. The census also reported that 2, 339 farmers were using an irrigation system. Of that number 196 were using drip irrigation, 274 were using micro sprinkler, 208 were using overhead sprinkler while 1661 were using other irrigation systems. The majority of the farmers (1931), were irrigating vegetables while 602 and 465 respectively were irrigating root crops and fruits. The largest number of farmers were using other sources of water for irrigation, while the next largest number of farmers were using potable water from the National Water and Sewerage Authority and the third largest number of farmers were using the river as source of water, the use of wells was negligible (Mapp 2017).

The overhead sprinkler system is not efficient but is still widely used and with the projected decrease in rainfall it is has become necessary for farmers to adopt water efficient irrigation systems.

Though Grenada is blessed with annual rainfall totaling 2350mm, due to the orographic effect contributed by the interior mountain ranges there is a marked spatial distribution in rainfall across the island which gives rise to the arid conditions experienced in the northern and southern extremes of he island. This spatial and timely uneven distribution of precipitation results in a water deficit for crops for areas where most of the arable land are located and experience drought conditions for 1-6 months of the year. These areas require supplementary irrigation for a variety of crops especially vegetables which are more sensitive to water deficit (Chengxiang 2008).

For those farmers who traditionally relied on rain fed agriculture it is becoming more challenging because of the erratic rainfall pattern. They now have to rely more on irrigation not only in the dry season but even during the rainy season sometimes Chi

(Chengxiang 2008).




Source: (Chengxiang 2008)
Figure Shows Grenada Water Deficit – Number of Consecutive Dry Months
(Mean monthly rainfall inputs are below monthly evapotranspiration)

The figure also shows that the areas, which experience the highest water deficit, are located along the eastern side of the island with the north and south having the greatest extremes.

The year round production of vegetables is important to achieving food security. The Irrigation Unit, Ministry of Agriculture has therefore set a target for 1000 vegetable farmers to adopt water efficient irrigation technology with 70 percent using drip irrigation technology and 30 percent micro spray irrigation technology by 2030.

Currently there is no agency with responsibility for supplying irrigation water to farmers and as a result they use many water sources. The sources include the river, potable water, wells (micro dams) and rainwater harvested and stored. The findings of the 2012 Agriculture Census showed that most of the farmers currently employing irrigation technologies use potable water as a water source, followed by the rivers. A much small number of farmers harvest and store rainwater for irrigation. The Government of Grenada is in the process of establishing a Land Bank with the objective increasing the amount of agricultural lands under production and that would increase the demand for irrigation water.

Not all of the lands in the land bank would be located near to rivers or would have access to water from the National Water and Sewerage Authority. Besides, there is a limit to the number of farmers who could abstract water from the river during the dry periods if the river is to maintain the ecological flows.  Availability of water from NAWASA is usually reduced during dry periods so less water is also available for agriculture during dry periods. Rainwater harvesting is deduced to be the sole solution for supplemental irrigation during dry seasons but rainwater harvesting for agriculture irrigation still remains in its initial stage and there is a lot to be done in terms of technology and infrastructure (Chengxiang 2008).

The Irrigation Department of the Ministry of Agriculture has therefore set a target to construct micro dams on the Eastern agricultural areas of Grenada to increase rainwater harvesting for irrigation by 2030.

The areas suitable for constructing earthen micro dams to harvest rainwater were identified in a hydrologic study of potential irrigation sites (Madramootoo 2001).

## 1.2 Barrier analysis and possible enabling measures for irrigation technology

### 1.2.1 General description of micro dam

A micro dam is a structure built for impounding water whether on or off stream. The dam creates a water reservoir. It can be constructed off stream on hilly areas to capture run-off from catchments, which will allow the water to be taken down by gravity for irrigation. The dam embankment could be built of concrete masonry or compacted earth. The dam could also be covered in either concrete or clay to prevent seepage. The site for the hillside dam should be flat as possible with good soil suitability and catchment yield.

The feasibility study on rainwater harvesting for Grenada (Chengxiang 2008) has recommended that earth be used where clay soil is available in order to reduce cost. The study noted that while the concrete structure is good, the high price of cement might not make it financially affordable. The study also recommended that the storage be a natural basin in stream and that the water be supplied using gravity to reduce the operational cost of irrigation The dam will have to be situated at a high level to provide enough hydrological pressure for gravity fed irrigation the study recommends (Caribbean Development Bank 2008).

The study further recommended that the system be designed to harvest rainwater from the slope and to locate the storage for it to receive the runoff easily. It may be necessary to build interception ditches crossing the slope and an associated convey channel at the lower position of the slope to collect flows from the interception ditches into ponds or concrete tanks the study suggests (Caribbean Development Bank 2008).

The storage capacity for the micro dams recommended for these small farms is in the range of 5 000 and 200 000 cubic meters (FAO 2014).

Special attention is to the size and construction of the concrete or masonry spillway in order to provide an outlet for excessive floods (Smith 2014).

### 1.2.2 IDENTIFICATION OF BARRIERS FOR MICRO DAM

A review of the literature on the use of the micro dam technology showed that the technology is not widely used in Grenada nor in the Caribbean the region. Antigua is the only country in the region where the technology is widespread but it is used mostly to provide water for livestock (CARDI 1983).

A micro-dam for agriculture irrigation was constructed in Grenada in the 1970's as part of a Soil and Water Conservation project. The project constructed an earthen dam on the higher land to provide a reservoir of 12000 $m^3$ to irrigate the lower land. (Clarke 1983) The project also served as a demonstration project but farmers have been slow to adopt the technology (CARDI 1983).

The 2012 Grenada Agricultural Census reported that 22 wells (micro dams) were in operation (Mapp 2017). Irrigated agriculture is largely undeveloped in Grenada and a significant amount of arable lands are located in areas where there is no available water source. (FAO 2014) The majority of farming done in Grenada depends on rain so irrigation systems are not wide spread. (Mapp 2017). Farmers rely on rainfall even though rainfall data collected at the Mt Horne Cocoa Station in St Andrew between 1953 and 2007 showed that the rainfall pattern has been erratic (Chengxiang 2008).

There is no agency supplying irrigation water to farmers although the National Water and Sewerage Authority Act No. 25 of 1990 states that the authority should provide a satisfactory supply of potable or otherwise satisfactory supply of water for agriculture except during drought or reduced rainfall periods (Government of Grenada 1990). Therefore, a variety of sources are used for irrigation. Small farmers in Grenada rely heavily on rainfed agriculture with only 200 ha of land utilizing irrigation technology and those practicing irrigation utilize mostly surface water or potable water as their sources of water (Mapp 2017).

The current daily demand for water in Grenada is 54,600 cubic meters in the dry season while the maximum water yield is 31 800 cubic meters (FAO 2014). This means there is a 22 800 cubic meters gap between demand and supply during the dry season and the water authority gives priority to the use of the available water for potable purposes.

Rainwater harvesting for domestic purposes is a well-established practice in Carriacou and Petit Martnique because it was the main source water until the recent commissioning of the Saltwater Reverse Osmosis plant in 2016. There is no formal programme for rainwater harvesting for agriculture irrigation in Grenada even though some vegetable farmers have been harvesting rainwater as a source of water (UNDESA 2012).

Irrigation systems are therefore established mainly on low-lying areas that have a constant water source close by. The irrigation systems are installed on farms that cultivate mainly vegetables or short crops. Fully controlled irrigation systems are used but farmers do not know the actual area under irrigation, most farmers have only one source of water and in some cases the area under irrigation too small and are unrecorded (Mapp 2017).

With the challenges posed by climate variability and change the use of micro dams for storage of rainwater for supplemental irrigation is been recommended (UNDESA 2012).

The Problem Tree methodology was used to find the root cause and the contributing causes to the limited use of micro dams for supplemental irrigation. A focus group meeting of key stakeholders representing the Ministry of Agriculture, Forestry Fisheries and Environment, Planning Division, Irrigation Management Unit, Agronomy Division, Environment Division and farmers to identify the root causes to the slow diffusion of micro dam technology. The meeting also explored the measures and required enabling framework for diffusion of the technology.

The slow diffusion of the technology was identified as the main problem because the micro dam technology for irrigation was introduced to Grenada since the 1970’s and to date it is still not widely used. The diffusion of the micro dam technology has been slow although farmers have been experiencing prolonged dry periods and those without a water source cannot grow vegetables and short crops year round.

Stakeholders identified several contributing causes, which are serving as barriers to the diffusion of the technology. They were prioritized and used to develop the problem tree. Since there were no case studies available for micro dam for Grenada a search was done for work done in the region and internationally. The findings supported the contributing causes identified by the key stakeholders.

#### 1.2.2.1 ECONOMIC AND FINANCIAL BARRIERS

It is well documented that farmers in developing countries seldom keep good records of their activities which are essential for any accurate economic analysis (Gumbs 1997) Although farmers have been operating microSWRO dams in Grenada the data required to conduct a financial and economic analysis for the micro dam technology for Grenada was not available.

Technical feasibility studies of micro dam technology for Grenada are available. (FAO 2014) and (Madramootoo 2001)conducted feasibility studies of rainwater harvesting in Grenada and confirmed that rainwater harvesting for supplemental irrigation for smallholder farmers using micro dams is technically feasible in Grenada. No studies on the cost of the micro dams were available.

In 1999 the Ministry of Water Resources in China conducted an economic analysis of Rain Water Harvesting (RWH) irrigation system with seven cases of cropping pattern. The study is relevant to Grenada because two of the crops grown were corn and vegetables, which are widely grown in Grenada. Results of the study showed that RWH for all seven patterns have benefit/cost ratio of more than 1, which means they are economically feasible. Vegetable and fruit cropping patterns had the highest benefit/cost ratio and this means cultivation of vegetables and fruit would produce the higher benefit (FAO 2014)

Given the unavailability of data required to conduct a financial and economic analysis of the adoption of the micro dam technology by farmers in Grenada and in the Caribbean, international financial and economic analyses were reviewed.

A recent study of the adoption of rainwater harvesting by small landholding farmers in developing countries proved to be feasible, with a benefit cost ratio of up to 1.6 and an internal rate of return of up to 76% although the net present value varies depending on the currency and the location. (Rozaki et al. 2017)

Rozaki et al (2017) explained in their research that the micro dam (SFR) cost include excavation and sealing material. The cost depends on the volume of the SFR (micro dam) and the type of sealing material.

Another aspect related to rainwater construction cost is the depreciation period, which depends on the lining material: soil base, plastic sheeting or concrete (Rozaki et al. 2017). Roazaki et.al relied heavily on the work done by Fox et.al (2005).

(Fox 2005) Conducted a study of rainwater harvesting for supplemental irrigation for Kenya and Burkina Faso. They noted that depreciation time for the reservoir is set at 20 years, being the expected operational life span of the reservoir and assuming proper maintenance.

The depreciation times for the sealants varied with choice of material. For the cement-lined option the deprecation time is estimated to 20 years. As for the plastic sealants, the thicker plastic tarpaulin (4 mm) is attributed a depreciation time of 10 years and the thinner plastic (1 mm) three years. At the expiry of the depreciation times the plastic sealants will need to be replaced (Fox 2005).

A 300-$m^3$ reservoir (micro dam) was used as the basis for the economic calculations, (Fox 2005) which is relevant to the situation in Grenada. The economic analysis is based on the material inputs required to produce a RHW system including a 300-$m^3$ (10X19X10 X3 m) reservoir (micro dam). Cost estimates for the construction material were based local market prices (Fox 2005).

Labour was a major capital input into the construction of the small scale, RHW reservoir because the calculations was done for a manually dug reservoir. (Fox 2005) Valued labour at its opportunity cost i.e. labour cost was set at the equivalent to income foregone.

(Fox 2005) Chose tomato as the off-season cash crop for fully irrigated cultivation during the dry season when the price is at its peak. The staple crop was cereal. Although the situation does fit Grenada totally because the farmers in Grenada irrigate mostly cash crops it is still useful because tomato is also a cash crop grown in the dry season and the peak price is also in the dry season.

A cost- benefit analysis was carried out for a combined system (fertilizer and SI) and compared to the control, the operation expenses and incomes for the investment in RWH with SI. Labour costs represent 0% and 83% of the fixed cost in the construction of the RWH system with the SI component. The cost depends on whether labour is valued is based on full opportunity cost, alternative opportunity cost or zero opportunity cost and the cost of the reservoir sealing technology used. (Fox 2005). The results of the cost-benefit analysis are presented in the table below.

Table showing Expense income investment for scenario with full labour cost and different dam sealants at the Burkina Faso and Kenya site in (USD).

| Country | Cement Seal | | Tarpaulin seal | | Plastic seal | | Self seal | | Control | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Burkina | Kenya | Burkina | Kenya | Burkina | Kenya | Burkina | Kenya | Burkina | Kenya |
| **Expenses** | | | | | | | | | | |
| **Loan** | 1228 | 1132 | 1388 | 1274 | 745 | 682 | 592 | 529 | 0 | 0 |
| **Running cost staple crop** | 229 | 189 | 229 | 164 | 229 | 164 | 231 | 166 | 154 | 98 |
| **Running cost cash crop** | 103 | 100 | 103 | 100 | 103 | 100 | 51 | 50 | 0 | 0 |
| **Loan repay labour** | 95 | 85 | 95 | 85 | 95 | 85 | 95 | 85 | 0 | 0 |
| **Loan repay seal** | 102 | 96 | 159 | 148 | 67 | 67 | 0 | 0 | 0 | 0 |
| **Total expenses** | 528 | 470 | 585 | 497 | 493 | 416 | 377 | 301 | 154 | 98 |
| **Income** | | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Staple crop** | 357 | 262 | 357 | 262 | 357 | 262 | 282 | 211 | 71 | 138 |
| **Cash crop** | 533 | 431 | 533 | 431 | 533 | 431 | 246[i] | 199[i] | 0 | 0 |
| **Total Revenues** | 890 | 693 | 890 | 693 | 890 | 693 | 528 | 410 | 71 | 138 |
| **Net prod. income** | 362 | 223 | 305 | 196 | 397 | 277 | 151 | 109 | -83 | 40 |

Source: (Fox 2005)

[i]Average annual income RWH over a 5-year period since RWH system capacity will improve over time.

The net profit for each labour-sealant option is calculated based on the classic format including a generated revenue – (installment + running cost). The results showed that all options at both sites were profitable except the Burkina site, control production which does not provide profit if the opportunity cost is applied to labour (Fox 2005).

Due to limited data and information it was not possible to make an accurate cost-benefit analysis of RWH as part of the study of the feasibility of rainwater harvesting for Grenada (Chengxiang 2008). However, an economic evaluation was done in China and is presented in the table below.   The table shows that RWH systems for all the seven patterns has benefit cost ratio of larger than 1 which means they are economically feasible.  Among them the pattern 4 and 5 have highest B/C ratio, it means cultivation of vegetable and fruit would produce the highest benefit (Chengxiang 2008).  This is relevant to Grenada because irrigation in Grenada is used mostly for vegetable and fruit production.

Table showing result of economic evaluation RWH irrigation system with six cases of changing cropping pattern Ministry of Water Resources China 1999

| No | Cropping Pattern | | Yearly benefit | | RWH Shared benefit | Yearly fees | B/C Ratio |
|---|---|---|---|---|---|---|---|
| | Before RWH | After RWH | Before RWH | After RWH | | | |
| **1** | Rainfed cereal/corn | Irrigated corn with plastic sheeting | 100 | 400 | 249 | 113 | 2.12 |
| **2** | Rainfed cereal/corn | Irrigated vegetable with plastic sheeting | 100 | 3150 | 1220 | 146 | 8.33 |
| **3** | Rainfed cereal/corn | Greenhouse vegetable | 100 | 7000 | 2070 | 1286 | 2.07 |
| **4** | Rainfed orchard | Irrigated orchard | 1800 | 3600 | 900 | 70 | 12.9 |
| **5** | Rainfed cereal/corn | Irrigated orchard | 100 | 3600 | 720 | 70 | 10.3 |
| **6** | Rainfed corn | Irrigated rice and corn | 180 | 750 | 456 | 154 | 2.96 |

Source: (Chengxiang 2008)

<u>Benefits</u>

(Chengxiang 2008) identified the benefits of RHW for Grenada as follows:

- Supply economical and reliable water source for supplemental irrigation for agricultural production for the area where neither surface nor ground water are available and promote sustainable agricultural yield and improve food security

- With store water for Carriacou and Petit Martinique, the farmers will have the ability to produce a wide variety of vegetables year round and provide a stable supply of agricultural produce
- Enhance agricultural employment, increase income of rural population and improve livelihoods of cropping.

The FAO study reviewed rainfall data which confirmed that rainwater harvesting to reduce or prevent water scarcity in rainfed production systems is a feasible strategy for sustainable food production in small scale farming in the sub region (FAO 2014).

The study also identified the benefits of micro dam technology and among them are the extension of the number of planting days through the application of water from cumulative storage, and improvements in yields from small and micro farms through reliable access to water for irrigation.

<u>High investment costs</u>
The high investment costs associated with the Supplementary Irrigation (SI) technology at respective sites may prove to be the most limiting hurdle for the farmer to engage in any investment (Fox 2005) and the construction cost of a dam can be substantial (Smith 2014)

In his study Fox 2005 found that labour costs were also high and attributed it to the use of manual labour but farmers in Grenada were considering the use of heavy equipment instead of manual labour and the costs for heavy equipment were also reported as high.

Fox found that the use of cement lined dams were the most expensive sealant material. In the case of Grenada it was noted that the high cost of cement could make a concrete structure unaffordable (Chengxiang 2008).

Most of the vegetable farmers in Grenada are small farmers but (Chengxiang 2008) proposed mini dams for nine sites because of the relatively large size of the farms to be irrigated and are suitable for building mini dams with volumes of between 10 000 $m^3$ and 500 000 $m^3$. The results of this study are therefore not relevant to farmers with small land holdings.

Conservation based on engineering structures are often too costly and technically difficult for resource poor farmers who comprise the majority of farmers (Gumbs 1997) and UNDESA 2012 recommended smaller dams with capacity from 50 $m^3$ to 450 $m^3$ depending on the availability of land. However Fox et al also verified in their study that mini dams the size of 300 $m^3$ can also be financially feasible.

<u>Affordability of the technology</u>
Key stakeholders highlighted that unaffordability of the technology will affect whether they could adopt it, particularly by smallholder farmers who lack financial resources. Operational and maintenance costs were also highlighted as a hindrance to adoption (Senyolo n.d.) Farmers also expressed concern about the potential high cost

of operation and maintenance and the cost of security fence to protect the micro dam. Farmers were particularly concerned about the cost of labour required to maintain the system to prevent blockages.

Access to loans

It is assumed that the investment in a micro dam would be covered through a loan since it is unlikely that a smallholder farmer will be able to provide capital necessary for investment otherwise (Fox 2005). There is one bank in Grenada with the mandate to provide financing for the agriculture sector. While other banks and micro finance institutions for example credit unions, offer loans for agriculture only the Grenada Development Bank has an agriculture loan portfolio. Farmers have been complaining that even when loans are available the terms and conditions for accessing those loans are too stringent. The Grenada Development Bank does not cover 100 percent of the loan and requires equity as well as security, which farmers may not have (GDB n.d.).

The lack of access to financing was found as a key constraint to investment in irrigation infrastructure (Fox 2005). Farmers in Grenada reported that they face the same constraints. There is only one bank offering financing specifically for agriculture and many of the small farmers do not possess the necessary collateral to allow them to meet the requirements to access loans.

### 1.2.2.2 NON-FINANCIAL BARRIERS

Economists make the point that when a new technology is introduced its success depends on it being both technically and economically viable (Fox 2005).

Inadequate data

Feasibility studies on RHW for irrigation agriculture have been conducted for Grenada but the data required for the design of the micro dam was unavailable.

The adequacy of the catchment area and the capacity requires knowledge of the water demand, rainwater collection efficiency (RCE) of the catchment. The design of the catchment and the irrigation system could be employed. Owing to the lack of RCE data of the various materials used in the Caribbean, the RCE is recommended according to the practice in China (FAO 2014).

Table showing RCE of different catchment material according to Chinese practice

| Material for catchment surface | Yearly RCE (%) with different annual precipitation | | |
|---|---|---|---|
| | 200-500 mm | 500-1000 mm | 1000-1500 |
| **Concrete** | 75-85 | 75-90 | 80-90 |
| **Cement tile** | 65-80 | 70-85 | 80-90 |
| **Clay tile (machine made)** | 40-55 | 45-60 | 50-65 |
| **Clay tile (hand made)** | 30-40 | 35-45 | 45-60 |
| **Masonry in good condition** | 70-80 | 70-85 | 75-85 |
| **Asphalt paved road in condition** | 70-80 | 70-85 | 75-85 |
| **Earth road, courtyard, threshing yard** | 15-30 | 25-40 | 35-55 |
| **Cement soil** | 40-55 | 45-60 | 50-65 |
| **Bare plastic film** | 85-92 | 85-92 | 85-92 |
| **Plastic film covered with sand and soil** | 30-50 | 35-55 | 40-60 |
| **Natural slope rare vegetation** | 8-15 | 15-30 | 30-50 |
| **Natural slope nice vegetation** | 6-15 | 15-25 | 25-45 |

Source: FAO 2014

Inadequate technical capacity

The Irrigation Unit Ministry of Agriculture confirmed that there is inadequate staff with the knowledge, skill and experience in designing and constructing micro-dam for agricultural irrigation. Farmers also acknowledged that that they do not possess the technical capacity to design and construct micro-dams.

High sedimentation rate

With the increase in daily rainfall intensity projected for the Caribbean (Tannecia S.

Stephenson 2014) sediment of the dams is expected to be a major problem. Spillway capacity is a problem as the first rains usually fall on dry capped soil, giving rapid run-off. It is often the runoff from these first storms of the year that cause failure of dams. (CARDI 1983) (Smith 2014).

Small size of farm

Gumbs 1997 found that many conservation practices are considered unacceptable because they reduce the already small land area for cropping. Stakeholders confirmed that the construction of the mini dam would reduce space available for cultivation on small farms especially for farms growing vegetables, which are usually small plots.

Proof of technology benefits

Farmers are reluctant to adopt a technology they have not seen in practice and are not aware of the benefits (Senyolo n.d.) Based on experience on adopting new technology and approach for agricultural development, it is very hard to convince the decision-maker for their support and the farmer to adopt it without physical sample to prove the advantage (Chengxiang 2008).

Key stakeholders were not familiar with micro dam technology and were not aware of the benefits and were also reluctant to adopt it until they are given proof that it is financially and technically feasible. Stakeholders also cited lack of a physical example to demonstrate to farmers how the technology works and prove the advantages of the technology.

Inadequate policies

There are no reports of institutional arrangements or policy and legislation to govern rainwater harvesting for agriculture. This is so despite the fact that many farmers (including farmers from Grenada) practice some form of rainwater harvesting. (FAO 2014). The Government of Grenada National Water Policy does not address the use of rainwater for supplemental irrigation although it recognizes the rising demand for water across the tourism, industrial and agricultural sectors (Government of Grenada 2007). Therefore rainwater harvesting for agriculture irrigation is not a major component of the work programme of the Irrigation Management Unit of the Ministry of Agriculture

Land Tenure

The Country Programme Framework 2011-2016 for Grenada's Agricultural Sector identified the major issues related to land tenure in Grenada. They were incomplete land registration, a lack of land titles, illegal land tenure and disputes over ownership create disincentives for farmers to invest and in many cases borrowers are unable to offer land as collateral.

A high percentage of the land in the Caribbean is not owner occupied as seen in the table below. This lack of secure tenure by the large majority of farmers restricts the incentive for long-term investments in land and agriculture (Gumbs 1997).

| Tenure | %of area of land | Area of agric. Land (ha) |
|---|---|---|
| **Owner** | 37 | 2,878 |
| **Owner/Renter combination** | 22 | 1,711 |
| **Renter** | 6 | 467 |
| **Manager** | 22 | 1,711 |
| **Family owned** | 11 | 855 |
| **Share cropper** | 1 | 78 |
| **Landless** | 0.7 | 54 |

Source: Gumbs 1997

Farm size distribution

| Size of farms (ha) | No. of farms | % of farms | % of area of land | Area of agric. Land (ha) |
|---|---|---|---|---|
| <2 | 7218 | 88 | 31 | 2,411 |
| 2-20 | 902 | 11 | 36 | 2,800 |
| >20 | 82 | 1 | 32 | 2,489 |

49% of farms were < 0.5 ha

Rising temperatures/High evaporation rates

Micro dams are often exposed to high rates of evapotranspiration. In general, the amount of water that can be stored and carried over into the dry season is limited, due to evaporation from the reservoir (Smith 2014) Farmers are concerned that these dams could dry up during a prolonged drought and would not provide reliable storage for agriculture.

Indications are that variability in rainfall and extended droughts are likely to continue with climate change, presenting more challenges to access water for small farms especially those located on hillsides (FAO 2014).

Many surface storage facilities including reservoirs are shallow and exposed to high rates of evaporation from prevailing winds and high temperatures. Micro dams, which are often exposed to high rates of evapotranspiration and most of these dams dry up during a drought and do not provide reliable water storage for agricultural use (FAO 2014).

Farmers in Grenada were also concerned about how rising temperatures would affect the water in the micro dam. The concern is that the water would evaporate during the prolonged dry periods when it is needed most.

### 1.2.3 IDENTIFIED MEASURES

#### 1.2.3.1 ECONOMIC AND FINANCIAL MEASURES

(Chengxiang 2008) concluded that it was more cost effective to build mini dams in areas where several farmers can share the water in the mini dam. UNDESA 2012 also recommended that the first option should be to engage groups of farmers to work together in developing these mini dams in such a way that one pond can be used by several farmers to minimize loss of land.

Special credit scheme

The establishment of a special credit scheme to provide low interest loans for irrigation to include micro-dam.

The Grenada Development Bank has an agriculture loan portfolio but it is part of the regular business loan portfolio. A special credit scheme for irrigation and including micro dam would be necessary. The scheme should have flexible conditions especially the requirements for equity and security.

The credit scheme could also be available through the micro finance institutions including the credit unions because many farmers are members of the credit union and therefore stand a good chance of receiving a loan from them. The interest on the loan should be low and should have a realistic payback period.

Another option is for government to provide labour support for the construction of the dam. Government had implemented a farm labour support programme in the past.

One option is to include the support for micro dam construction as an option for rainwater harvesting as part of one of the many Climate Smart Agricultural projects, which are being implement or planned.

Rainwater harvesting for agriculture should be promoted and encouraged through policy and institutional support and implementation of discreet national progamme. Special consideration should be given to farmers operating on hillsides. (FAO 2014). Rainwater harvesting for agriculture irrigation should be included in the Grenada National Water Policy.

The extension department to be strengthened to build capacity among lead farmers and farmers organizations in the selection of natural slopes for rainwater runoff collection and storage facilities (FAO 2014).

Establish a baseline from which to monitor and evaluate the benefits of rainwater harvesting on small-scale production (FAO 2014)

Continue the mapping of sites according to design rainfall as input to phased programme for rainwater harvesting for agriculture (FAO 2014).

Organise technical training on rainwater harvesting for professionals on knowledge ad skill of planning and design and construction of rainwater harvesting systems for agriculture irrigation (Chengxiang 2008).

Provide field support on planning, designing and implementation of trial or pilot project. The pilot project would have the following objectives:

- Test and adapt new technology on rainwater harvesting
- Be a demonstration site on the contribution of rainwater harvesting in augmenting water for food production enhancement
- Provide an opportunity for extension staff to learn and gain experience on application of the technique
- Be a showcase for best practice and training of local technicians and farmers (Chengxiang 2008).

The trial or pilot could either be located on government property on a private farm. (Chengxiang 2008) proposed two sites for the dams; one in Chambord on mainland Grenada and on at Dumfries in Carriacou. Among the objectives of the pilot project would be to improve the technology on design of layout of RWH for irrigation and to experiment on economic structure for storage.

National agriculture extension service should include or to be strengthened to build capacity among lead farmers and farmer's organizations in the selection of natural slopes for rainwater runoff collection and storage.

The Ministry of Agriculture should establish a programme to map sites according to design rainfall as an input to the phased programme from rainwater harvesting for agriculture.

The Ministry of Agriculture should establish a baseline from which to monitor and evaluate the benefits of rainwater harvesting on a small-scale production, as well as the impact of the practice on stream flow and other products and services in the watershed (FAO 2014).

## 1.3 BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR MICRO IRRIGATION

### 1.3.1 GENERAL DESCRIPTION OF DRIP IRRIGATION AND MICRO SPRAY

**Drip irrigation**

This is a low-pressure irrigation system in which water is delivered through an emission device (emitter) in drip mode. The drip mode delivers the water, which is either applied as droplets or trickles.

The drip modes can be further delineated as a line source or point source. The line source type emitters are placed internally in equally spaced holes or slits made along the line. Water applied from the close and equally spaced holes usually runs along the line and forms a continuous wetting pattern.

The point source type emitters are attached external to the lateral pipes. Water applied from the point source emitter usually forms a round deep wetting spot. Drip lines are either buried below the ground or laid on the surface. Point source emitters are typically installed on the outside of the distribution line.

**Micro sprinkler**

This is a low-pressure irrigation system in which water is delivered through an emission device (emitter) in micro-sprinkler mode. In micro sprinkler mode the water is sprayed, sprinkled or misted. The emitters operate by throwing water through the air, usually in predetermined patterns. Depending on the water throw patterns the micro-sprays, jets, or spinners. The sprinkler heads are external emitters individually connected to the lateral pipe typically using “spaghetti tubing” which is very small diameter tubing. The sprinkler heads can be mounted on a support stake or connected to the supply pipe.

The micro spray is a cross between surface spray irrigation and drip irrigation. It typically operates with pressures between 15 and 30 psi. and with application rates of 5 to 70 gallons per hour (gph) (Alliance for water Efficiency n.d.).

Micro spray typically creates a larger wetted area than drip irrigation. Micro spray is delivered through micro tubing to a series of nozzles attached to risers. These risers may be fixed or designed to pop up. Micro sprinklers are desirable because fewer sprinkler heads are necessary to cover larger areas.

Each irrigation system has at least three components that must be maintained for trouble- free operation; namely the headworks, conveyance system, and on-farm systems. The headworks are any intakes e.g. dam for delivery to the conveyance system. The conveyance system includes for e.g. pipelines that convey water from the source to the on-farm systems. The on-farm systems could be micro-spray or drip irrigation and include and subsystems required pumping, filtration and distribution.

Drip or micro spray systems are the most efficient types of irrigation system, with application-rate efficiencies of over 90%. Drip or microspray irrigation systems also use less energy than conventional sprinkler systems. Due to the small diameter of the emitter openings, filtration of the water is normally required to reduce potential blockages in these systems (UNEP 1998).

### 1.3.2 IDENTIFICATION OF BARRIERS FOR DRIP IRRIGATION

The 2012 Agricultural Census was reviewed to determine the status of the use of drip and micro irrigation in Grenada. The census showed that farming in Grenada is still mostly rainfed with only 25% of farmers using some form of irrigation and of that number 25% or one quarter were using drip and micro irrigation. Crops, which were irrigated, were vegetables, root crops and fruits in that order. Farmers were using overhead sprinklers more than any other irrigation technology (Mapp 2017).

According to data from the 2012 census most of the farmers who use drip and micro sprinklers are in St Andrew and St Patrick respectively and most farmers use potable water from the National Water and Sewerage Authority as their main source of water for irrigation. The data from the census also showed that most of the farmers who use drip and micro sprinkler operated as an individual farmer.

Although farmers have been using drip and micro sprinkler the diffusion of these water efficient technologies have been slow.

Business models for maximizing the diffusion of technological innovations for climate smart agriculture was studied in Europe. The study explored the perspectives of the provider and the user. The study found that the successful adoption and diffusion of technology innovation is dependent upon many factors. It looked at critical issues for the diffusion of technological innovations. They were value proposition, channels, customer relationships and cost structure (Long 2016). Although the study was conducted in a developed country the findings are very relevant to Grenada and it was used to guide the stakeholder discussions.

In order to find out the barriers to the adoption of the technologies locally a focus group meeting was convened to engage key stakeholders from the ministry of agriculture, and representatives from farmers' organizations. An interview was also conducted with a representative from the Marketing and National Importing Board that is currently selling agriculture irrigation equipment to farmers.

The key stakeholders identified the barriers to the diffusion of the technology, proposed solutions, and made proposals for the development of the enabling framework. A review of the literature showed that studies were conducted locally on the technical feasibility of irrigation but not on the economic and financial feasibility.

Since technical feasibility studies of micro irrigation technologies were available locally, a search was done for economic and financial studies at the region and internationally levels.

There was an abundance of information available on the benefits of micro irrigation technology but few studies on economic and financial feasibility of the technologies.

#### 1.3.3.1 ECONOMIC AND FINANCIAL BARRIERS

Small size of the market

The demand for irrigation equipment is very low and there were several attempts to get local companies to operate as an agent for companies selling irrigation products but they were not successful. Most the farmers in Grenada have smallholdings and there is no market for large irrigation systems. There is a demand for replacement parts for existing irrigation systems but farmers reported that the existing systems were sourced from different manufacturers outside of Grenada and they are not compatible, so it is uneconomical for a company to stock those spare parts. The demand for spare parts is also very low because according to farmers parts are not replaced frequently.

Availability of the technology

The Marketing and National Importing Board (MNIB), which is a government owned statutory body, is currently selling agriculture irrigation equipment to farmers. The government of Grenada provided the equipment and most of the agriculture irrigation equipment existing on the island was provided with the support of the government of Grenada; either through small-scale irrigation projects with grant funding or funds from the capital budget. Therefore the demand for agriculture irrigation equipment was being supplied under non-market conditions. More recently agricultural irrigation is being promoted as part of Climate Smart Agriculture projects.

Cost of micro irrigation technology

There were no studies available on the financial or economic feasibility of micro irrigation systems in Grenada or in the Caribbean. However, Puebla 2008 provided some basic data on costs of the technology.

The lowest irrigation cost by acre (1359USD/acre) was obtained when the area was irrigated with micro sprinkler. The cost /acre using micro sprinkler was 8/21 percent lower than the cost of using overhead micro sprinkler and drip respectively. This cost did not include the cost of the pump which is 13 and 53 (electrical and diesel) percent of the total cost of the irrigation system.

A study of the performance of irrigation projects in the region (LAC) has often been disappointing. A comprehensive World Bank review of its irrigation portfolio worldwide found relatively low returns on irrigation investment in LAC. Inefficient irrigation contributes to the relatively low returns to investment in LAC (Ringler 2000).

The International Finance Corporation commissioned a series of studies on the Impact of Efficient Irrigation Technology on Small Farmers. One case study was done in Burkina Faso, which was relevant to Grenada because of the small size of the farm (0.25ha) and the cultivation of cash crops, which are similar to the Grenada situation. A financial analysis was done based on three different scenarios. Scenario one was most relevant to Grenada. In that scenario the crops grown were onion, corn and tomato; with the use of the drip kit and a motor pump. The financial analysis confirmed that the adoption of efficient irrigation technology can be highly beneficial to farmers. The results are as follows:

| | |
|---|---|
| Investment cost | $1783 |
| Operating and maintenance cost | $ 386/y |
| Payback period | 1 year |
| Life of technology | 3 years |
| **Gross margin** | $9,158/yr 395% (after 5 years) |

Source: Adapted from (IFC n.d.)

<u>Benefits</u>

Some benefits may not be easily and accurately quantifiable. Farmers in developing countries (such as Grenada) seldom keep good records of their activities, which are essential for any accurate economic analysis. (Gumbs 1997) Evidence of this was that water meter (flow meters) were installed on only two farms in Grenada and data for only one irrigation season was collected from one of the two meters (Puebla 2008).

However, a study of the use of micro-irrigation technology in India (Priyan 2017) listed the following advantages:

(i) Micro-irrigation technology ensures water use efficiency a much as 50-90% because it reduces runoff, evaporation losses, seepage and deep percolation losses.
(ii) Since low flow rate is required, small wells can also be used as a source and it helps for energy use savings up to 30.5%.
(iii) The direct application o fertilizers to the roots results in the saving of fertilizers consumption up to 28.5%.
(iv) Crop yield for fruits was increased up to 42.4 % and increase in productivity of vegetables up to 52.7%
(v) More focused and judicious use of water has resulted in the increase in farmers’ income.

<u>Affordability of technology</u>

Studies on the affordability of the technology were done in Africa and Europe. The unaffordability of some technologies will affect their adoption, particularly by smallholder farmers in Africa. First the price, then operational costs and maintenance (Senyolo n.d.) Farmers in Europe see the technological innovations as generally too expensive for example with a drip irrigation system (Long 2016).

The Grenada Agricultural Census 2012 reported that in most cases only a portion of the land was irrigated and farmers explained that it was because the system was too expensive and they could not afford a system to irrigate the entire farm. Farmers wanted the opportunity to purchase a system that can be expanded. The Ministry of Agriculture Irrigation Management Unit confirmed that farmers often request a small system to start and for the system to be designed so that they could add pipes.

A study of Affordable Drip Irrigation for Small Farms in Developing Countries suggests that the reason for the high price is because the irrigation system sold to farmers are commercial “state of the art” drip irrigation systems.

The study further suggests alternatives, which are low-cost, available in small packages, operate at very low pressure and are easy to understand and maintain.

Access to financial capital

There are limited institutions providing credit for agriculture. Government has been providing support to farmers to install irrigation systems.

The systemic lack of finance was also found to be a barrier to improving water infrastructure for irrigation in in Caribbean. Lack of finance was also described as a barrier to improving water infrastructure for irrigation, which would allow farmers to diversify and increase crop production. Compounding this challenge was that many smallholder farmers did not own farmland to use as collateral in securing a loan for irrigation (Lowitt 2015).

The Burkina Faso case study found that the lack of access to finance to purchase efficient irrigation equipment was considered to be the main constraint to technology adoption. Only 5 percent of overall bank lending was devoted to agriculture and an even smaller proportion supports irrigation investments. This situation is exacerbated for small farmers by their lack of credit history, collateral and limited or no prior experience with efficient irrigation systems (IFC n.d.)

Proof of benefits of the technology

The Marketing and Importing Board is supplying irrigation equipment but is not an agent of the company, which is manufacturing the irrigation equipment. There is no after sale service from the MNIB because the suppliers are not qualified on technical support for design or repair (Chengxiang 2008). There is a lack of verified impact or proof that the technology would deliver as advertised so farmers are unsure or unconvinced about the value of the technology (Long 2016).

#### 1.3.3.2 NON-FINANCIAL BARRIERS

Technical capacity

Lack of knowledge of micro-irrigation system design, operation and management strategies are well known barriers to the adoption of micro irrigation systems which was also found to be a barrier in the World Bank Project Small holder Irrigation Initiative (World Bank 2002).

CARDI and the Chinese Agriculture Mission also provides limited assistance to small farmers in irrigation system design and technologies however, demands for irrigation design expertise are mostly unmet (Puebla 2008)

Puebla 2008 highlighted the deficiencies in capacity at the Irrigation Management Unit and among farmers; and the need to provide the IMU with the capacity to assist farmers with the operation and maintenance of irrigation equipment and selection and maintenance of pumps. Local farmers are demanding small-scale systems, which can be expanded. This situation also poses a problem for the selection of the appropriate pump size from the start, to cope with the expansion of the system.

Access to source of water

Lack of raw water sources was found to be the greatest barrier to the diffusion of irrigation technology in Grenada. Currently rivers are one of the main sources of water for irrigation, which restricts irrigation to only areas near to rivers but the feasibility study observed that most of the arable lands are not located near rivers or another water source.

Farmers who do not have access to surface water either use potable water or harvest rainwater. As a result irrigation systems are established mainly on low-lying areas that have a constant water source close by as seen in the table below (Mapp 2017).

Table: Estimated irrigable area at each site with and without in-stream storage

| Site | Scenario for 20% withdrawal of river flow for irrigation | | Scenario for 30% withdrawal of riverflow for irrigation | | Area from GLIS ha. | Area from NC ha. |
|---|---|---|---|---|---|---|
| | Maximum possible area without storage. ha. | Maximum possible area with storage, ha. | Maximum possible area without storage. ha. | Maximum possible area with storage, ha. | | |
| Mardrigras St. Georges | 7 | 17 | 11 | 23 | N/O | 9 |
| Hope Vale St Georges | 33 | 74 | 49 | 112 | 22 | 73 |
| Paradise St. Andrew | 247 | 633 | 370 | 950 | 205 | 32 |
| Grand Bras St Andrew | 247 | 633 | 370 | 950 | 205 | 42 |
| Diamond St. Mark | 68 | 179 | 103 | 269 | 70 | N/O |
| Beausejour St George | 81 | 227 | 121 | 340 | 13 | N/O |
| La Sagesse St David | 33 | 92 | 49 | 138 | 35 | 119 |
| Snell Hall St Patrick | 40 | 106 | 60 | 160 | 20 | N/O |
| Chambord St Patrick | 28 | 68 | 42 | 103 | 162 | 81 |
| Mt Reuil St. Patrick | 20 | 44 | 29 | 65 | 65 | 44 |
| Poyntzfield St Patrick | 39 | 111 | 58 | 167 | 140 | 9.7 |
| Boulonge St Andrew | 41 | 117 | 61 | 175 | 11 | 12 |
| Pearls St. Andrew | 44 | 127 | 66 | 191 | 37 | N/O |

Source: (Madramootoo 2001)
GLIS- Grenada Land Information System Ministry of Agriculture
NC- National Consultant Dr. Everson Peters
N/O- Not Obtainable

Knowledge of technology

Farmers were of the view that drip and sprinkler irrigation require a great deal of capital, they are difficult to manage and labour intensive. These perceptions are also limiting investment in irrigation. Farmers have been relying heavily on the Ministry of Agriculture to provide maintenance services and advice for their irrigation equipment. The current situation where many irrigation systems are in disrepair because of lack of maintenance is lending support to these perceptions. The problem of insufficient limited knowledge and information is a regional one. Access to information and technical assistance was identified as a challenge to smallholder production in the region (Lowitt 2015).

Cultural practices

Cultural practices are also a barrier to the diffusion of irrigation technology. For example small farmers are used to growing crops with different water requirements on the same plot. This poses some constraint from the point of view of irrigation design. Data collection is not a cultural practice in Grenada and farmers using irrigation equipment do not install flow meters and the amount of water used for example cannot be calculated. This is a very important barrier because data collection is very important for design.

Farming on small plots, which are dispersed all over, the island has proved to be a challenge to the design of irrigation systems. The rugged terrain means that agriculture is done on slopes and this has also posed a challenge to the design of irrigation systems and this has proven to be an additional barrier.

There are farmers' organisations in Grenada but the members of these organisations grow mostly tree crops and are practicing rain fed agriculture. Vegetable farmers are the ones currently utilizing irrigation but they are is no organization representing them. The absence of an organization representing farmers using irrigation has also acted as a barrier to the diffusion of the technology.

Land ownership and land tenure

There is fear that land owners are always looking to see if they will receive a better price by selling their land for housing development rather leasing for agriculture. Some farmers are squatters and have no legal title to the lands they occupy. The absence of a national land policy and associated legislation, there is no guarantee that agriculture will continue at those sites (Madramootoo 2001).

Availability of appropriate pumps

The MNIB is selling irrigation equipment but it does not include the pressure pumps. Not all pumps which are available locally are not appropriate for agriculture irrigation and farmers have been purchasing the without the proper technical specifications and have been purchasing inappropriate pumps.

Inadequate data

Puebla (2008) noted that the basic data for needed for the design of an irrigation system were unavailable. Data on crop water demand and soil hydrological characteristics, which are necessary for designing an irrigation system, were lacking. Madramootoo (2001) also noted that few studies have been done in Grenada on crop water requirements. Data on water usage was also lacking because flow meters were not generally installed and in the cases where they were installed the readings are not recorded.

Institutional support

NAWASA has the mandate to provide water for agriculture but there is no irrigation water supply and farmers use potable water from NAWASA for irrigation. There is no institution responsible for water resources management and the National Water Policy does not address the issue of agriculture irrigation water.

### 1.3.3 IDENTIFIED MEASURES

#### 1.3.3.1 ECONOMIC AND FINANCIAL MEASURES

Special credit scheme

Farmers are recommending that a special credit window for irrigation be established at the Grenada Development Bank or with micro finance institutions. Climate Smart Agriculture projects should give priority to agriculture irrigation. The MNIB should offer irrigation equipment on credit to farmers who sell produce to them.

Many Climate Smart Agriculture Projects are being planned and irrigation must be included as a major component in any such project.

In India the government has been providing support to farmers for micro irrigation since 1992 and has credited it success to single implementing agency, with quality standards and provisions for after sale service and government support for demonstration (Priyan 2017).

After-sale service

The sale of spare parts for key components of existing systems locally was seen as an important measure for increasing the diffusion of irrigation technology. The adoption and effectiveness of efficient knowledge of its proper use is also important. This includes suitability of the farmers' land, their choice of crops, the level of intensity of cropping practices, and proper maintenance of equipment (IFC n.d.). In this regard the MNIB should provide important technical support and after-sales services to the farmers.

Review of incentive programme

The government of Grenada has been offering concessions on pumps for irrigation but there is a need to review the incentive programme and limit the concessions to pressure pumps for agriculture irrigation. This would encourage farmers to purchase the approSWROpriate pumps.

### 1.3.2 Non Financial measures

Land Tenure

Settlement of land ownership issues, which will allow farmers to feel secure about making significant investment in micro irrigation technology, should be a priority (Madramootoo 2001). The Land Bank project should be completed urgently to provide security of tenure for farmers.

Policy guidance

Government's policy position on support for micro irrigation technology as a measure for Climate Smart Agriculture should be stated. This should be included in the major policy documents. This will ensure that micro irrigation technology would be taken into consideration in the preparation of government projects and act as a signal to the private sector that it is a priority for government.

Demonstration site

The establishment of a demonstration site where farmers can get hands on experience, learn about the technology and see it in operation is viewed as an important part of capacity building. This measure was recommended based on the perception that farmers will do what they see other farmers doing. Training was a given a high priority because farmers expressed the desire to participate in the design of the system and to be able to maintain them.

A system was designed for the Mirabeau Farm School. This system should be implemented and used as the demonstration and training site for farmers and ministry of agriculture staff.

Build capacity

Designing smaller irrigation systems, which are affordable, scalable and small, enough to fit their plots is the main recommended measure. Sessions should be organized for the equipment manufactures to provide initial awareness for new farmers and for the ministry to help build farmers capacity to design.

The capacity building should also be on the selection and maintenance of the appropriate pumps for agriculture irrigation including the use of solar powered pumps. The Ministry of Agriculture may have to organize these trainings because the MNIB does not sell agriculture irrigation pumps.

Increase the number of trained staff of the Irrigation Management Unit, training and capacity building in the design and operation of smaller irrigation systems was cited as a key measures to support the diffusion of the irrigation technology. There should also be capacity building in the area of micro dam construction and maintenance.

Data collection

A system to collect data required for designing irrigation systems should be implemented. The collection of data on water usage is critical but it must be done in collaboration with the farmers who operate irrigation systems.

## 1.4 LINKAGES OF THE BARRIERS IDENTIFIED

Farm size had an effect on the adoption of the technology. Most of the small farmers do not have access to a source of water and therefore cannot invest in micro irrigation technology. At the same time they are reluctant to use part of their farms to construct a micro dam because it reduces the amount of land available for cultivating their crops but the micro dam is the most feasible option as a source water.

NAWASA has the mandate to provide water for agriculture but it does not supply irrigation water and there is no institution responsible for water resources management and the issue of rainwater harvesting for agriculture irrigation is not included in the National Water Policy. There farmers have to compete with other users of potable water supply and priority is given the tourism sector.

The small size of the farms also affects the farmers ability to access credit and farmers need access to credit to invest in the technology which has a high initial investment cost.

Land tenure has also affecting access to credit. Most farmers do not have title to the land they are farming on. Farmers who do not have title for the land face challenges in access credit because the land cannot be used as collateral. In addition they are reluctant to invest in the micro dam and micro irrigation technologies because their tenure is insecure.

The MNIB is supplying irrigation equipment to farmers but it is not an agent for the company manufacturing the equipment and does not provide after sales service. Therefore, farmers have to rely on the staff of the Irrigation Management Unit to design their irrigation systems because they don't have the capacity to do it themselves. The IMU is operating with limited capacity.

There is no demonstration site where farmers can observe the value of the technology and learn of the benefits. The IMU involves the farmers in the installation of the irrigation equipment but for new farmers there is no opportunity to see the technology in operation before they purchase.

## 1.5 ENABLING FRAMEWORK FOR OVERCOMING THE BARRIERS

Institutional support

The removal of the barriers to the diffusion of the technologies for water for the agriculture sector requires government guidance and support. The issue of water resources management must be given priority and the recommendation to establish a water resources management authority has to be implemented if the barriers to technologies are to be overcome.

The water resources institution will be responsible for managing water resources including water for agriculture irrigation. Rivers are one of the main sources of water for agriculture irrigation in Grenada and there are other users competing with agriculture irrigation such as for recreation, domestic water supply and household use. Currently there is no institution responsible for allocation of water in the river and it has resulted in user conflict. The competing uses are not only among the different users but also among farmers especially during the dry season, which have resulted in user conflict.

It is very important that the water resources institution be established to addresses the allocation of the water in the river to the different uses and among users to avoid user conflict. All farmers must have the security that they can use the water supply to irrigate their farms for the required times and at the same time leaving enough for other users and maintaining environmental flows.

The use of water from rivers for irrigation purposes would also have to be regulated through allocation of water resources by the water resources management authority. Micro dam technology offers an option for supplemental irrigation using RWH and it should be considered as a source of irrigation water.

The mandate for the water resources unit should include rainwater harvesting for agriculture irrigation and rainwater harvesting should be included in the National Water Policy.

There have been attempts at establishing informal water users group for irrigation. Government should seek to formalize these groupings because they are key stakeholders in addressing issues related to allocation, abstraction and conflicts. Water users associations are also important in establishing communal micro dams.

Puebla (2008) proposed a well organized Irrigation Management Unit working in close collaboration with Extension Division. The IMU should be staff with four specialists (including the Manager of the IMU) to accomplish the following tasks:

- Record all statistical data on efficiency and water use capacity of each system
- Assist the farmer in the irrigation system operation and management as well as pump selection and operation
- Advise farmers on the selection and acquisition of pump and irrigation equipment
- Conduct training for farmers and other officials of the Ministry of Agriculture in the best practices in irrigation management

- Maintain up-to-date data on rainfall, crop water need and soil water related properties for Grenada’s condition

Economic

Currently government provides concessions on the importation of irrigation equipment and companies have been importing equipment for landscape irrigation and receiving concession on them. Those equipment, especially the pumps are inappropriate for agriculture irrigation but farmers are unaware of the appropriate pumps and purchase them. It is recommended that the government set the standards for agriculture irrigation equipment.

Consideration could be given to the setup of a special lending facility at a financial institution to provide farmers with soft loans for irrigation. The Government can also set up a special irrigation fund.

Regulatory

NAWASA’s mandate to supply water for agriculture but only in the absence of drought conditions and reduced rainfall should be reviewed. The use of potable water for agriculture irrigation should be discontinued but not before farmers are provided with alternative sources of water.

A Government-defined policy on agriculture irrigation is key to supporting the diffusion of the technology. The water for agricultural irrigation should be included in the National Water Policy.

## CHAPTER TWO DOMESTIC WATER SUPPLY SECTOR

### 2.1 PRELIMINARY TARGETS FOR TECHNOLOGY TRANSFER AND DIFFUSION SEAWATER REVERSE OSMOSIS

The Southern George's water supply area has experienced rapidly increasing growth in both non-residential (tourism and industrial) and residential areas. This significant growth has resulted in increased demand on the Southern St George's water supply system. The water supply facilities have a maximum yield of 31800 $m^3$/day (7 mgd) during the dry season and a maximum demand during dry season 54 600 $m^3$ (12mgd). There is a high risk of insufficient water supply during the dry season and particularly during periods of drought. (CDB 2016). With an end –of-century drying projected for the Caribbean under global warming (Taylor 2011) it is expected that the situation could worsen.

An assessment by NAWASA of the water supply network has revealed that augmentation of the water supply system is required to meet future projected demands (CDB 2016).

Currently the St. Georges University has a reverse osmosis plant, which is operated to augment the potable supply from NAWASA. NAWASA currently operates two Saltwater Reverse Osmosis plants, one in Carriacou and one in Petit Martnique. The target is to install one Saltwater Reverse Osmosis Plant in the southern St George's area of Grenada by 2030 to augment freshwater resources, which are projected to decline because of a drier Caribbean.

The target for the diffusion of Saltwater Reverse Osmosis technology is in keeping with the National Sustainable Development Goals 6.6a.

## 2.2 BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR SEAWATER REVERSE OSMOSIS TECHNOLOGY

### 2.2.1 GENERAL DESCRIPTION OF SEAWATER REVERSE OSMOSIS (SWRO) TECHNOLOGY

Reverse Osmosis is a process where water from a pressurized saline solution is separated from the dissolved salts by flowing through a water permeable membrane. The permeate (the liquid flowing through the membrane) is encouraged to flow through the membrane by the pressure differential created between the pressurized feedwater and the product water which is at near atmospheric pressure.
A reverse osmosis system consist of four major components/processes:

Feedwater intake – This is the structure that withdraws the water from the source (seawater) and conveys it to the treatment system.

Pre-treatment – this process removes suspended solids, controls biological growth and prevents scaling and clogging of the membranes during desalination.

Membrane - based desalination – this is the process used for desalting saline water based on the process of osmosis using a membrane barrier to separate the salts from water.

Post treatment – this stage involves adding chemicals to the water to prevent corrosion and ensure it meets public health standards. GE Power and water and process Technologies

Concentrate discharge – this process the discharge of the concentrated salt solution generated during the desalination process. It is discharged in the ocean at 30 – 40% greater salinity.

The National Water and Sewerage Authority is currently operating two SWRO plants, one in Carriacou and one in Petit Martnique. The plant in Carriacou is capable of producing up to 300 $m^3$ (79,251 US Gallons a day) while the one in Petit Martnique has a capacity of 5 m3/hr and both plants are powered by Photo Voltaic (PV) renewable energy system.

### 2.2.2 IDENTIFICATION OF BARRIERS FOR SEAWATER REVERSE OSMOSIS TECHNOLOGY

A review of the literature showed that National Water and Sewerage Authority (NAWASA) previously operated three SWRO plants, one in Grenada, one in Carriacou and one in Petit Martnique but by 2005 none of the plants were operational. The literature also showed that a few hotels were also operating reverse osmosis plants (UNESCO 2006).

A focus group meeting was held with staff of NAWASA and discussions were held with key government informants to identify the current barriers to diffusion of the technology in Grenada.

An interview was conducted with the Caribbean Community Climate Change Centre (CCCCC) to gather information about the challenges faced with the operations of the two reverse osmosis plants, which are currently being operated in Carriacou and Petit Martnique. The plants were installed as part of a project implemented by the CCCCC and are being managed by NAWASA.

The barriers to the adoption of reverse osmosis technology both for Grenada and the region are well documented. The barriers to the diffusion of Saltwater Reverse Osmosis technology were found to be standard so that the barriers, which were identified in the literature, also existed in Grenada.

#### 2.2.2.1 ECONOMIC AND FINANCIAL BARRIERS

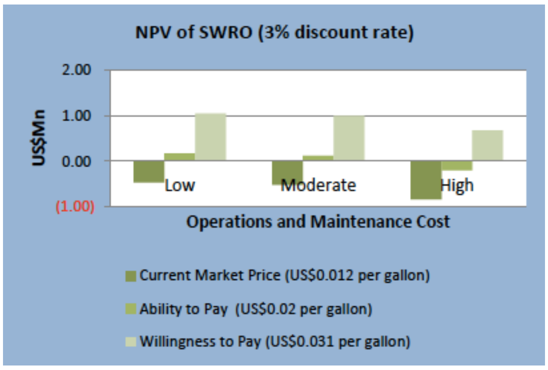
Benefit and cost

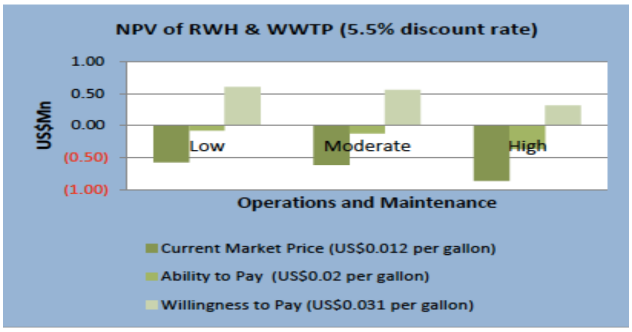
Desalination technology remains very costly relative to traditional methods of water supply because of large capital investment and high operational and maintenance expenses (Greaves 2012). There are four main costs associated with Saltwater Reverse Osmosis operations. The highest cost is capital, second is energy followed by membrane, chemicals and maintenance. Energy costs would be a large percentage of the produced water costs because electricity costs are high. High cost of membranes and chemicals are also considered barriers to the use of the technology.

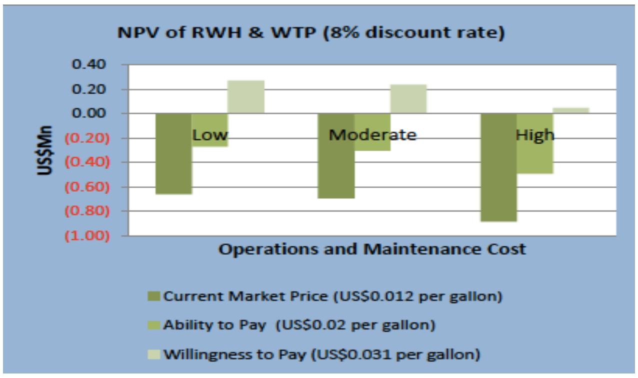
Bynoe et. al (2011) conducted a benefit and cost analysis of a Salt Water Reverse Osmosis (SWRO) which the organization installed at Paget Farm in Bequia St. Vincent and the Grenadines to augment the rainwater supply on the island. The circumstances on the island are different from Grenada because the island only has one source of water, which is rainwater, but the lessons learned are still relevant although Grenada has many sources of water.

Bynoe et. al used willingness to pay rather than prices actually paid because many of the project impacts that are to be included in the analysis either will be non-marketed. Furthermore, many project impacts that are marketed will be bought and sold in markets where prices are distorted by various government interventions.

Figure:  Financial analysis for SWRO Bequia



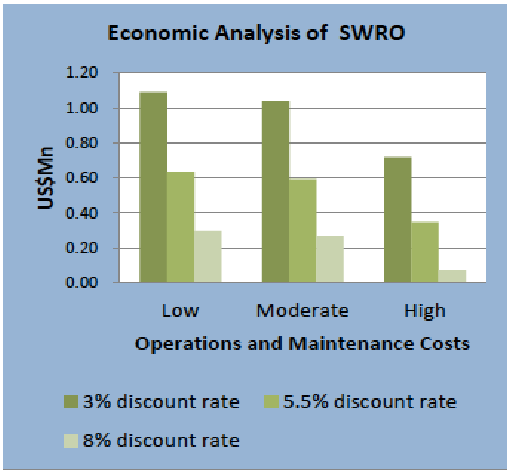




Source: (Bynoe 2014)

The financial analysis was conducted using a high, moderate and low operational and maintenance cost scenarios with a three different discount rates 3%, 5.5% and 8% respectively. Bynoe et al found that the project was neither financially feasible for any of the discount rates nor operational and maintenance costs scenarios used when the when the market price was US$0.12 per gallon of water.  However, when they set a moderate price of US$ 0.20 per gallon of water (populations ability to pay) the project was financially feasible, with a discount rate of 3% and with low to moderate operational and maintenance cost.  If the operational and maintenance costs are high and the discount rate is above 3% the project becomes financially undesirable as seen in Fig. Additional if renewable energy is used as was done with PV system the project would provide more benefits and it becomes more desirable. (Bynoe 2014).

Bynoe et al also conducted an economic analysis and capture the further benefits related to carbon offset and health. They pointed out that the difference in the analyses is that the benefit stream was expanded even though remaining extremely conservative. In this case the willingness to pay was used as an indicator for the price and it was applied to the three scenarios. The project was found be feasible at the applied discount rate for all three scenarios as shown in figure (Bynoe 2014).

Figure: Economic Analysis for SWRO's for Bequia




Source: (Bynoe 2014)

Another method of analysis was used to determine the feasibility of desalination technology for Bequia as well as the competitiveness in using this technology. The levelised water cost (LWC) was determined and it was compared with LWC of other countries in the region. The LWC gives an indication of the practicality of desalination for the study area and it competitiveness in using this water supply option (Greaves 2012).

To determine the LWC Greaves calculated the all the major costs including: SWRO system, energy recovery device; energy cost and operating and maintenance cost – membrane replacement cost, general maintenance, spare parts, labour and administration. The LWC was estimated to be US$2.82/$m^3$ (Greaves 2012).

Greaves concluded that since the calculated value is comparable to some of the LWC for these other islands the cost is very competitive and adds to the practicality of using this option as a reliable source of water.

The results of the analysis would have been ideal if the cost competitiveness was a comparison between the costs of operation of desalination as a source of fresh water and the tariffs charged for existing traditional forms of water supply. However, the computed LWC for desalination water on the island of Bequia is competitive to the mainland St. Vincent (which uses surface water like Grenada) because the cost of water there is US$ 2/$m^3$ and is therefore a workable solution (Greaves 2012).

Table: Bequia estimated LWC compared to LWC of other small island developing states

| Country | Capacity ($m^3$/day) | Water Source | LWC (US$/$m^3$) | Remarks |
|---|---|---|---|---|
| **St. Vincent** | | Rivers, streams | 2 | |
| Bequia | **60** | **Seawater** | **2.87** | |
| **Canouan** | No data | Seawater | 3.05 | Privately owned and sold to residents |
| **Cap-Haitien Haiti** | 10 | Seawater | 5.36 | Energy was assumed to be provided by a stand-alone diesel generator. Hence, the capital cost of the diesel generator was included in the analysis |
| **Barbados** | 30,000 | Brackish | 1.01 | |
| **British Virgin Islands (BVI)** | 10,446 | Seawater | 1.51 | Government subsidized the electric cost $0.66/$m^3$ |
| **Trinidad &Tobago (T&T)** | 136000 | Seawater | 0.70 | |
| **Antigua & Barbuda** | 4,500 | Seawater | 1.54 | |
| **New Providence, Bahamas** | 1650 | Lake (6000-13,000 ppm) | 2.02 | Old SWRO system. Plant decommissioned in early 90's |
| **Nassau, Bahamas** | 7,570 | Seawater | 1.77 | |

Source: (Greaves 2012)

<u>Tariff rates</u>

NAWASA raised the issue of the difference in cost of production of the fresh water produced by SWRO plants operated in Carriacou and Petite Martinque and the surface water produced in Grenada. However, there is no separate tariff rate for water produced by SWRO and consumers pay the same price as the surface water.

#### 2.2.2.2 NON-FINANCIAL BARRIERS

Feed water intake /location/water quality

A (UNESCO 2006) study of desalination plants in the region found the availability of a suitable site for feed water intake was a problem in Grenada. In that study NAWASA reported damage to suction pipes resulting from severe weather conditions.

The recently installed Saltwater Reverse Osmosis plant at Carriacou is also experiencing that problem and has suffered many interruptions during its operations due to the inadequacy of the salt-water intake. The intake extends approximately seventy-five (75) feet offshore in open water and is consistently affected by wave action and turbidity of the water (CCCCC 2018).

Cultural acceptability

There is a perception among the local population that water produced by the technology is not of drinking standard and the taste is different. The local perception that Grenada has unlimited sources of fresh water is acting as a barrier to the consideration of the technology for Grenada.

(UNESCO 2006) found that desalinated water as a potable source faces a major hurdle. The results of a random survey revealed that even under drought conditions, persons were reluctant to consume desalinated water. Discussions with key stakeholders also revealed that the situation is still the same in Grenada.

Availability of surface water

In the mid-90's NAWASA implemented several major projects to improve the water supply situation in Grenada (Grenada. 1995). These projects helped to address the shortage of water but it contributed to the perception that Grenada has unlimited surface water.

Legislative authority

The Act governing NAWASA does not give it a mandate for desalinated water. The act covers surface and ground water.

Institutional support

Desalinated water is not addressed in the National Water Policy so there is policy guidance on desalinated water for Grenada even though NAWASA is currently operating two SWRO plants one in Carriacou and one in Petit Martnique.

NAWASA has indicated that it is desalination would only considered in a worse case scenario when the company will bring in a portable desalination plant or two and set it up in particular areas where persons can connect to the transmission and distribution systems (New Today Newspaper 2016).

### 2.2.3 IDENTIFIED MEASURES

#### 2.2.3.1 ECONOMIC AND FINANCIAL MEASURES

Funding mechanism

The investment cost of reverse osmosis is high and there are two options for funding. One is grant funding as a climate change adaptation measure as was done in Carriacou and Petit Martnique and the other is a loan to NAWASA with government support.

Investment in renewable energy

A Photo Volatic renewable energy system was used to address the issue of high energy costs for the SWRO plants in Carriacou and Petit Martnique. The project partnered with Grenlec's Community Partnership Initiative to implement the Photo Voltiac system to assist in offsetting operating costs for the Saltwater Reverse Osmosis plants on Carriacou and Petit Martnique (Grenlec 2015). This approach should also be explored with Grenlec for the installation of the SWRO plant for Grenada.

Revision of tariff structure

There is a proposal for the development and implementation of a new tariff structure for NAWASA to sustainably finance investments as part of the Project for a Climate Resilient Water Sector in Grenada (CREWS) (GIZ 2017). The project does not include desalination but investment in desalination should be considered in the review of the tariff structure. NAWASA is selling water from the SWRO plants to consumers in Carriacou and Petit Martnique at the same rate for surface water for Grenada.

Another option is to consider should consider selling desalinated water to only commercial consumers in the south of the island where they are concentrated because they already pay a higher rate than domestic customers and would be in a better position to pay a higher price for water than a domestic consumer.

The use of desalinated water by commercial sector in Grenada is not new. During the mid-90's when the southern part of Grenada was experiencing severe water shortages hotels in the southern part of Grenada were given incentives to install desalination plants to cope with the water shortages (Grenada. 1995). Following the improvement in the surface water supply the hotels abandoned the desalination plants and today only the St. Georges University operates a desalination plant in Grenada.

Benefit and cost analysis

A benefit and cost analysis of an SWRO plant for Grenada should be done. This information is necessary for both selling the idea of an SWRO plant to the policy makers as well was providing justification for funding for the plant. It is important to capture both the benefits and the costs because as the amount of rainfall reduces and less surface water becomes available, consumers are expected to be willing to pay more for water.

#### 2.2.3.2 NON FINANCIAL MEASURES

Public education

The UNESCO (2006) report on desalination in Grenada documented the need to educate the public and made reference to the success of the Barbados approach where the water authority educated the public before the introduction of the desalination water.

Education of the public should not only involve providing the public with information but should also include an opportunity to taste water produced by the SWRO plant in Carriacou and Petit Martnique. The (UNESCO 2006) recommendation that is necessary for countries where desalinated water is being introduced to a population that has traditionally relied on other sources, and where myths or lack of knowledge of desalination may have produced negative perceptions is very applicable to the Grenada situation.

Grenadians should be given the opportunity to taste the water produced at the SWRO plant in Carriacou and Petit Martinique because one of the barriers was found to be the negative perception of the public towards desalinated water even if they had not tasted it.

NAWASA also need to create the awareness in Grenada of the operation of the SWRO plants in Carriacou and Petit Martinique. Many of the key stakeholders involved in the process were unaware of the operation of the SWRO plants in Grenada and in Carriacou and Petit Martnique.

(UNESCO 2006) further recommends that the public education should also focus on the cost of desalinated water, even where it is subsidized by government so that consumers have a realistic idea of the cost of water because the public would need to be suitably prepared for any increase in tariff rates. This recommendation is also appropriate because NAWASA is already considering increase in tariff rates for surface water and cost of desalinated water is higher than surface water.

Location site of feed water intake

Due the small size of the island there are limited areas, which are appropriate for location of the feed water intake and disposal of the brine. Already there are lessons to be learned from the location site for the intake pipe especially the fed water intake in Carriacou.

It would be useful to identify potential sites for the location of the intake pipes and conduct social and environmental impact assessments of the sites to determine which location is appropriate as the site for the feed water intake pipes and areas suitable for brine disposal.

Regulatory

The Act governing NAWASA should be reviewed in light of the operation of the two SWRO plants and the sale of desalinated water.

## 2.2 LINKAGES OF THE BARRIERS IDENTIFIED

Desalination is generally constrained by mainly high investment and operational and maintenance costs and environmental concerns.

The high cost of operations results in the price of desalinated water being higher than fresh water. Electricity expenses represent the highest part of the operating cost while chemical treatment cost was the next highest. The use of high quality membranes is also contributing to high operational costs because the quality of the membrane affects the quality of the water produced and if poor quality water is produced it is unacceptable to the public.

The higher priced desalinated water is a challenge for NAWASA because their current tariff structure is based on the cost of production from surface water, which is much lower. The current tariff structure does not allow NAWASA to charge a different rate for desalinated water and the desalinated water would have to be subsidized.

The availability of surface water is a barrier to the use of desalination technology for augmentation of fresh water supplies because based on the discussions with key stakeholders there is a perception that Grenada has an unlimited supply of surface water and there is no need for desalinated water. Stakeholders were unaware that Grenada has a gap in the water supply in the dry season.

NAWASA is only considering the use of mobile desalination technology to augment fresh water supplies during water crisis situations. The National Water Policy does not give NAWASA any direct to use desalination technology to augment fresh water sources neither does the Act governing NAWASA gives it a mandate for desalinated water.

### 3.3 ENABLING FRAMEWORK FOR OVERCOMING THE BARRIERS

Regulatory

Development standards including intake pipes and brine disposal are needed to protect local environments or human health. The National Water and Sewerage Act would have to be revised to include desalinates water.

Economic

Government would have to guarantee funding for the water utility to access loan for the investment in the desalination technology or government could also request grant funding for the investment in the technology under a climate change adaptation project similar to the arrangement for the existing two SWRO plants.

Government would have to consider granting subsidies to the utility to keep the water from the different sources at the same price or grant permission for an adjustment in the tariff structure, which would allow the utility to charge a different rate for the water based on source.

In order to address the high cost of electricity renewable energy should be considered as the source of energy.

Institutional arrangements

In order to ensure public health, all water from desalination plants must be monitored and regulated. When new or unregulated contaminants are introduced, new legislation, regulatory oversight, or standards may be needed. Water managers should be required carefully monitor, report, and minimize the concentrations of chemicals in brine discharges.

Capacity building in the operation and maintenance of the plant would be required. The skill sets of the regulatory agencies responsible for monitoring water quality as well the disposal of the brine would also have to be broadened.

Desalination as a water augmentation option should be included in the National Water Policy. The Physical Planning Unit should develop guidelines for social and environmental impact assessment for desalination plants.

# CHAPTER THREE TOURISM SECTOR

## 3.1 PRELIMINARY TARGETS FOR TECHNOLOGY TRANSFER AND DIFFUSION

Many hotels in Grenada are currently operating onsite wastewater treatment systems because they are not connected to the central sewerage network operated by NAWASA. They are not connected because they are located in remote areas away from the central sewerage network.

NAWASA is currently seeking funding under the Southern St. Georges water supply expansion and wastewater improvement project to improve wastewater management of the network; but not all the hotels would be connected at the end of the project. Many existing hotels and new hotels located outside of the Southern St Georges would continue to operate onsite waste water systems and have the opportunity reuse wastewater for irrigation.

The target is to have all existing and new hotels operating onsite wastewater treatment systems reusing the water for irrigation purposes by 2030. The target is in keeping with the National Sustainable Development Goals number 6.3.

## 3.2. BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR THE REUSE OF TREATED WASTEWATER IN THE TOURISM SECTOR

### 3.2.1GENERAL DESCRIPTION OF DECENTRALISED WASTEWATER TREATMENT TECHNOLOGY

Before wastewater can be reused, it must be treated (Peters 2015). Technologies for treating wastewater for reuse can vary depending on the treatment or discharge standard that is required for end users or end-point disposal. Treatment of wastewater shall be targeted towards producing an effluent fit for reuse in irrigation in accordance with Annex III of the LBS Protocol as a minimum (GEF CReW 2015).

Most of the hotels are located near to the coast with limited space. Technologically advanced package plants are the preferred option for coastal locations with space unavailability. The preferred options are Small Footprint (SFP) type systems membrane Bioreactors (MBR) and Biologically Engineered Single Sludge Treatment BESST) (CEHI 2009).

A centralized sewer system was completed for the town of St. George in the 1940's and was expanded to the south of the island in 1993 (United Nations Environment Programme n.d.). Due the variable terrain it would be difficult to expand the centralized sewerage system without constructing several pumping stations, which is not feasible. The cost of developing adequate systems are very high and with such high financial requirements mean that the national governments are constrained in raising the necessary capital, which makes it virtually impossible for many islands to attain full wastewater treatment in the near future (Peters 2015)

Many of the hotels are not located in the areas served by the centralized sewerage network and therefore decentralised wastewater treatment systems are necessary. The installation of onsite system provides the opportunity for wastewater reclamation for landscape irrigation.

Decentralized wastewater treatment can create a new resource stream by making wastewater reusable. In remote areas in Caribbean Islands like Grenada, the infrastructure cost required to deliver effluent to a centralized system is higher than the cost to construct a decentralized facility. Installing underground pipelines for a few kilometers can be costly for many public agencies and hoteliers. There are decentralized wastewater system which are small and containerized and this means that they take up less valuable real estate. They also have the added benefits of reducing risk of pollution and contamination and easing strain on local water resources (Slobhan 2017).

The level of treatment of wastewater depends on the end use. The following are the levels of treatment.

There are five stages of wastewater treatment, they are:

Preliminary stage – Refers to the removal of the larger suspended and floating materials to protect the pumping equipment and the subsequent treatment units.

Primary stage – Primary stage aims to settle large suspended matter, by means of physical or chemical processes.

Secondary stage – Secondary stage generally involves biological treatment and it is aimed at reducing organic matter.

Tertiary treatment – Tertiary treatment includes processes required to remove various pollutants. It is used to improve the effluent by additional removal of suspended solids and a further reduction in pathogens. It takes different forms such as ultra violet light irradiation, micro filtration or chemical dosing.

Disinfection – Disinfection is treatment of the effluent for the destruction of all pathogens. Sandals hotel has been doing disinfection by chlorination.

The Caribbean Environmental health Institute has recommended the following decentralised or onsite systems for Grenada (UNEP 2004)

**Package Plant – Membrane Bioreactor**

The membrane bioreactor system utilizes filtration technology to replace the traditional clarifier and sand filters in secondary treatment systems. The process is a biological utilizing a semi-permeable membrane as the final filtration barrier.

The first step in the process is the screening of the wastewater to remove particulate matter. The screened wastewater is pumped from the holding tank to an aeration tank. Air is introduced into the system by blowers to aid the biological process. A vacuum pump is then used to pull the clear treated water through the hollow fibre membranes.

The system has moderate capital, operation and maintenance costs and requires minimal operator supervision. It requires extremely little space requirements and it produces consistent high quality effluent.

**Intermittent Slow Sand filter**

This technology is designed for on-site treatment of domestic and mixed wastewaters. The process may be defined as the intermittent application of waste water to a bed of granular material (sand) and which is under-drained to collect and discharge the final effluent. The process is one of polishing wastewater that has passed through primary and secondary treatment and which produces effluent of very high quality.

The correct grading of the media may not be readily found and after 3-6 months the dirty layer must be manually scrapped off, washed and sand replaced.

It produces high effluent quality, can be constructed with material that can be found locally, can be operated by semi-skilled operators and there is flexibility in the siting of the system.

The capital cost of the technology is low to moderate and operation and maintenance cost is also low.  A pump may be necessary if the wastewater has to be pumped to higher elevation for irrigation

### 3.2.2 IDENTIFICATION OF BARRIERS TO THE REUSE OF WASTEWATER IN THE TOURISM SECTOR

The first step in identifying the barriers to wastewater reuse was to determine the status of wastewater reuse among the hotels operating wastewater treatment plants in Grenada and to explore the barriers from the perspective of the hotel operators. The interviews with hotel operators confirmed that wastewater reuse was minimal. One exception was Sandals La Source resort, which operates a mechanical treatment plant, and the wastewater is chlorinated and reused for irrigation.

A literature review on the reuse of wastewater in the tourism sector was conducted and it was found that several studies on wastewater treatment systems were undertaken but not water reuse. The studies identified the hotels in the region, which are reusing wastewater for irrigation but only one case study was done on reuse of wastewater at a hotel.

Much of the studies done in the region focused on the cost of installing wastewater treatment systems in the Caribbean and the public health benefits.

A focus group meeting was held with NAWASA to discuss barriers to the reuse of wastewater by hotels from the perspective of the utility with the mandate for providing water and wastewater services. NAWASA did not have any information on the hotels operating onsite wastewater systems because their mandate only covered the centralized wastewater system.

Another focus group meeting was held with key government departments to explore government policy position on the reuse of wastewater by the hotel sector. The policy position was unclear because there is no legislation or regulation requiring wastewater treatment and the roles of the Ministry of Health and the Environment Department was not clear.

It was not clear which ministry was responsible for setting the standards for wastewater treatment, although the Ministry of Health Environment Department has been the one reviewing the designs for wastewater systems for new hotel development and for monitoring the operations of wastewater systems.

Interviews were conducted with hotel operators in Grenada with onsite wastewater treatment systems and with Coconut Bay Resort and Spa in St. Lucia. Coconut Bay Resort and Spa recently implemented a project to retrofit its wastewater treatment system to reclaim the wastewater and reuse it for landscape irrigation.

#### 3.2.2.1 ECOMOMIC AND FINANCIAL BARRIERS

Cost of equipment/operation/maintenance

The costs of wastewater treatment are high but vary widely according to location, type of wastewater being treated and regulations prescribing the degree of treatment needed before reuse is acceptable. However, costs for treating and reusing wastewater in Small Island Developing States like Grenada is not readily available but the main component of the wastewater treatment is the treatment plant. Wastewater treatment facilities require a high level of operation and maintenance and close monitoring of discharge effluent quality to minimize health ad environmental risks associated with wastewater reuse. Close monitoring of the treatment processes by skilled staff is required (UNEP 1998).

Most data available relate to the cost of treating the wastewater prior to reuse. Additional costs are associated with distribution system (in this case irrigation system). Costs can be recovered out of the savings derived from the reduced use of potable fresh water. The feasibility of wastewater reuse ultimately depends on the cost of recycled or reclaimed water relative to alternative supplies of potable water (OAS 1997).

Water reuse requires prior installation of wastewater treatment and the irrigation systems of which all require financial resources. There is no universal way for doing cost benefit analysis that is relevant to all reuse applications and local settings. Despite some attempts to do cost benefit analysis none of the approach or analysis has been comprehensive and accurate (Slobhan 2017). Hotels and resorts find upfront expenses to be a significant barrier to adopting decentralized solutions (Slobhan 2017). All respondents except Sandals La Source confirmed that cost of the technology for treating the wastewater was a barrier but another significant barrier was the cost of operation and maintenance because the plants were purchased in Europe and that there was no local company available to provide adequate maintenance services.

The cost of effluent treatment vary widely according to location and levels of treatment and all hotels which had onsite wastewater treatment plants except True Bay Resorts were operating packaged plants. True Blue Bay was operating the Slow Sand Filter system.

Benefits

The main benefit elements from water reuse for irrigation is the value of the useful water gained from wastewater which can be directly computed and which is available for irrigation. The assignment of this monetary value for this water would depend on the local situation and is governed by the freshwater availability and willingness to pay. The benefit from the resources (water and nutrients) can be evaluated based on fresh water tariff. Benefits related to the environment, which includes the reduced pollutant loading are improved public health, local environmental protection and reduced impact of the downstream aquatic ecosystems. While improved public health and environmental improvement are considered benefits in one situation where the wastewater is thoroughly treated and as a cost in a situation where the system is performing under capacity (Slobhan 2017).

(Kihila 2014) concluded that because the cost benefit analysis approaches did not comprehensively account for all costs and benefit elements the customization of any model would be necessary. The major costs were the investment cost for the treatment plants, the operation and maintenance costs.

Reduced consumption of potable water is one of the main benefits to be derived from the wastewater reuse but while it is a benefit for the hotel it could be a loss of revenue for NAWASA.

If wastewater is implemented on a large scale, revenues to water supply and wastewater utilities may fall as the demand for potable water for non-potable water uses is reduced (OAS 1997). NAWASA has also expressed concern about the loss of revenues because the hotel sector falls in the category of non-domestic and it attracts a higher rate than domestic sector as seen in the table below.

Table showing NAWASA Tariff Rate Structure

| Tariff Structure (gal/mth) | Variable Rate (EC$/1,000gal.) | Fixed Monthly Charge |
|---|---|---|
| **Domestic** | | |
| **Less than 2,800** | 8.10 | 10.80 |
| **2,800-5,500** | 13.50 | 10.80 |
| **Greater than 5,500** | 20.25 | 10.80 |
| **Non-Domestic** | 21.35 | Below 2,800 gals/month – 15.00<br>2,801 – 20,000 gals/month -33.75<br>20,00 – 100,00 gals/month – 140.00<br>Over 100,000 gals/month – 550 |
| **Ships** | 33.75 | N/A |

Source: Our Rates nawasa.gd

Benefit and cost analysis

The Caribbean Community Climate Change Center undertook a project in St. Lucia, which included the retrofit an existing sewage treatment facility at the Coconut Bay Resort and Spa and installation of an irrigation system. The project also included the installation of a rainwater harvesting system.

Bynoe et al (2014) undertook a Benefit Cost Analysis (BCA) of the project. The cost included the capital cost of retrofitting the sewage system and the irrigation system and incremental operation and maintenance cost while the benefits were environmental benefits. This study is very relevant to Grenada because many of the hotels have existing sewage treatment systems but the wastewater is not being treated and reused for irrigation.

The results of the of the BCA showed that the Net Present Value of (NVP) and the conclusion of the analysis is sensitive to the system's total electrical usage and cost and the value placed on the environmental benefits to be derived from this project. It was also noted that as the electricity cost increases, the operational and maintenance costs increases, and the project becomes less worthy.

At all discount factors used in the analysis (2%, 4.5% and 7%) and under the different cost scenarios presented, Bynoe et al (2014) found that the project exhibits a negative NPV value both with and without initial investment, when no environmental benefit is included into the analysis. However, when the economic analysis is conducted and social and environmental benefits are included in the project, under some of the cost scenarios it is viable.

Bynoe et al (2014) identified several economic, social and environmental benefits, which were not included in that analysis due to lack of credible and sufficient data, which may have indicated a greater feasibility of this intervention.

The social benefits that were identified which are associated with this project included reduced consumption of the potable water produced by the national water utility and health and social benefits.
(Kihila 2014)

#### 3.2.2.2 NON-FINANCIAL BARRIERS

Technical capacity

Technical capacity in operating and maintain treatment systems, monitoring and analyzing discharge and impacts are barriers to use of wastewater technology (Caribbean Regional Fund for Wastewater Management 2010) these barriers were the most common cited by respondents.

Several other non-financial barriers exist and they include lack of operational and maintenance skills. Some of the local hotels, which are currently operating decentralised systems, reported that they were experiencing challenges with the maintenance and operation of these systems. The reliance on technologies imported from overseas is proving to be a barrier. The package plants used in Grenada were bought in Europe and the local skill sets to maintain them are not available. Maintenance services and spare parts are also sourced from Europe in some cases, which increase the cost. This has resulted in a perception that wastewater treatment is expensive. The challenges experienced by those hotels currently operating wastewater treatment plants is a barrier to the implementation of the wastewater technologies.

Knowledge and awareness

Respondents also confirmed the findings in the literature that there is limited awareness, knowledge and understanding of technology and that there was poor communication and collaboration between various sectors which resulted in a fragmented approach to wastewater management (Caribbean Regional Fund for Wastewater Management 2010).

There is an unfavorable perception of reuse of wastewater and the low level of awareness of wastewater treatment technologies at all levels and this is a critical barrier.

The curricular of the local tertiary institutions do not include management of decentralized wastewater technology. Documented knowledge on the performance of decentralised technology is not available locally.

Legislation/regulations

The search of the literature verified that there are inadequate national policies, laws and regulations and limited enforcement of existing laws (Caribbean Regional Fund for Wastewater Management 2010). There is a weak regulatory system. There are no local regulations, which requires hotels, or any other institution to treat and reclaim wastewater, which is another barrier. The legislation, which is referenced in reviewing wastewater systems, is the Public Health Act but the Act is outdated (Pan American Health Organisation 2000). The National Water and Sewerage Authority Sewerage Regulations SRO 40 of 1993 address the centralised sewerage system, which is operated by the National Water and Sewerage Authority. There is no legislation or regulations covering decentralized wastewater treatment.

Excess water

During rainy season, reuse of wastewater may not be needed for irrigation purposes by hotels and the challenge becomes how to dispose of this water during wet periods (Peters 2015). Reuse of wastewater may be seasonal in nature, resulting in the overloading of treatment and disposal facilities during the rainy season; if the wet season is of long duration and/or high intensity the seasonal discharge of raw wastewaters may occur (OAS 1997). Coconut Bay Resort and Spa confirmed that during the rainy season there is excess water, which they dispose off, in a nearby mangrove.

In the absence of the regulations not all hotels are equipped with waste water systems with the capability to treat the wastewater and reclaim it. In addition there are no effluent discharge standards for those hotels, which operate wastewater systems onsite, and there is inadequate technical capacity to monitor and analyze wastewater discharges.

Limited space

One important barrier identified for local hoteliers is the lack of land space on hotel properties to construct onsite wastewater treatment facilities, which leaves them with the package plant as the only option.

Institutional support

The absence of an institutional framework to support the widespread implementation of wastewater technologies is a very important barrier. Some hoteliers reported that while they see the value of using the wastewater technologies there is no existing institutional support. There are no technical guidance documents available for example and there is no institution providing technical support.

There is no integration between the planning for wastewater and water resources and as a result the reuse of wastewater from onsite wastewater treatment for irrigation to build resilience to drought is not considered.

After sale service

Hotels which currently operate wastewater treatment packaged plants were concerned that there is no local agent for the product and technicians and spare parts have to be imported from Europe.

### 3.2.3 IDENTIFIED MEASURES

#### 3.2.3.1 ECONOMIC AND FINANCIAL MEASURES

Hoteliers recommended wastewater treatment and reuse incentive programme which is similar to the energy efficiency assistance programme under the CARICOM Development Fund (CDF) Country Assistance Programme (CAP). It involved direct grant assistance for the implementation of energy plans for the hotel sector in partnership with the Grenada Hotel and Tourism Association (Government of Grenada 2013).

The funds were administered through the Grenada Development Bank and hotels were allowed to access loans under the CDF CAP loan component. According to the hoteliers they made the investment and made the claims for the 50% rebate afterwards (GHTA 2016).

The other option is a pilot project similar to the Coconut Bay Resort and Spa wastewater treatment and reuse project in St. Lucia, which was jointly funded with a grant and funds from the hotel. The grant funding could be requested as part of a climate change adaptation project. The funding that will be required is to retrofit an existing wastewater treatment plant to treat wastewater to disinfection stage and to install an irrigation system.

The hotel and tourism services is a priority sector for the Grenada Industrial Development Corporation (GIDC) and hotels are eligible to receive tax concessions on investment made on their properties. Wastewater treatment and reuse equipment should be included on the list of items, which are eligible for tax concession under the Grenada Industrial Development Corporation.

### 3.2.3.2 NON FINANCIAL MEASURES

Capacity building

Education on wastewater treatment technologies is necessary if there is to be an uptake of the technologies. Introduce a course on decentralised wastewater treatment and management at the T. A. Marryshow Community College to train technicians to maintain the decentralized wastewater treatment systems. Include wastewater management as part of the Environmental Health component of the Master in Public Health programme of the St. Georges University. Provide training in wastewater management for the staff of the Environmental Health Department of the Ministry of Health to improve public health monitoring of effluent discharge from decentralized wastewater treatment systems and approve designs for decentralized wastewater systems.

Institutional support

Development of guidance documents on appropriate wastewater management technologies for Grenada and guidance on the design of onsite wastewater management systems. The water policy should be updated to include reuse of wastewater and a national sanitation plan should be developed.

Public awareness

Hold public education session on wastewater treatment technologies for existing hotels with field visit to Sandals La Source hotel to observe the operations of their wastewater treatment and reuse system.

## 3.3 LINKAGES OF THE BARRIERS IDENTIFIED

Lack of knowledge of the subject is also a barrier to the diffusion of the technology because institutions, which are responsible for providing technical guidance, do not have the capacity to do so. The lack of capacity is not limited to knowledge but also the absence of the regulatory system. There is no law requiring hotels to treat wastewater and reuse the water. Wastewater is not integrated into water resources management because there is no institution responsible for water resources management.

The omission of wastewater reuse from the National Water Policy is evidence of lack of institutional support.

The high price of the technology is a key barrier especially for those hotels with limited land space and has the package plant as the only option. The limited skill set is also contributing to the high cost of maintenance because maintenance personnel have to be brought in from Europe and that raises the cost of maintenance. Importation of spare parts from Europe also increases the cost of maintenance.

Currently there is limited access to private capital for investment in wastewater treatment systems that allows for reclamation and reuse and the absence of the regulatory system does not require hotel operating wastewater treatment to make waste water reuse a priority.

NAWASA has the mandate for managing the central sewerage network and is concerned about the use of decentralized wastewater systems. The use of decentralized wastewater treatment by hotels would mean that NAWASA would lose revenues if they are not connected to the central sewerage system and if wastewater is reused for landscape irrigation.

## 3.4 ENABLING FRAMEWORK FOR OVERCOMING THE BARRIERS

Regulatory

Currently there are no regulations requiring hotels to have onsite wastewater treatment systems. Although hoteliers interviewed were in support investment in wastewater treatment systems for wastewater reclamation and reuse, it may be necessary to introduce regulations requiring hotels which are not connected to the central sewerage network to reclaim and reuse wastewater for irrigation purposes. So far two hotels had invested in wastewater reuse for landscape irrigation.

The roles of the various government departments and institutions have to be rationalized and clarified inorder to overcome the barriers to wastewater reuse in the hotel sector. The Environment Department could be responsible for enacting legislation for wastewater reuse and protect the environment, while the Public Health regulations would be revised to cover standards and monitoring of effluent discharge from wastewater to safeguard public health.

Build capacity of the relevant government institutions and departments in wastewater treatment and reuse.

Economic

Hoteliers requested a special credit arrangement to allow them to access low interest loans for the investment in wastewater treatment systems due to high interest rates charged by financial institutions. Their proposal is for the funds to be administered by the Grenada Development Bank.

The Grenada Industrial Development Corporation should be given the authority to give incentives to existing and new hotels to invest in wastewater reclamation and reuse technology.

Institutional arrangements

The National Water Policy should be revised to include wastewater reuse. Wastewater reuse should be integrated into national planning for climate change adaptation.

The Ministry of Health should secure access to the services of a sanitary engineer as the need arises until a dedicated officer is hired. Training should be offered to the staff of the relevant government departments at university level.

The Human Resource Development Department of the Ministry of Education should to ask to include wastewater as a priority area for training.

Guidance documents on wastewater treatment and reuse should be developed and made available to new hotel developers who apply for develop permission.

Annex

Bibliography

Alliance for water Efficiency. "Drip and Micro Spray Irrigation Introduction." *Alliance for Water Efficiency.* www.allianceforwaterefficiency.org/Drip_and_Micro-Spray_Irrigation_Introduction.aspx (accessed April 20, 2018).

Bynoe, Mark., Cain, Donnel. and Peralta, Ahnivar. *The Use of Benefit Cost Analysis to assess Adaptation and Mitigation Interventions in the Caribbean: Case studies.* Economic and Social Impact Sub-Unit, Caribbean Community Climate Change Centre, Caribbean Community Climate Change Centre, 2014.

CARDI. "Water Resources and Conservation." In *Soil and Water Conservation Windward and Leeward Islands Phase 1 Reconnaissance Study*, by Caribbean Agricultural research and Development Institute. 1983.

Caribbean Regional Fund for Wastewater Management. "CEP Technical Report:62 Wastewater Management in the Wider Caribbean Region: Knowledge Attitudes and Practice (KAP) Study." Technical , UNEP, 2010.

CCCCC. "Project: Extending Water Availablity to the Rural Areas of Carriacou." Caribbean Community Climate Change Centre, 2018.

CDB. "Water Supply Expansion and Sewerage project - Grenada." Caribbean Development Bank, 2016.

CEHI. "Financial Assessment for Wastewater Treatment and Disposal (WWTD) in the Caribbean." Caribbean Envirobnment Health Institute, 2009.

Chengxiang, Ma, Luwen, Zhou. *Feasibility Study on RWH for Agriculture in Grenada.* Country Report, Gansu Research Institute for Water Conservation, Caribbean Devekopment Bank, 2008.

Clarke, Robin. *Protect and produce: Soil and water conservation.* Food and Agricultural organisation, 1983.

Daniel, Judy. "Legislative Policy Brief on Food Safety, Water Quality and Environmental Health in Grenada." Pan American Health Organisation, 2000.

FAO. "Feasibility Study of Rainwater Harvesting for Agriculture in the Caribbean Subregion." Food and Agricultural Organisation, 2014.

Fox, P., Rockstrom, J., Barron, J. "Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya." *Agricultural Systems* 83 (2005): 231-250.

GDB. *Business Loans.* grenadadevelopmentbank.com (accessed April 15, 2018).

GEF CReW . "Regional Wastewater Management Policy Template." GEF Caribbean Regional Fund for Wastewater Management, 2015.

GHTA. "CDF CAP Assist Accomdation Providers Through Grant Funding for Energy Efficiency." *Grenada Hotel and Tourism Association.* June 15, 2016. http://ghta.org/the-association/press-releass/cdf-cap-assist-accomodation-providers-through-grant-funding-for-energy-eff (accessed April 20, 2018).

GIZ. "Project for a Climate Resilent Water Sector in Grenada (CREWS)." 2017. https://www.giz.de.downloads/2017giz-de-gcf-grenada-eisa-esmp.pdf (accessed April 15, 2018).

Government of Grenada. "Grenada and CARICOM Development Fund to sign Country Assistance Programme for Grenada." October 24, 2013. gov.gd (accessed April 20, 2018).

Government of Grenada. "Grenada National Water Policy." 2007.

—. "National Water and Sewerage Authority Act, CHAPTER 208, Act No. 25 of 1990." 1990.

Greaves, Geneille, E. *"On Water Augmentation Strategies for Small Island Developing States: Case Study of Bequia St Vincent".* National Central University, 2012.

Grenada. "Grenada- National enviromental action plan (English)." 1995. http://documents. worldbank.org/curated/en/127651468749362979/Grenada-National-environemental-action-plan.

Grenlec. "Solar PV Farm Commissioned in Carriacou." March 26, 2015. htpp://grenlec.com/Blog/Tabld/126/ArtMID/657/ArticleID/77/Solar-PV- Farm-Commissioned-in-Carriacou.aspx (accessed April 15, 2018).

Gumbs, Frank, .A. "Farmers and Soil Conservation in the Caribbean." *UWICED Occasional Paper Series*, 1997.

IFC. "Impact of Efficient Irrigation Technology on Small Farmers." International Finance Corporation. https://www.ifc.org/wps/wcm/connect/d7f6b6004689f35abc8abd9916182e35/Impact+of+Efficient+Irrigation+technology+Small+Farmers+IFC+Brochure.pdf?MOD=AJPERES (accessed May 03, 2018).

Kfouri, Claire. "Water Reuse Cost Benefit Analysis Moroco Example." *Water Week.* World Bank Group, 2009.
Kihila, Jacob, Mtei, Kelvin, Mark., and Njau, Karoli, Nicholas,. "Development of a Cost Benefit Analysis Approach for Water Reuse in Irrigation." *International Journal of Environmental Protection and Policy* 2, no. No.5 (2014): 2014.
Long, Thomas, & Blok, Vincent & Coninx, Ingrid. "Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: Evidence from the Netherlands, France, Switzerland and Italy." *Journal of Cleaner Production*, October 2016.
Lowitt, Kristen, Hickey, Gordon, M., Saint Ville, Arlette, Raeburn, Kaywana, Colon-Thompson, Theresa, Laszlo, Sonia, Phillip, E., Leroy,. "Factors affecting the innovation potential of smallholder farmers in the Caribbean Community." *Regional Environmental Change* 15, no. 7 (May 2015): 1367-1377.
Madramootoo, Chandra, A. "Hydrologic Study of Selected Sites for Irrigation Development and Expansion Grenada." Food and Agricultural Organization, 2001.
Mapp, La Verne. "Grenada Census of Agriculture 2012: Items on Irrgiation." *Regional Roundtable on World Programme on the Census of Agriculture 2020.* Trindad and Tobago: Food and Agriculture Organization, 2017.
New Today Newspaper. "NAWASA discusses 2016 dry season." *The New Today.* February 25, 2016. https://thenewtoday.gd/local-news/2016/02/25/nawasa-discusses-2016-dry-season/#gsc.tab=0 (accessed April 20, 2018).
OAS. "Desalination." In *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean*, by Unit for Sustainable Development and Environment. Organisation of American States, 1997.
OAS. "Wastewater Reuse." In *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean*, by Unit for Sustainable Dvelopment and Environment. Organisation of American States, 1997.
Peters, Everson, James. "Wastewater reuse in the Eastern Caribbean : Case study." *Proceedings of the Instiute of Civil Engineers* (Institution of Civil Engineers) 168, no. No.5 (November 2015).
Priyan, Khadeeja, and Panchal, Ratansharan. "Mico-Irrigation: An Efficient Technology for India's Sustainable Agricultural Growth." *Kalpa Publications in Civil Engineering* (ICRISET2017. International Conference on Research and Inovations in Science, Engineering & Technology. Selceted papers in Civil Engineering) 1 (2017): 398-402.
Puebla, Julian, Herrera. "Report on Irrigation Work." LandUse Division Irrigation Unit, Ministry of Agriculture Forestry and Fisheries, 2008.
Ringler, Claudia, Rosegrant, Mark, W. and Paisner, Michael, S. "Irrigation and Water Resources in Latin America and the Caribbean: Challenges and Strategies." Discussion Paper No. 64, Environment and Production Technology Division, International Food Policy Research Institute, 2000.
Rozaki et al. "Feasibility and Adoption of Rainwater Harvesting by Farmers." *Reviews in Agricultural Science*, 2017: 56-84.
Senyolo, Mmapatla, Precious, Long, Thomas N., Blok Vincent, Omta,Onno,. "How the Characterisics of Innovations Impact their Adoption: An exploration of Climate-smart Agriculture innovations in South Africa." *Journal of Cleaner Production (2017).*
Slobhan, O'Niell. "Talking Point: Could going offgrid help hotels save water?" *Green Hotelier.* November 14, 2017. greenhotelier.org (accessed April 23, 2016).
Smith, Martin, Munoz, Giovanni, Alverez, Javier, Sanz. "Irrigation Techniques for Small-scale Farmers : Key Practices for DRR Implementation." 2014.
Tannecia S. Stephenson, Lucia A. Vincent, Theodore Allen, Cedric J. Van Meerbeck, Natalie Mc Lean, Thomas C. Peterson, Michael A. Taylor, Arlene P. Aaron- Morrison, Thomas Auguste, Didier Bernard, Joffrey R. I. Boekhoudt, Rosalind C. Blenman, George C. Brawaithe, Glenroy Brown, Mary Nutler, Catherine J.M. Cumberbatch, Sheryl Etienne-Leblanc, Dale E. Lake, Delver E. Martin, Joan L. Mac Donald, Maria Ozaria Zaruela, Avalon O. Porter, Mayra Santana Ramirez, Gerad A. Tamar, Bridget A. Roberts, Sukarni Sallons Mitro, Adrian Shaw, Jacqueline A. Spence, Amos Winter, Adrian R. Trotman. "Changes in extreme temperature and precipitation in the Caribbean region, 1961-2010." *International Journal of Climatology* 34, no. 9 (July 2014): 2841-3000.
Taylor, Michael, A.,Stephenson, Tannecia S., Owino, Albert, Chen, Anthony, A., Campbell, Jayaka, D. "Tropical gradient influences on Caribbean rainfall." *Journal of Geophysical Research*, September 2011.
UNDESA. "Climate Change Adaptation Grenada: Water Resources, Coastal Resources and Renewable Energy." Division for Sustainable Development, 2012.

UNEP . "Desalination." In *"Source Book of Alterantive Technologies for Freshwater Augmentation in Small Islad Development States*. 1998.
UNEP. "A Directory of Environmentally Sound Technologies for the Integerated Management of Solid, Liquid and Hazardous Waste for SIDS in the Caribbean Region." 2004.
UNEP. "Water Conservation." In *Source book of Altenative Technologies for Freshwater Augmentation in Small Island Staes*. 1998.
UNESCO. "The use of desalination plants in the Caribbean." *PHI-LAC.* Vol. No5. 2006.
World Resources Institue. "Valuing the Costs and Benefits of Improved Wastewater Management: An Economic Valuation Resource Guide for the Wider Caribbean Region Part ll: Economic Valuation and Methodology Guidance." Global Environment Facility Caribbean Regional Fund for for Wastewater Management (GEF CReW), 2015.
World Resourcses Institute. "Valuing the Costs and Benefits of Improved Wastewater Manageent: An Economic Valuation Resource Guide for the Wider Caribbean Part 1: Summary Report." Global Environment Facility Caribbean Regional Fund for Wastewater Management (GEF CReW), 2015.

Annex

## List of Stakeholders involved and contacts

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| | | | |
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| Gibbs Blakie | Coconut Bay Resort and Spa St. Lucia | Interview | 1 758 714 2549 |

FIGURE 1 MICRO-IRRIGATION SOLUTION TREE

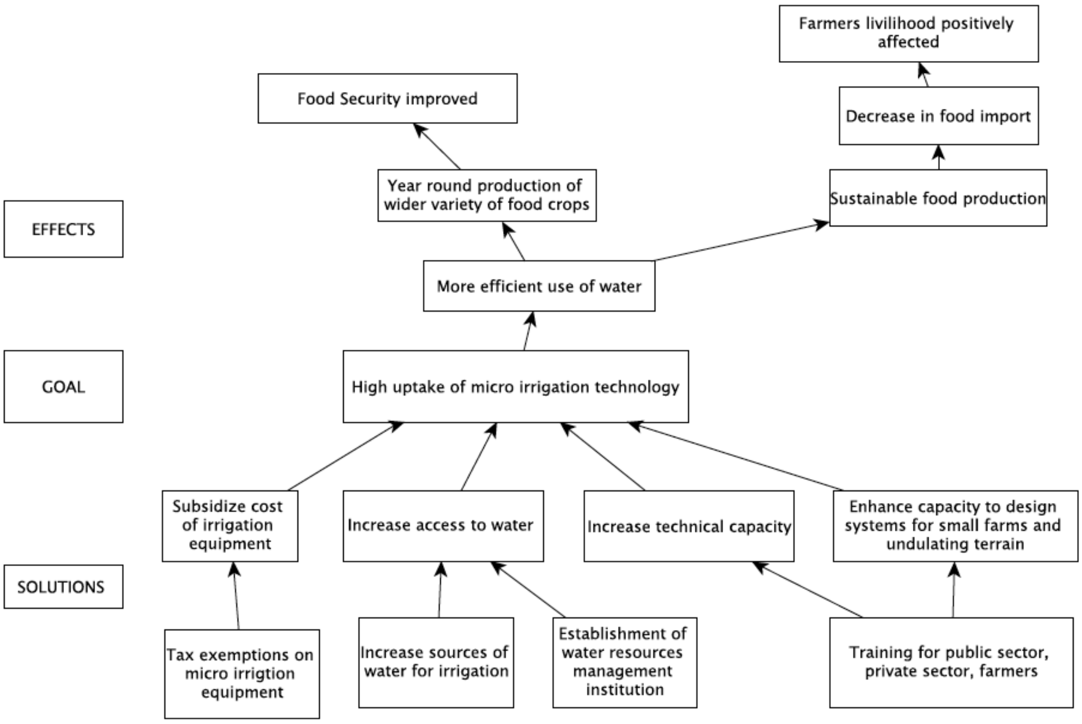

FIGURE 2 MICRO IRRIGATION PROBLEM TREE

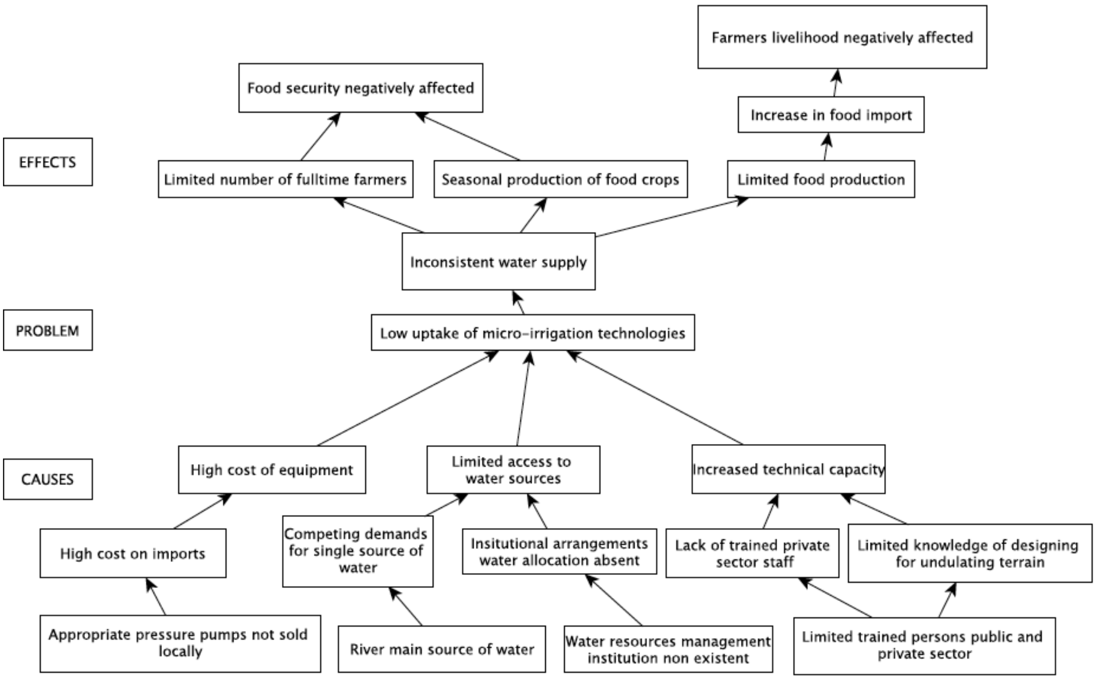

FIGURE 3 MICRO-DAM PROBLEM TREE

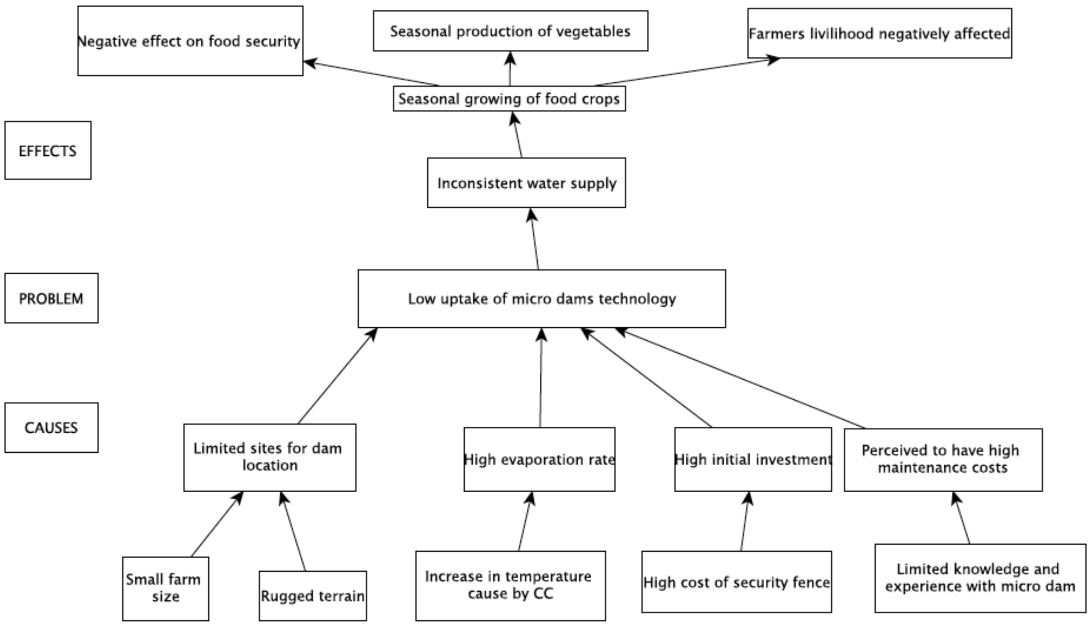

FIGURE 4 MICRO – DAM SOLUTION TREE

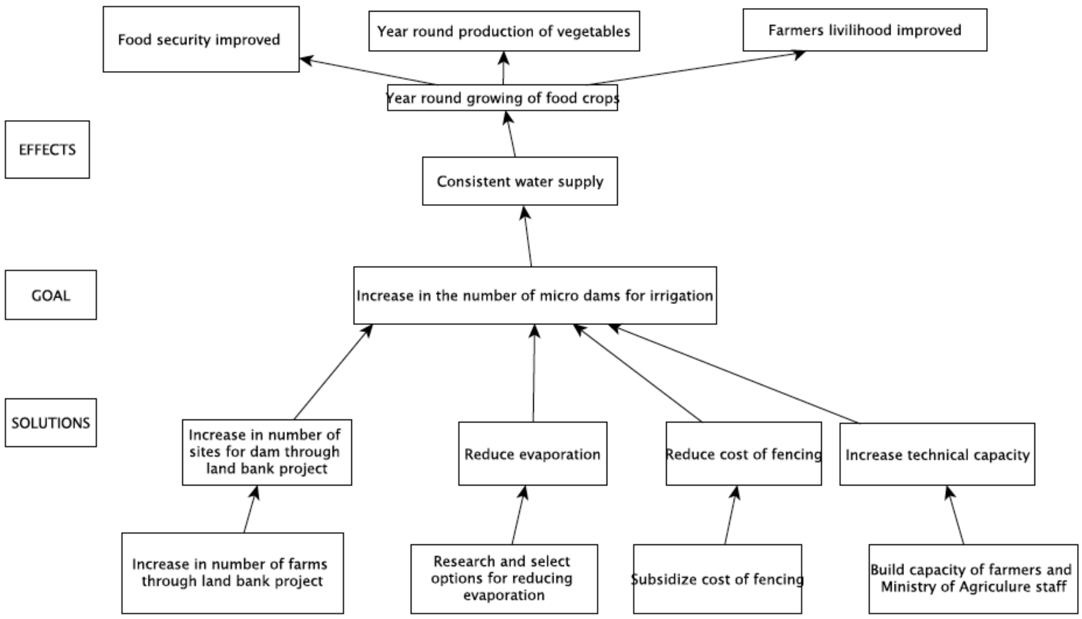

FIGURE 5 SALTWATER REVERSE OSMOSIS PROBLEM TREE

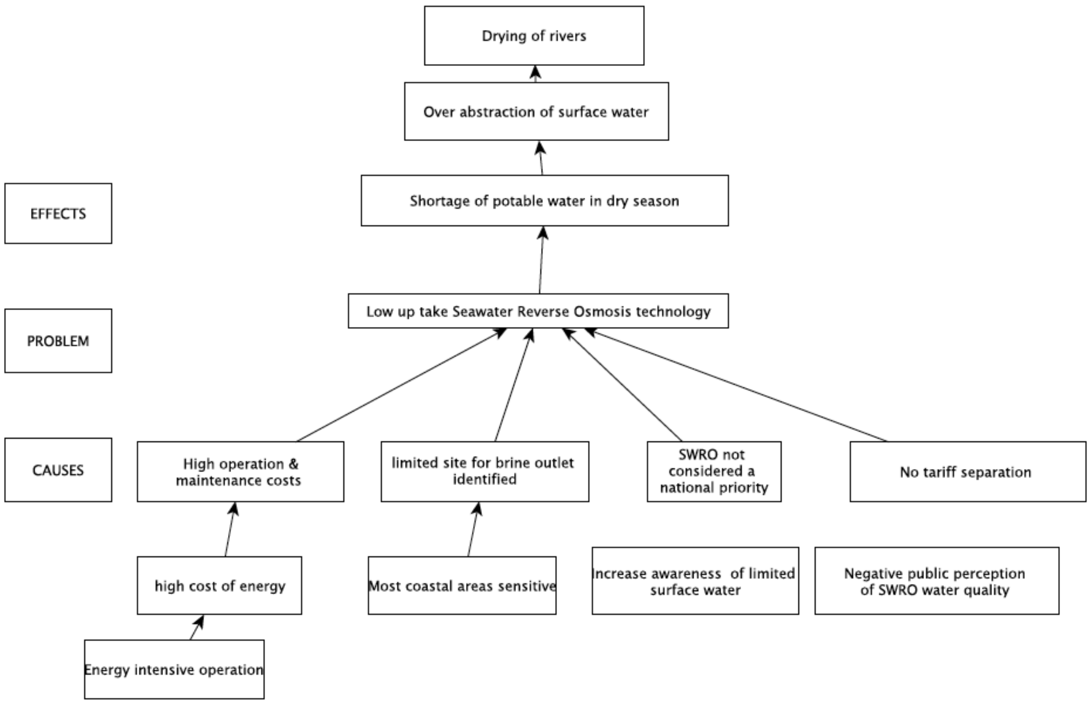

FIGURE 6 SALTWATER REVERSE OSMOSIS SOLUTION TREE

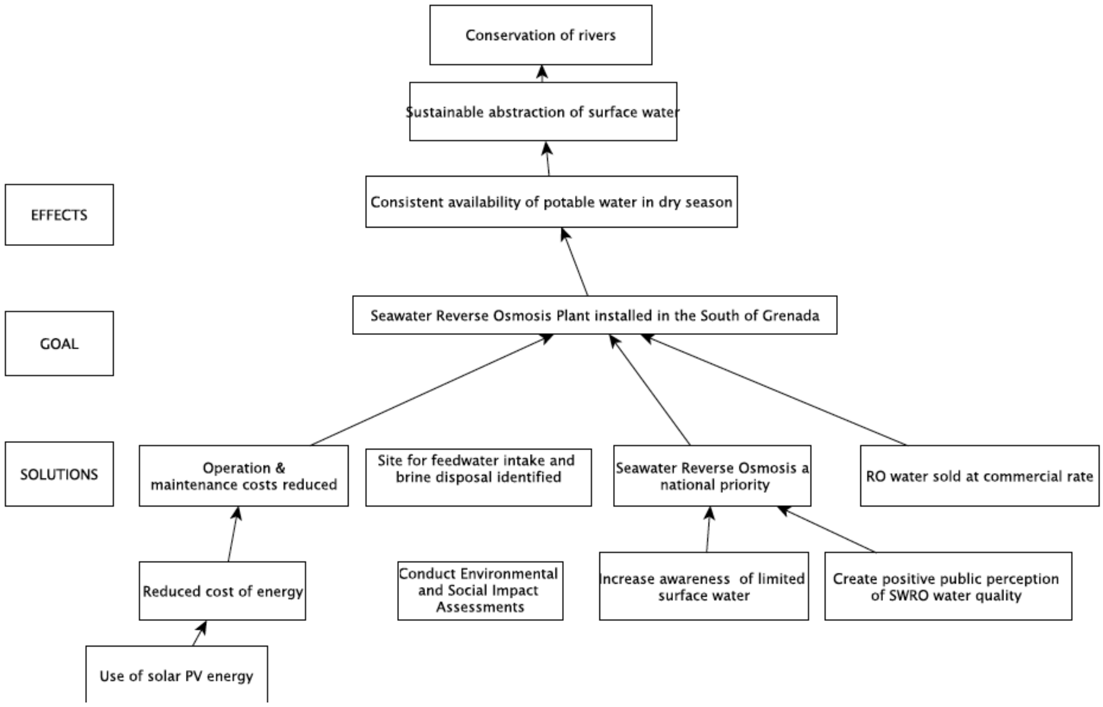

FIGURE 7 WASTEWATER REUSE PROBLEM TREE

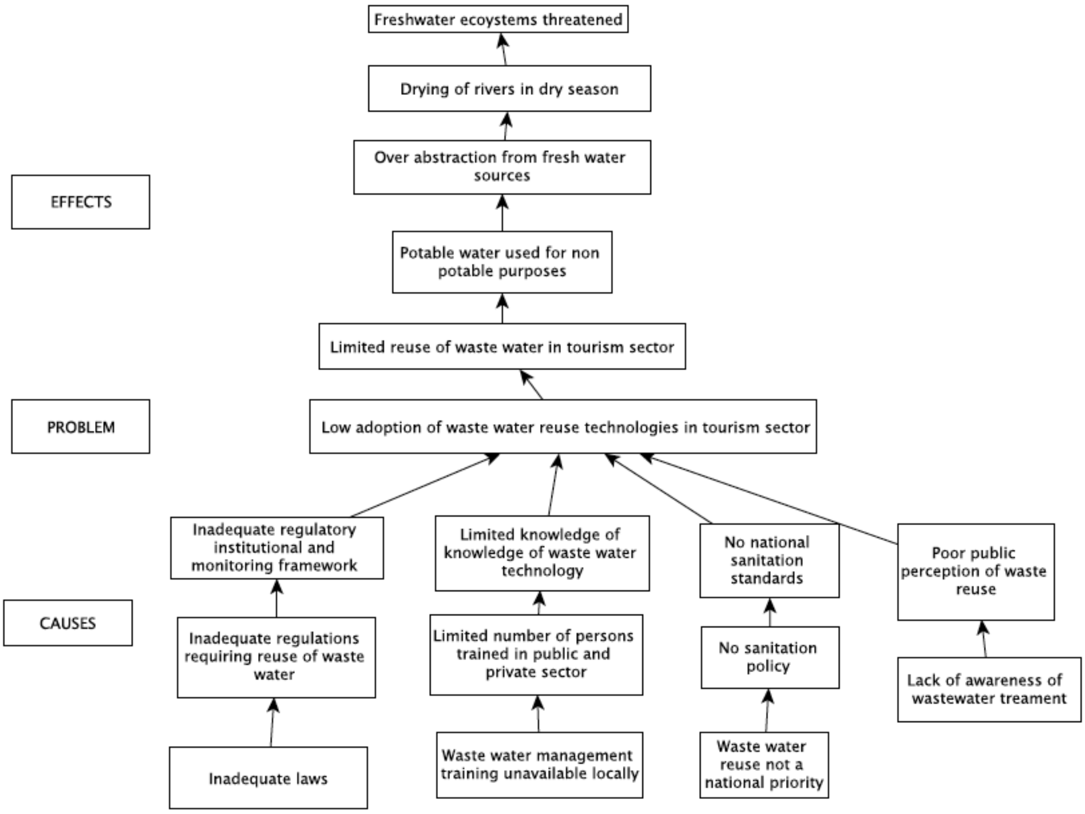

FIGURE 6  WASTEWATER REUSE SOLUTION TREE