Republic of Mauritius

TECHNOLOGY NEEDS ASSESSMENT

BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR ADAPTATION

AGRICULTURE, WATER & COASTAL ZONE

TNA REPORT II

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Supported by:

Disclaimer

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List of Acronyms

AREU	Agricultural Research and Extension Unit
CWA	Central Water Authority
GFDI	Gravity Fed Drip Irrigation
EE	Energy Efficiency
EIA	Environment Impact Assessment
EPA	Environment Protection Act
ESA	Environmentally Sensitive Areas
FAO	Food and Agriculture organization
FI	Financial Institution
GEF	Global Environment Facility
IAEA	International Atomic Energy Agency
IFAD	International Fund for Agricultural Development
IPM	Integrated Pest Management
LPA	Logical Problem Analysis
MAIFS	Ministry of Agro Industry and Food Security
MI	Micro-irrigation
MW	Mega Watt
NGO	Non-Governmental Organisation
PV	Photovoltaic
RE	Renewable Energy
RET	Renewable Energy Technology
RWH	Rainwater Harvestor
SFWF	Small Farmers Welfare Fund
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNEP	United Nations Environment Programme
WRU	Water Resources Unit

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Acknowledgements

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1. Prime Minister's Office (Mauritius Meteorological Services , Mauritius Oceanography Institute)
2. Ministry of Energy and Public Utilities (Water Resources Unit, Wastewater Management Authority, Central Water Authority)
3. Ministry of Finance & Economic Development (Statistics Mauritius)
4. Ministry of Public Infrastructure, National Development Unit, Land Transport and Shipping (Land Transport Division, National Development Unit)
5. Ministry of Education and Human Resources
6. Ministry of Agro Industry and Food Security (Agricultural services, Agricultural Research Extension Unit, Food and Agricultural Research Council, Forestry Service, National Parks and Conservation Service, Irrigation Authority, Farmer's Service Corporation, Sugar Cane Planter's Association and Small Planters Welfare Fund)
7. Ministry of Environment and Sustainable Development
8. Ministry of Tertiary Education, Science, Research and Technology (Mauritius Research Council)
9. Ministry of Fisheries
10. Ministry of Local Government and Outer Islands (Outer Islands Development Corporation)
11. Ministry of Tourism and Leisure
12. Ministry of Industry, Commerce and Consumer Protection
13. University of Mauritius
14. Beach Authority
15. Mauritius Sugar Industry Research Institute
16. Mauritius Agricultural Marketing Cooperative Federation Ltd
17. Indian Ocean Commission
18. United Nations Development Programme Country Office
19. Association of Hoteliers and Restaurants in Mauritius
20. Mauritius Chamber of Commerce and Industry
21. Mauritius Chamber of Agriculture
22. Mouvement Autosuffisance Alimentaire
23. NGO Platform – Climate Change
24. Pesticide Action Network of Mauritius

Executive Summary

This report on Barrier Analysis and Enabling Framework covers adaptation technologies for three sectors, namely: (1) agriculture, (2) water, and (3) Coastal Zone. For each sector, the report covers the following:

- Setting up preliminary target of technology transfer and diffusion of each of the adaptation technology
- Identifying and prioritizing the barriers using the following barrier analysis tools: bilateral meetings, brainstorming, informal interview of documents, market mapping linking all the market actors and the Logical Problem Analysis involving barrier decomposition and root causes analysis
- Investigating, assessing and categorising the possible measures to address the barriers for the transfer and diffusion of each technology and eventually
- Identifying the enabling environment and support services to enhance the uptake of the technologies.

The Mauritian agriculture is dominated by sugar cane but based on the vulnerability analysis this study focused on the foodcrop and forestry sectors. In view of likely impact of climate change on the sectors, adaptation technologies were selected and prioritised to ensure that they are effectively transferred to improve resilience. In the development of TNA three prioritized adaptation technologies that best suit needs of small scale farmers were retained. They included (1) up-scaling of proven IPM technologies to reduce pest damage likely to amplify with increase in pest population due to temperature rise, (2) micro-irrigation in order to optimise use of water which is likely to become scarce in the future while enhancing food production and (3) decentralized pest and disease diagnosis to enable farmers to make informed timely decision concerning pest and disease control as well as reduce unnecessary pesticide application and minimize risk of crop failure.

Technology Action Plan (TAP) was developed for only 2 of the technologies namely: up-scaling of proven IPM technologies focusing on all food crop growers and micro-irrigation focusing of small scale growers of horticultural crops in the drought prone areas of the island.

The main barriers identified were limited research and development capacity, inadequate training and awareness, limited demonstration and technical support, weak inter institutional collaboration, lack of policies promoting climate change adaptation policies, gap between R&D and market chain. A range of measures and enabling environment required to overcome the barriers were identified including policy, economic incentives, research and institution support and public awareness.

The water sector in Mauritius is characterised by high rainfall, 2500mm on average, with the higher elevation regions receiving up to 4000mm rainfall annually; high surface runoff, 60% losses to the sea, increasing high intensity rainfall events which produce large volumes of surface runoff, variability in annual rainfall recorded over time; an increase in the minimum and maximum temperature and an increasing water demand with time. A number of measures will need to be implemented in order to address water security, and the Technology Needs Assessment study undertaken with the collaboration of stakeholders, has shortlisted three particular technologies which are considered as being key to help the country adapt to the negative impacts of climate change.

The TNA for the water sector retained three technologies, namely; Rainwater Harvesting at Residential level (RWH), Hydrological Models (HM) and the Desalination Technology in the hotel sector (Desal). These adaptation technologies reflect the priority for the country to climate change adaptation. The country is already recording flood type rainfall events which give rise to high surface runoff. In addition, the country falls under the category of the water stressed country, as per the IHDP classification, hence the need to both improve the water resource management practices and the need for alternative water sources.
The rainwater technology is firstly aimed at reducing the volume of rainwater which is lost as surface runoff and secondly is also aimed at educating the general public on sustainable use of water resources. The general public in Mauritius use potable water for secondary uses and are not aware of the cost and energy implications of water treatment and distribution processes that go into producing potable water. About 14% of the total water consumed per household goes into cleaning and gardening, hence the need to promote rainwater harvesting at residential level. Rainwater harvesting technology will contribute towards capturing the excess surface runoff which is lost to the sea and also to a more optimal use of treated potable water.

About 17 hotels located along the coastal zone have already embarked onto the desalination technology. The practice is desalination of brackish water, which is relatively less saline, with conductivity values of less than 30,000 mg/l. The desalination technology in use is the reverse osmosis process. The Government is encouraging hotels located along the coast to implement the desalination technology, in order to alleviate the pressure on water demand. By implementing a desalination plant, the hotels also have the guaranteed of satisfying the water demand of their customers. The Desalination process is relatively highly energy intensive and hence costly. During long dry periods the hotels buy water from the Central Water Authority at the rate of Rs. 30. per m3, and based on this rate the cost of implementing such a plant becomes relatively a good option. However during the wet period, the cost of water is around Rs. 5 per m3 and this makes the water produced from desalination plants a poor option. As per the prevailing environmental legislation EPA (2002), all coastal hotels need to look into the possibility of desalination technology.

Following the recent long dry period, the Government is encouraging the hotel sector to set up desalination plants. The major concern of the water authorities is that the practice is about the desalination of brackish water rather than sea water.

Modelling and forecasting is an important working tool for effective decision making in the water sector. The use of hydrological models will help decision makers take more informed decisions on water management during long dry periods and to improve water management following climate change situations.
All the three retained technologies are highly crucial for adaptation to climate change; they address effective water management issues, sustainable use of water resources and alternative source of water, which are key issues to adaptation to climate change. Components of each prioritized technology have been analysed in terms of technical requirement, transfer and diffusion requirement, and current status of accessibility and readiness for implementation. From there Technology Action Plans have been prepared for two of the three technologies.

The TNA for the Coastal Zone sector has retained four technologies, namely; Restoration of coastal vegetation, Wetland protection, Dune restoration and Rock revetment. Mauritius with its varied coastline ranging from sandy beaches to rocky shores and cliff is very much affected by coastal erosion. The causes of erosion as identified by several studies including the Study on Coastal Erosion in 2003, were from the direct interaction of the sea with the shoreline, mainly during extreme events such as cyclones and storm surges. The extent of erosion is however exacerbated in certain places because of the negative anthropogenic impacts on the health of lagoons, beaches and dunes.

Three of the four technologies retained, Restoration of coastal vegetation, Dune restoration and Rock revetment are applicable directly on the shoreline and would provide direct benefits to the location where they are applied. In contrast, wetland protection would act indirectly in mitigating the erosion impacts on an adjacent coast. Wetland, through their hydrological services they provide, contribute to improve the water quality of the lagoon around Mauritius and thus a healthy marine environment which in turn would contribute to the stability of the shoreline. The soft technologies, such as dune restoration and restoration of coastal vegetation, are used in conjunction. Both financial and non-financial barriers have been discussed for the combination of different coastal adaptation technologies, and unlike the other two sectors, a site-specific approach has been adopted. This is because the use of any coastal technology is critically dependent on the extent of erosion, near-shore dynamics, type and extent of human pressures, like coastal developments, and access and use of coastal sites, and topographical constraints, among others.

1. Agriculture

The TNA report (Government of Mauritius 2012) identified three adaptation technologies for agriculture sector namely up-scaling of locally proven Integrated Pest Management, micro irrigation and decentralising pest and disease diagnosis for the development of the technology action plan (TAP). However, given that recently IFAD supported a project on "E-Pest Surveillance" (approved September 2012) whereby IT facilities un AREU Extension officers were upgraded to provide farmers with a rapid pest and disease diagnosis service , it was decided at the technical committee that the development of the Technology Action Plan (TAP) will focus only on 1) up-scaling of locally proven Integrated Pest Management (IPM) technologies and 2) micro-irrigation. This choice was justified as both IPM technologies and decentralising pest and disease diagnosis service aim at promoting judicious use of pesticides for control of targeted pests and diseases and thus assist in minimising environmental, ecological and health hazards associated with.

This chapter will start with preliminary targets for technology transfer and diffusion. Then the barriers for the two selected technologies and the possible measures to overcome these barriers are identified and analysed in section 1.2 and 1.3. Based on the analysis about the linkages of the barriers and possible solutions to them, section 1.4 will offer some suggestions on how the barriers can be addressed. More precisely, the resource requirements, strength and weaknesses of each solution will be discussed. An overall strategy for overcoming the barriers for energy industries and how to achieve specific technology transfer, diffusion, and deployment targets in this sector will be formulated and described in 1.5.

1.1 Preliminary targets for technology transfer and diffusion

This section will provide a broad view of the target of the technologies and the potential beneficiaries likely to be affected by changing climate. The targets for the technologies were: 1) Integrated Pest management technologies to reduce risk of pest damage, minimise use of synthetic pesticides, improve productivity while enhancing food safety, minimising environmental impacts and promoting sustainable agricultural practices and 2) micro-irrigation to optimise use of irrigation water resources, reduce risk of crop failure while improving productivity, food security and farmers livelihood.

Climate change and climate variability is a threat to the local agricultural sector and particularly small scale farmers who unlike large producers (>10 ha) do not benefit from economies of scale and to do not have the ability to invest into practices to deal with climate risks. While being vulnerable, small scale growers also have the advantage over large producers, as they can modify their agricultural practices relatively easy, within short time frame and adjust to changes it comes to adoption of climate change adaptation measures.

Mauritian agriculture is mainly rainfed with only around 30 % of the cultivated area under irrigation. Irrigation areas consist mainly of the sugarcane land and around 10 % of the land under food crops. The main type of irrigation is overhead (81%), surface (10.3%) and drip (8.5%). In 2009, out of 1726 ha of irrigated land under fruit and vegetables production (including public and private sector) 9.6 % was under drip irrigation (Source: Irrigation Authority survey, December 2009) representing around 2.3 % of the total area under food crops. Given that rainfall is expected to decline, it is projected that soil moisture deficit will further increase particularly in the north, west and south of the island and a potential irrigated area of around 27 638 ha is estimated by 2030 (Table 1). With this likely increased competition for diminishing water resources in the future, there is need to assist farmers to optimise water use. Micro-irrigation technology is identified mainly for small scale farmers in drought prone areas such as the north, south and west part of the island with high soil moisture deficit and lower productivity. This technology is also in synergy with the government policy to promote rainwater harvesting to enhance farm productivity and livelihood of small scale farmers.

Table 1. Projected irrigated areas in the different region of the island and the targeted area under permanent garden for micro irrigation.

Region of the island	Soil moisture deficit	Projected irrigated areas (ha)		
	M3/ha/yr	2020	2025	2030
North	1200	9598	9598	9598
West	1400	5800	6300	6300
East/Centre	800	5700	6300	6300
South	1000	5140	5440	5440
Total		**21108**	**27638**	**27638**

Source: Irrigation Authority and AREU

On the other hand, to help farmers to reduce crop damage likely to occur with increasing pest outbreaks, up-scaling of locally proven Integrated Pest Management technologies aiming at improving management of plant pests is targeted some 8500 foodcrop growers throughout the island. IPM technology will help to reduce risk of cop damage and increase crop yield and food security despite climate shocks. Considering the low technical knowhow on pest and disease management, low capacity of growers to invest climate change adaptation technologies and vulnerability of certain agricultural zones to drought, the transfer and diffusion of the 2 selected adaptation technologies for the sector is geared towards small scale foodcrop growers

The barriers hampering the transfer and uptake of IPM and micro-irrigation technologies and the possible measures and incentives to overcome them are being discussed and analysed in section 1.2 and section 1.3 respectively.

1.2 Barrier analysis and possible enabling measures for Integrated Pest Management technology

This section provides a detailed analysis of barriers hampering the transfer and uptake of IPM technologies including the Logical Problem Analysis (LPA) was used to identify the root causes of main barriers and the possible measures and incentives to overcome them.

1.2.1 General description of Integrated Pest Management

Integrated Pest Management (IPM) is a sustainable approach to pest management, which combines cultural, biological, physical, and chemical control methods to keep pest populations at levels where they have minimum economic injury to the crops under production (Uhm,2002, Morse et al, 2000) while protecting the environment. It emphasises on growth of a healthy crop with the least possible disruption of agro-ecosystems, thereby encouraging natural pest control mechanisms. It is based on four principles:

- Sanitation (maintaining clean crop production and storage environments)
- Prevention (quarantine measures to avoid invasion by alien pests)
- Exclusion (creating barriers between the pest organism and the host), and
- Destruction (killing the pest organisms causing damage).

It encourages a move from heavy reliance on routine use of chemical pesticides to a combination of methods including

- **Biological:** use of natural enemies: predators, parasites, and pathogens and sterile male insects, bio-pesticides, plant-based pesticides (biological pesticides);
- **Cultural:** disease free seed, crop rotation, inter-cropping, pest-resistant varieties, timing of planting and harvest; water, soil and nutrient management, intercropping, mulching, trap crops and field sanitation;
- **Physical:** traps, hand-pulling, hoeing, mowing, and tilling;
- **Chemical:** safer and lower risk pesticides, pheromones and growth regulators.

Implementing of IPM programs involve a good understanding of the biology and ecology of pest populations, the broader agro-ecosystem in which they reside (other host plants), regular monitoring of crop for both pest and beneficial insects, decision making regarding when to spray (based on economic thresholds) rather than prophylactic (preventive) and the choice of the best pest management tactics and strategies. It also utilise selective insecticides and those with shorter residual period which will have a lesser impact on non-target species.

In Mauritius, a range of IPM technologies have already been tested in farmers field and greenhouses and proven effective in the management of pest of economic importance under local conditions, however, their uptake at farm level has been very low. Some of the successful IPM proven technologies include:

- Suppression of melon fly, Bactrocera cucurbitae, major pest in cucurbits by use of field cages (augentorium) for sanitation, protein bait and MAT block to attract and suppress the pest
- Control of fruit bat, a major pest of fruits through tree pruning and use of bird net
- Control of Tetranychusurticae a mite causing major damage on solaneceous crops, roses and strawberry through breeding and release of predators
- Control of White fly, serious insect pest in greenhouse production through inoculative releases of parasitoids (Encarsiaformosa and Eretmoceruseremicus)

Given that each of the above proven IPM technologies have different requirements in terms of technical support, this study will focus on a detailed barrier analysis hindering the uptake of a range of IPM techniques including use of field cages (augentorium) for collection and destruction of fruits infested by flies(sanitation), coloured sticky trap, trap crops with protein bait and insecticide, release of male sterile insect to disrupt reproduction, use of pheromone for mass trapping of male insects, use of predators and parasites, use of improved seed and natural and bio-pesticides.

1.2.2 Identification of barriers for Integrated Pest Management

The first step to identification of barriers and enabling measures to up-scaling of IPM technologies was to characterize the technology. IPM technologies consists of both

- consumer goods such as baits, colour sticky traps, natural and bio-pesticides and improved seeds in the supply chain and
- non-market public goods such a predators, parasites, pheromone traps usually provided by government agencies requiring large investment funded by internationa donors or government.

The following barrier analysis tools: bilateral meetings, brainstorming, informal interview, review of documents, market mapping, Logical Problem Analysis and Objective tree were used to identify, screen and prioritize the key barriers likely to hinder the adoption of IPM by small scale farmers under the local context. Reference was made to the TNA guidebook series "Overcoming Barriers to the Transfer and Diffusion of climate technologies" to categorize, decompose and find the causal relations of each of the key barriers.

Bilateral meeting and brainstorming were conducted with technical experts (entomologist and pathologist) with experience in IPM past and ongoing pilot projects and consultation with relevant stakeholders such as the Crop Protection Department of AREU, Entomology Division of the Agricultural Services and Extension officers of AREU involved in the on-farm demonstration and dissemination of the IPM technologies. Review of agricultural policy documents and progress report of IPM projects were also undertaken to gather information on main challenges / barriers faced in the implementation of IPM pilot projects such as fruit fly control. A list of all potential barriers hindering the transfer and diffusion of locally proven IPM technologies was worked out. Each of the barriers was carefully analysed and screened to retain only the essential ones based on consultant own knowledge in the area, experience acquired and lessons learned from IPM pilot projects undertaken locally and also on the ease of removing them. These key barriers were then prioritised through stakeholder's consultation. The prioritised barriers earmarked for this particular technology were then grouped into 2 broad categories namely: economic and financial barriers and non-financial barriers.

Service providers and stakeholders involved in the research, extension and marketing IPM technologies as well as the end users were identified and the market mapping was developed to identify the missing links and the market constraints as well as the enabling environment facilitate the uptake of IPM technologies. Barriers in each broad category were further decomposed into the causes and effects to identify the root cause(s) using the Logical Problem Analysis (LPA) also known as the Problem Tree (Annex 1(a)). The LPA was very useful in bringing together all the key elements of a problem and thus guide systematic and logical analysis of inter-linked key elements. The LPA was then used to build the Objective Tree (Annex 1(d)) and assess the measures and incentives to overcome the barriers and effects of adoption of IPM technologies at wide area farmer's community level. This exercise also helped to review existing policies and identify lacking policy incentives.

Stakeholders played a predominant role in identification and understanding of the key barriers so as they can be effectively addressed and removed in the TAP process. The barriers hindering the uptake of locally proven IPM technologies developed by Entomology Division of the Ministry of Agro Industry and Food Security (MAIFS) and the Agricultural Research and Extension Unit (AREU) under short-term project funded by the International Atomic Energy Agency (IAEA) Technical Cooperation were found to be technology specific exist and at each level: policy, regulation, financial availability, market, education, institutional technical and human capacity.

1.2.2.1 Economic and financial barriers - Integrated Pest Management

Similar to most developing countries where inadequate financial support to IPM programs is cited as a major barrier to the adoption of environmentally sound technologies for pest management (Kiss and Meerman (1991) and Knausenberger et al. (2001), in Mauritius too its low adoption is mainly due shortage of financial support to ensure investment to remove institutional and technical barriers such as limited R& D facilities infrastructure, inadequate mechanism to generate and disseminate information and limited expertise. Thus the economic and financial barriers identified were as follows

- Insufficient resources to sustain IPM pilot programs initiated with the support of international organisations (IAEA/ FAO)
- Insufficient resources investment in research capacity development and infrastructure
- Lack of financial/market resources and incentives to encourage farmers adopt IPM/ sustainable practices
- Limited fund allocated for research to continually develop IPM tools and techniques
- Limited fund to support on- farm demonstration of IPM program on wide area
- High discount rate due to high perceived risk and uncertainty
- Damage to environment and ecosystem services is not valued in pricing the positive real impact of IPM technologies
- High cost of environment friendly alternatives to chemical pesticides (more labour)
- Lack of disincentives to discourage the use of chemical pesticides

Benefit to Cost Ratio of financial support to Dissemination of IPM technologies

Cost-benefit analysis was undertaken to compare conventional pest control to IPM technology at farm level. The costs elements included cost of investment in R & D, training of field staff and farmers, development of appropriate IPM package, cost of pest monitoring and evaluation activities and cost of public awareness. The market benefits that were accounted were increase in revenue as a result of improved yield and quality of produce(less pesticide residue), saving in pesticides and saving in labour required in pesticide spraying. The analysis was based on the assumption of targeting 20 % of the land under food crop (1200ha, involving approximately 2,400 small scale foodcrop growers). It was also assumed that crop yield drops in the first year of implementation of IPM and then gradually increase over time to a maximum of 5t/ha. Similarly, the produce market price was estimated to increase due to the expected increase in quality in terms of less pesticide residue. On the other hand, the amount of pesticide saved was estimated to increase gradually over time. The benefit/cost ratio for IPM technology was estimated to 1.6 (Annex 4). This figure clearly indicated the overall benefits of using IPM over conventional pest control. This technology also provide non-market benefits such as positive environmental effects, i.e. an increase in biodiversity and the stock of beneficial insects, reduced probability of pest developing resistance against pesticides, reduced risk of health impairments due to a reduction in pesticide exposure of farmers and lower pesticide residue in horticultural produce which was not valued in the cost benefit analysis.

1.2.2.2 Non-financial barriers - Integrated Pest Management

Despite the long term ecological and environmental benefits several non-financial barriers were identified to hamper the full adoption of an agricultural innovation such as IPM under local conditions. They were each analysed and grouped under into 8 main areas: market failure and imperfections, policy and regulations, network failure, institutional and organisational capacity, human skills, social, cultural and behavioural, information awareness and technical.

1. Market failure and imperfections:

- Low demand from farmers who perceive IPM as being less effective than chemical control
- IPM technology has limited application at individual farm level , it is effective only if applied to a wide area
- Poor quality pesticides available a relative cheap price on local market

2. Policy legal and regulatory

- Agrochemicals (including pesticides) are provided to assist farmers to recover from damage after a natural calamity as part of Agricultural Calamity Solidarity Scheme (ACASS) set under the Small Farmers Welfare Fund

3. Network failures

- Few suppliers of IPM technologies (mostly by government organization)
- Farmers poorly organized when it comes to collaborate for pest control
- No market incentives to encourage adoption of IPM
- Agro-chemical salesmen carry out aggressively marketing of crop protection products and providing plant protection advice directly to farmers (easy access to chemical pesticides)
- Absence of pesticide quality control

4. Institutional and organizational capacity

- Limited institutional capacity on agricultural research due to decline in budget allocated for R& D
- Weak inter-institutional collaboration to increase effective of research and sharing of knowledge
- Limited capacity of government organisation of support island wide IPM program
- Limited capacity for pesticides residue monitoring
- Extension agents not specialised in IPM and little emphasis on participatory IPM
- Most of the IPM programme are funded by international agencies and there is sustainability beyond the project time frame
- Inadequate extension services

5. Human skills

- Limited /experience /expertise of extension agents and farmers in IPM

6. Social, cultural and behavioural

- Famers perception of complexity of implementing IPM package (requiring more time and labour
- Perception that chemical pesticides is more effective than IPM
- Farmers lack biological and ecological information for exploratory approaches to IPM
- Resistance to change from conventional pest control to IPM approach
- Farmers are more concerned with their profits and seek immediate prevention of crop loss rather than reflecting on long-term consequences of continued pesticide use

7. Information and awareness

- Limited training of research and extension in IPM
- Lack of technical IPM information resources and package of IPM compatible practices
- Farmers have little or no access to information about alternative approaches , their cost and effectiveness
- Limited training of farmers

8. Technical

- Limited infrastructure to support national IPM programme (facilities for Sterile insect techniques , rearing of predators and parasitoids, etc)
- Inadequate support infrastructure for research for testing and evaluating IPM compatible
- technologies
- Fragmented research and development efforts
- IPM package of technology are crop/ regional specific, it cannot be easily transferred from one region to another
- Complexity of the process and lack of IPM guidance

9. Others

- Limited accessibility to climate data and   data redundancy
- Inadequate farmers participation in IPM on-farm demonstration projects;
- Social and environmental costs of pesticide are not internalized in prices of pesticides;
- Weak enforcement of legislation to control use of pesticides;
- Public sector extension service promotion of pesticides
- No facilities available for the safe and environmentally sound disposal of pesticides and empty containers

1.2.3 Identified measures - Integrated Pest Management

Development of the objective tree and the market mapping exercise have facilitated the identification of measures ranging from policy, financial incentive, regulations and support to research, extension, education and training to enhance the uptake of integrated pest management practices. The measures were broadly categorised into economic and financial measures and non-financial measures.

1.2.3.1 Economic and financial measures - Integrated Pest Management

The economic and financial measures identified to facilitate the transfer; diffusion and sustainability of IPM technologies were as follows:

- Substantial investment in research to continually develop and support IPM tools and technologies, technology transfer, extension services, growers education and consumer awareness in IPM;
- Fund allocation for establishment of pesticide quality control an reinforcing pesticide residue lab (human resources and capacity building);
- Investment in reinforcing national pest monitoring and surveillance to guide decision making
- Encourage financial /market incentives such as IPM brand , voluntary code of practice to encourage farmers to adopt IPM practice
- Investment in early warning system;
- Economic feasibility study of IPM products (considering the long term environmental and social benefits) and the cost associated with transition from conventional pest control to IPM approach;
- Need to invest in more on farm demonstration of IPM techniques
- Financial disincentives such as review the true price of chemical control by internalising the environmental, ecological and social costs through polluter pays tax; and
- Budget allocations for IPM training for extension agents or crop protection

1.2.3.2 Non-financial measures - Integrated Pest Management

The non-financial measures identified were grouped into:

(a) Policy and regulatory tools

1. Government should integrate IPM with national policies that cut across the following areas:

- National Plant Protection policy (pest risk management, seed inspection and certification and
- quarantine),
- Food safety policy (pesticide management, food safety and pesticide residue monitoring)
- Environmental policy (air, water pollution, ecosystem services, biodiversity)
- The Dangerous Chemical Control Act (import, storage, labeling and sale of pesticides)
- Public health policy (pesticide risk)
- Trade and export policy

- Agricultural extension policy
- Land use policy
- Education policy (inculcating IPM approach to young) to foster IPM adoption and

ensure sustainable agricultural development under the “Maurice Ile Durable” policy, strategy and action plan.

2. The Dangerous Chemical Control Act should be reviewed so as to enforce quality control, control sale of pesticide and lower risk pesticides identified as IPM compatible products so as to improve t heir availability on local market.

3. The food safety legislation should be enforced with respect to pesticide residue monitoring and sanctions.

4. Reform of agricultural policy to support IPM and reduce biases towards chemical control for promoting sustainable agriculture (e.g. phasing out of highly hazardous and/or persistent pesticides and review of pesticide procurement to foster the transition to and implementation of IPM practices)

5. Government should facilitate safe and environmentally sound disposal of empty pesticides containers and obsolete pesticides.

6. Sharing of information on IPM technologies across islands in the Indian Ocean through regional Indian Ocean Commission (IOC) initiative such as Acclimate and IRACC (Regional initiative of agro-ecology and climate change) should be encouraged.

7. Private/voluntary certification scheme for agri-environment measures that integrate IPM approach and support certification, labelling and branding of IPM based crop production to improve market access should be encouraged. Such certification scheme would ensure that production is carried out according to good agricultural practices to produce high quality food with minimal environmental impact while also ensuring worker health and safety. Branding of IPM products with preferred selling price would persuade growers to adopt IPM.

(b) Research capacity development

Given that wide range of expertise is required for the successful development and promotion of IPM. Comprehensive human resources development program need to be developed to strength and improve existing scientific and technical skills in local institutions to create a team of local IPM experts, including those who are active in participatory research and learning approaches and those would be involved in raising farmers and public awareness.

Due to new pests constantly emerging with the change of farming systems, there is need to provide continuous investment to support IPM research, especially for development of locally adapted pest management solutions focusing on:

- management of emerging new pests of global importance (example: the whitefly)
- biological control and bio-pesticides (e.g Spinosad for melon fly)
- assess, adapt and develop IPM techniques
- build capacity in sterile insect techniques (SIT) for more species
- set threshold level for pest of economic importance
- use of IT in forecasting and scouting
- integration of various control methods into locally adapted IPM approaches to allow the export of pest free agricultural products and thus overcoming non-tariff trade barriers.

Implementation of IPM program is a classically a public good, however, private companies being aware of stringent market standard and consumer demand for no pesticides residue, must be encouraged to invest in research and development (R&D) of technologies such as pheromone traps, baits, bio-pesticides and reduced-risk chemicals through market incentives as benefits cannot be easily captured to repay capital investment. This would fit well in the long term strategy for sustainable agricultural development.

(c) Farmer Participatory Training and Research

As long as research is driven by farmers' needs, it is recommended to use Farmer Participatory Training and Research (FPTR) approach to bridge the gap between research and implementation of IPM by farmers. This new approach promoted by CABI promotes training methods that favours the integration of traditional and 'science-based' knowledge and improves understanding of ecological and economic principles to empower farmers to develop the ability to make informed decisions. Farmers are involved in all stages of the process from setting the research agenda and the experimental treatments, conducting observations, and discussing and interpreting results. As such, farmers improve their knowledge in ecology and become research partners in field-based research with research institutions and extension staff. It will also allow researchers to evaluate farmers' knowledge on ecological crop management methods and thus improve their understanding of how to address the social and behavioural barriers to IPM uptake.

(d) Education, training and knowledge transfer

Researchers and extension agents require appropriate IPM training so as to improve their understanding of pest ecology and agro-ecological processes to make informed decisions on how best to manage crops to avoid pest infestations, as well as managing pests once they become a problem. Given that IPM technologies rely on agro-ecological principles which vary with circumstances and are thus not fixed prescriptions or technical package that can the transferred as per conventional method (from research to extension and then to farmers) of transfer of technology. Extension services have to innovate and adopt a paradigm shift in extension methods of technology transfer involving the support from research, NGOs and farmers associations working together to observe, monitor, anticipate, and intervene constantly to achieve desired results. They have to change from teaching to a learning concept through a participatory process that involves farmers and IPM extension specialist in decision-making, problem analysis and generation of solutions (Toness, 2001). Hence, the need to have IPM extension specialist closely linked to farmers through IPM demonstration projects and participatory adult learning processes to improve knowledge on IPM strategy and techniques and to boost farmers confidence in IPM methods. Increasing farmers', public and consumers' awareness of environmental problems arising through pesticides can also help to overcome the personal attitudes and misconceptions related barriers to adoption of IPM practices.

In addition, collaboration between institutions (government research institutions, academia, private sector, extension services, farmers and experts) should be promoted and reinforced at national and regional levels to enhance technology and knowledge transfer on pest and disease outbreak and IPM practices. The development of a national spatial data infrastructure is required to facilitate sharing of information among organizations

(e) Regional collaboration

IPM can build from experiences of the region. Regional cooperation with the Indian Ocean RIM can be further strengthening to develop a platform for sharing of knowledge and experiences in IPM Programme developed in the regions. An example of a successful IPM program in the region that Mauritius can learn from is the GAMOUR (Gestion Agroécologique des Mouches des légumes de la Réunion) project for agro-ecological management of insect pest of vegetables in Reunion Island. This project was supported by CIRAD (Centre for Research in Agricultural Development) who work hand-in-hand with the local people in the local environment.

(f) Institutional collaboration

Due to the intensive knowledge and dynamic quality of IPM, there is need for constant updating with current information and thus foster collaboration between all stakeholders in agricultural development for successful implementation of IPM program.

(g) Communication and raising awareness

There is need to futher develop effective strategies to communicate and educate consumers including children about improved environmental sound products and safety of food through use of IPM so as to drive market needs . Demand and support by consumers would definitely foster IPM uptake by growers.

1.3 Barrier analysis and possible enabling measures for Micro-irrigation

1.3.1 General description of Micro irrigation

Micro-irrigation technologies can be of 2 types: the low- cost micro irrigation such as low-head, low-cost gravity-fed drip (GFD) irrigation kits, micro sprinklers, micro tube drip system suited for smallholder farmers to highly sophisticated, capital intensive pressurised commercial micro-irrigation. These technologies are suited growing mainly horticultural crops such as high value vegetables, fruits and ornamentals in open field, greenhouses or orchards. They are useful in addressing the growing competition for scarce water resources and have shown to have positive effects on yield, incomes, and food security.

Drip Irrigation involves technology for irrigating plants at the root zone through emitters fitted on a network of pipes (mains, sub-mains and laterals). The emitting devices could be drippers, micro sprinklers, mini sprinklers, micro-jets, misters, fan jets, micro sprayers, foggers and emitting pipes, which are designed to discharge water at prescribed rates. The use of different emitters will depend upon specific requirements, which may vary from crop to crop. Water requirement, age of plant spacing, soil type, water quality and availability are some of the factors which would decide the choice of the emitting system. Sometimes micro-tubes are also used as an emitter, though it is inefficient. All types of surface and subsurface irrigation systems are covered under MI Technology
The unit cost of Drip Irrigation system varies with respect to plant spacing and location of the water source.

Sprinkler Irrigation involves sprinkling water under pressure into the air and plant foliage through a set of nozzles attached to network of aluminum or High Density Poly Ethylene (HDPE) pipes in the form of rainfall. These systems are suitable for irrigating crops where the plant density is very high and where adoption of Drip Irrigation Systems may not be economical. Sprinkler irrigation is suitable for horticultural crops like vegetables.

Micro irrigation technology improves water use efficiency by 50-70 % under sprinkler and up to 90-95 % under drip irrigation. Unlike large public irrigation schemes characterised as weak sustainability due to poor governance, high operation and maintenance cost and low recovery cost (Peacock et al, 2007), micro irrigation requires relatively lower investment cost but guarantee high economic impact due to strong local community governance and lower operation and maintenance costs Adoption of micro-irrigation technology is reported to lead to enhancement of crop yield and quality, water savings, expansion in areas under irrigation due to reduction in water requirement per unit area, increase cropping intensity (allow to grow more crops /year), allowing fertigation (application of fertiliser through irrigation system),enhanced land and water productivity, reduced non-beneficial evaporation loss, reduced labour cost and risk of crop failure, savings and advancement in produce harvest, all resulting in social benefits (Kumar et al, 2008). Micro irrigation includes low pressure gravity fed drip irrigation system suitable for small plot or pressurised systems suited for larger plots. Unlike the off- the self the gravity fed small irrigation kit, the pressurised irrigation is usually customised system designed based on field characteristics (slope, dimension, shape and soil type, etc.), cropping system and water availability requiring technical expertise for the design and installation.

It provides precise delivery of water and nutrients to plants and thus help to save water and increase productivity. Implementation of this adaptation technology requires:

- a water source which can be from small streams, boreholes, tank, reservoir, field ponds and rainwater harvesting;
- a water storage facility;
- design/ layout of irrigation system;
- Installation of irrigation system which consist of pipes, valves, filtersand small drippers or emitters for drip irrigation and a network of pipes with spray heads;
- a manual or small motorised pump to pump to lift, convey and apply irrigation efficiently (except, if it is a gravity fed system); and
- a filtration system in case of poor water quality.

With projected decline in rainfall and fresh water availability, micro-irrigation technology aims at improving land and water productivity while reduce risk of crop failure, provide opportunity to grow more crops per year and cultivate additional areas (using water saved) to enhance food security and famers' livelihood. This technology works in conjunction with other on-going schemes such as the rainwater harvesting scheme and sheltered farming scheme to better adapt to climate change stress. Numerous pilot micro-irrigation projects have shown to be both economical and efficient leading to greater food security and increased incomes thus buffering smallholder farmers against the adverse effects of climate change.

1.3.2 Identification of barriers for Micro-irrigation

Micro-irrigation technology being a consumer good with a high number of potential users and a complicated market chain involving several market actors for each of the micro-irrigation system components, it was quite complex to study the barriers. A review of relevant literature and web-based resources on current trends and past experiences existing national reports, bilateral meetings with selected informants such as AREU extension officers, researchers with experience and responsibilities in water resource management and agriculture, NGOs, actors in the marketing of irrigation equipment, consultation with irrigation experts from the relevant institutions (Irrigation Authority and MSIRI) as well as consultant own knowledge was used to identify a list of all possible barriers hindering the transfer and diffusion of micro-irrigation under local conditions. Each of the barriers identified was carefully analysed and screened to retain only the essential ones based on local experience acquired and lessons learned in implementing irrigation projects and also the ease of removing those barriers. These key barriers were then prioritised through stakeholder's consultation. The prioritised barriers identified for hindering the uptake of micro-irrigation technology were then grouped into 2 broad categories namely: economic and financial barriers and non-financial barriers.

Barriers in each broad category were decomposed to identify the barriers within each category and the elements and dimension of each barrier. The root cause(s), the causal relationship between barriers were analysed using the Logical Problem Analysis (LPA) also known as the Problem Tree (Annex 1(b). The LPA assisted in bringing together all the key elements of a problem and thus guide systematic and logical analysis of inter-linked key elements. Service providers and stakeholders involved in the research, extension and marketing agents involved in the dissemination of micro irrigation as well as the end users were identified and the market mapping (Annex 1 (c)) was developed to identify the missing links and the market constraints. Results of bilateral meetings were also used to develop a consensus of expert opinions on the feasible "best bet" interventions / measures and priority investments to enhance micro-irrigation as a coping and adaptation strategy to climate change and variability among small scale farmers. This is summarised in the objective tree in Annex 1(e)

1.3.2.1 Economic and financial barriers – Micro- irrigation

The main economic and financial barriers hindering the uptake of micro irrigation technologies among small farmer communities were identified as

- High initial investment required for purchase of various units of the equipment (main pipes, lateral, sub-lateral pressurised PVC pipes, water tanks, fittings, tanks, pump), transport and installation cost compared to other irrigation systems (suppliers keep the price high enough to recover their interest on capital and transaction costs and reduce their risk).
- Lack of economic incentives for the purchase of irrigation equipment and to use water efficiently
- High capital investment needed for creating irrigation water sources /investment in water supply infrastructures)
- Lack of clear economic incentive for saving water due to inefficient pricing of water
- High interest rate on loan
- Cost involved in renewing irrigation system (drip) which has a life time of around 7 years
- High cost involved in design, installation and maintenance (high labour requirement)
- Lack of socio-economic analysis of use of micro irrigation system under small scale

Benefit to Cost Ratio of financial incentives for investing in micro-irrigation

Taking into account the cost of implementing micro-irrigation technology involves cost of capital investment in irrigation equipment, cost of subsidy of 40 % by the government, cost of interest on capital, cost of operation and maintenance and that the benefits include incremental increase in yield, saving on water and labour for irrigation, the benefit/ cost was estimated to 4.67 (Annex- 4 (b)). This ratio shows the viability of this technology to cope with water stress conditions with forecasted decreasing trend in rainfall. This adaptation technology also provides other non market benefits such as increase cropping intensity; reduce risk of nutrient leaching which in turn minimises the risk of environmental contamination and allowing cultivation of high value crop sensitive to water stress. Micro-irrigation also allows the application of fertilisers in irrigation water (fertigation). Besides making efficient use of water, it can also improve fertiliser use while enhancing crop productivity. Water saved though this efficient irrigation system may be used to irrigate additional land. The uptake of this technology can also provide opportunity to create farm employment for design, installation and maintenance of irrigation system and also expand the local supply chain of irrigation equipment and other agricultural inputs.

1.3.2.2 Non-financial barriers – Micro- irrigation

The non-financial barriers identified as hindering the uptake of micro- irrigation grouped different different categories.

Policy/ regulation

- non-conducive policy and institutional frameworks with respect to water management in the agricultural sector
- Present irrigation water pricing not encouraging water savings
- Water rights not well defined for water pumping from rivers and particularly boreholes leading to negative externalities
- Drainage discharge limits of canal limiting water flow and use of micro-irrigation system

Technical

- Need access to a reliable daily water supply;
- Inadequate water quality for drip and mini sprinkler irrigation;
- High cost of water for those small scale farmers using potable water source;
- Power supply for pumping to lift water and pressurized system to ensure uniform distribution of water requires additional investment reduce economic viability of MI
- Fluctuating low flow rate in irrigation canals and mis-match between water delivery schedules in irrigation canal and that required for MI systems (in case water is delivered under gravity) requiring additional cost to invest in intermediate storage system;
- High cost of lifting water in groundwater irrigated areas reducing economic viability of MI
- Lack of scientific data or proper socio- economic analysis of MI at national level;
- Limited research data quantifying the real water saving and water productivity of MI on various crops and different field conditions (data is available only for experimental farms, for limited number of crops and system types and for a few locations).
- Too small sizes of land holding of farmers to make the MI economical due tomfixed overhead costs of energy, and the various components such as filters, overhead tanks
- Choice of MI is highly site specific as it requires technical expertise to consider the soil type , field size , slope and field characteristics
- Drip irrigation not suitable for all crops due to different crop spacing and height soil types / topography and slopes
- Sprinkler irrigation not suitable in areas exposed to high wind velocity
- Gravity fed irrigation system suitable for a limited land area (maximum 1250 m^2)
- Inadequate well trained local technician/ skilled labour for design of irrigation system / network, layout and dripper line placement for uniform water and nutrient application placement and maintenance
- Inadequate farmer access to technical support and information
- Micro irrigation system need to be disconnected for land preparation
- Clogging of drippers requiring regular maintenance and cracking of pipes
- Salt encrustation reduces system performance and complete failure
- Farmers lack technical know-how in installation, operation, monitoring and maintenance
- Regular maintenance required (farmer not willing to bear the burden)
- Presence of clay soil , irregular rainfall or steep slopes can increase implementation and maintenance costs or affect drip system efficiency

- Difficulty in intercultural operations
- Risk of salinity build up causing soil degradation

Market failures

- Limited number of suppliers of irrigation equipments and lack of competition (monopoly)
- Suppliers are not decentralised/ poor access to farmers
- No quality control of MI equipment available locally to check if equipment on sale is of required standard
- Absence of local standard for MI equipment
- Inadequate availability of spare parts
- High cost of fuel to run the water pump to lift water
- Low crop prices in period of gluts making the return from investment low
- Poor marketing infrastructure/ Inadequate skilled workers trained in irrigation design system, installation , maintenance and trouble shooting
- Shortage of after-sales services to assist farmers in troubleshooting and repairs
- Insufficient market information
- Lack of collaboration between the different actors across in the market chain (supplier of tanks, pipes, dripper lines, pump and spare parts)
- Limited market for repurchased equipment

Institutional

- Limited institutional capacity for research and development (staff, and infrastructure)
- Weak links between research and extension and end users
- Inadequate Extension services due to reduced budget, lack resources and over-extended
- No extension specialist in MI to set up demonstration in farmers' fields
- Weak link between suppliers and R&D
- Limited collaboration between the different stakeholders /institutions dealing with water management

Social/Cultural/ Behavioural

- Resistance of farmers to change/ Perception of complexity and fear of not being able to pay back
- Designing and installing MI may be extremely difficult in un-even field conditions
- Farmers not perceiving water as a limited resource due to climate variability
- Farmers lack technical knowhow in managing and maintaining irrigation system
- May require shifting to high value cash crops for economic viability requiring farmer to adopt new agronomic practices
- Require increased grower management effort
- Land tenure: farmer leasing land requires owner authorisation for investing in MI
- Water saving is not a farmer priority due to its low price
- Theft and vandalism

Information and awareness

- Lack of communication between research and policy makers
- Limited sensitisation of farmers on the benefits of investing in a micro irrigation
- Inadequate access to training services and information
- Absence of knowledge base on successful case studies undertaken locally to demonstrate impact of MI systems on water use efficiency (water saving is dependent on climate)

Others

- Uncertainty in availability of water for irrigation due to climate change and increasing pressure
- Can be damage by rats and rodents
- In some areas land tenure system provide little incentive for tenant farmers to invest in irrigation system

1.3.3 Identified measures – Micro- irrigation

1.3.3.1 Economic and financial measures – Micro- irrigation

Taking into consideration the main barriers hindering the adoption of micro-irrigation systems by small scale farmers, measures explored using the objective tree developed for this technology, the main economic and financial measures identified in this study include:

- Provision of credit facilities, grant, subsidy or economic incentives as an instrument to motivate small and marginal farmers to invest in MI equipment. These financial measures can support the purchase of irrigation system, investing in storage facility and pump. They should be targeted at regions, farmers particularly women who farm part of the backbone of small scale farming system and technologies level, where MI adoption would results in real water and energy saving and maximize socio-economic impacts. This may involve study physical and socio-economic profile of the targeted region to analyze the physical impacts, and economic and social benefits of MI as this will depend on the soil, climate, geo-hydrology and crops as well as the socio-economic factors such as land-holding pattern, crops and nature of access to irrigation sources. And also assessment of the investment required in terms of irrigation and power supply infrastructure to be put in place.
- Investment in agricultural research and extension and on farm demonstration for MI
- Establishment of a preferential cheap loan facility for investment in micro irrigation
- Investment in after-sales support services for design of irrigation system and advice on trouble shooting
- Review water pricing so as it reflects its long-term marginal cost taking care not under value crop production and to consider cost of making the water available in the field and for use
- Public investment / financial Incentives to encourage rainwater harvesting and water storage at field level (including lining of field ponds)
- Seek external funding and provision of bank loan to construct irrigation infrastructure (dam, reservoir and canals) and improve irrigation system conveyance to field and within fields(provision for new pipes, feeder canals and filter system)
- Financial disincentives to encourage optimal use of water using water efficient irrigation system

1.3.3.2 Non-financial measures – Micro- irrigation

The non-financial measures identified to overcome the barriers to the adoption of efficient micro irrigation technologies were as follows:

- Government should fit MI as part of a larger investment in horticultural production to improve production and market access and thus increase investment in promotionof efficient micro-irrigation system
- Review pricing of water so as to create a direct incentive for efficient water use.Total metering and agricultural consumption based on pricing would encourage farmers to applying water saving devices or alternately invest in intermediate water storage system such as rainwater harvesting review water pricing
- Faced with the increasing pressures to improve irrigation water use efficiency and to minimize environmental impacts such as salinization and groundwater pollution, research is required to address the technical barriers in the operation, design, and management of micro-irrigation systems.
- Collaborative research effort is required to carry out proper socio-economic analysis of MI that take into consideration the climate, soils, crop type, type of MI technology and geo-hydrological environment in assessing the physical impacts of MI adoption on water and energy use, to determine the real economic and social benefits.
- Research on crop water requirement and irrigation scheduling for different crop, crop stages, soil types and climatic conditions.
- Assessment of the actual cropped areas that can be brought under drip systems in catchment areas which would benefit from them in terms of water productivity improvements
- Training of water users and service providers in design, installation, operation and maintenance
- Training of farmers on how to use real-time climate and soil-based information to determine crop water requirement and irrigation water management and irrigation scheduling (when and how much to apply)
- Development of practical guidelines for micro-irrigation system design and management
- Improving competitiveness of market chain of MI products and also provide good and timely technical input after sales services to farmers
- Promotion campaign to raise awareness on MI kit and boost sale
- Organise farmers' exposure trip on demonstration site to expose farmers to the MI technology and provide them with all the information of the products, suppliers , cost and economic benefit
- Technical support and capacity building to help farmers to acquire minimum skills required to manage the technology effectively
- Research and development of guideline for fertigation to further increase productivity and minimise leaching below the root zone
- Set up standard for MI equipment
- Develop facilities to monitor and control quality of irrigation equipment on the market
- More on farm demonstration need to be undertaken with research, extension and farmer participation

1.4 Linkages of the Barriers Identified

According to the barriers described for each of the adaptation technologies in the agricultural sector described in the above section, the common barriers were identified and classified as follows: Low investment in R &D, research and institutional capability, policy and regulation, and technical capability for dissemination scope of each technology.

Low investment in R&D

One of the biggest barriers to the adoption of adaptation technology among small scale farmers is inadequate financial support to invest in research and development capacity (human and infrastructure). The decline in public investment in agricultural R & D has limited the innovation of technologies related to climate change resulting in disconcerting impacts on productivity). Implementation of technology requires know-how and capacity of technological adaptation and dissemination. There is actually a lack of human resource capacity development in technology for climate change adaptation and consequently very limited capacity to develop necessary adaptation technologies. Given that transfer of technology across agro-ecological and climatic zones may not necessarily adapt to local conditions there is need for substantial investments in research to resolve location-specific problems and develop technology adapted to local need and local growing conditions prior to their diffusion.

Moreover, private sector investment in the transfer of technologies is insignificant due to non-profitability of the adaptation technologies, the small market size, and absence of protection for intellectual property. R& D is a cumulative process that required support and investment from both government and private sectors to push forward environmentally sound technologies suitable for the needs of the country.

Research and institutional capacity

It is recognised that limited collaboration between government agencies and research institutions at national level have often led to duplication of efforts and a loss of resources. Hence the need for a clear policy or high level coordination mechanism for cross-sectoral cooperation to promote collaboration between public and private sectors to conducting advanced research with greater mobilisation of resources and exchange information. This would help to reduce fragmented incomplete research and provide opportunity to formulate action attracting international support. Such collaboration could also be extended at regional or international level to promote technology exchange to address climate change and improve resilience of the agricultural sector.

Another root of the barriers to the uptake of the adaptation technologies is limited skilled human resources to carry out research and develop locally adapted technologies, socio-economic analysis of impact of these technologies under projected climate change scenarios, development of information and technical support materials to ensure effective transfer and diffusion of technologies. Continuous technical training is required for both research and extension staff to bridge the gap between generation of agricultural scientific knowledge and its dissemination to produce expected benefits under farmer field conditions. The transfer of new technology requires coordinated actions of research and extension as well as different stakeholders, proper planning, financial resources and farmers' involvement in field demonstration.

Policy and Regulation

The absence of a national climate change policy or appropriate national agricultural policies to address climate change are recognised as key barriers to foster development of human and institutional capacity to develop adaptation technologies as well as create of enabling environment for promoting adoption of these technologies to improve the resilience of the agricultural sector to climate change impacts. Policy framework to enhance research collaboration, intellectual property rights and public awareness and education to improve understanding of climate change impacts and new technologies for adaptation need to be considered. Farmers perception and resistance to change from conventional farming to new adaptation options is another issue that affect technology adoption and thus requires national policy support in terms of regulatory framework such as standards, promoting efficient irrigation systems, monitoring of pesticide residue on agricultural products and large investment in irrigation infrastructure.

Technical capability for dissemination scope of each technology

Resource limitation is one of the important factors that determine the technical capability and distribution scope of any adaptation technology. Time, financial resources, human resources, technical know-how and infrastructural and institutional capacity will determine the ability of a country to implement a prioritized technology. Each adaptation technology targeting a specific problem may satisfy the need of a particular group of users. For example, micro-irrigation is targeted to small scale farmers in the drought prone areas where water scarcity is impacting on farmers' income and livelihood requiring urgent intervention to optimize limiting water resources and boost productivity to improve food security.

On the other hand, integrated pest management is targeted to all food crop growers who are very vulnerable to pest and disease problem which likely to become more severe with changes in temperature and precipitation profile. This intervention aims at managing pest population to reduce economic damage while decreasing pesticide use, minimizing risk of crop failure, improving cop yield and net return, improving health benefits as well as addressing long term ecological and environmental benefits.

1.5 Enabling Framework for Overcoming the Barriers in Agriculture

This section explores the possible solutions to address the common barriers of hindering the transfer and diffusion of micro irrigation and IPM technologies. The enabling framework to address the common barriers include investment in research and development , training and human and organisational capacity building, information and education, awareness raising, strengthening of institutional collaboration and infrastructure, setting of appropriate policies (incentives or disincentives), setting of quality standard and enforcement, relevant policy support financial services and public and private partnership.

Based on the market characteristics of each of the technologies (IPM: public good and micro-irrigation: consumer good), the conducive environment for effective transfer of specific technology is addressed separately in sections 1.5.1 and 1.5.2 below.

1.5.1 Enabling environment to address barriers to the transfer and diffusion of IPM technologies

Bearing in mind that climate change can exacerbate the scarcity of water resources through reduced rainfall, run-off and high evaporation regimes and worsen pest and disease pressure which is a threat to food security hence need to provide the appropriate enabling environments to overcome the barriers hampering the adoption of locally proven IPM technologies for the control of pest of economic importance were discussed as follows:

- Neighbouring small scale producers in an agro-ecological zone collaborate closely to plan and implement IPM program collectively at wider area and thus improve its chance of success.
- AREU who is already equipped, conduct regular training of farmers in identificationof pest of economic importance, pest scouting, and alternative to chemical control of pest
- More field demonstration are undertaken to serve as show case for interested farmers
- Provision is made for continuous financial resources to support R&D in IPM as there is need to continually research of new adaptation technologies to manage emerging pest of economic importance
- The use of environmentally sound technologies such as IPM need to be integrated in long term planning to for sustainable agricultural production to address climate change as well as food safety, environmental pollution, loss of biodiversity (pollinators) and ecosystem services.
- AREU responsible for research and extension in the non sugar crops uses a client-oriented approach to improve farmers' knowledge in ecological pest management and empower them to make informed decisions.
- Good linkage and feedback mechanism is maintained between research and extension to raise the success of technology transfer
- The is close collaboration and sharing of information between Entomology Division of the MAIFS, AREU and The University of Mauritius to implement IPM programs at national level.
- Adequate technical support is provided to farmers in implementing IPM programme
- Necessary manpower is recruited to assist in implementing IPM research at larger scale
- Strengthening of existing research capacity such sterile male techniques and greenhouses for the rearing parasites and parasitoids
- Capacity building in Economic analysis of adaptation technologies
- Consumer education on IPM and IPM produce to create the market for safe food
- Market incentives available to encourage farmers to invest in IPM (premium on crops grown through IPM practices)
- Policy support to promote ecological pest management through creation of incentives via scheme offering payment for environmental services

1.5.2 Enabling environment to address barriers to the transfer and diffusion of micro-irrigation

A number of enabling environment required to ensure adoption of micro irrigation technologies among small scale farmers were discussed. These required conditions identified were:

- There should be actual and perceived water scarcity justifying the need for efficient water management
- Policy support to promote efficient irrigation system(incentives) is in place
- Farmer awareness is raised on benefits of micro irrigation (including economic benefits)
- Targeted farmers
  - have ready access to a water source located close to their production sites but limited
  - have access to agricultural inputs and credit
  - have access to existing market for their produce
  - have established cultivation of vegetable and high value crops amendable to drip irrigation
  - be ready to shift to high value cash crops and change cropping pattern and practices
- The technology promoted is affordable, effective and easy to operate and maintain
- Basic agronomic guidance on alternative crop type, improved cropping systems, mulching and the use of fertilisers and insecticides are provided to farmers through existing extension services. Support to early MI adopters to ensure technical and financial viability will attract neighbours to take up the technology and eventuall creating a sustainable supply chain for the MI product and employment on the supply side.
- There should be an adequate supplier of MI technology on the local market and a good network marketing structure within reach of farmers
- Availability of technical expertise and experience at national level to support the dissemination of MI technology. A strong collaboration of Irrigation authority, AREU, suppliers of MI products and service providers would be very useful in implementing MI projects.
- Farmers are grouped in organised water users associations responsible to manage irrigation schemes and are also willing to collaborate to purchase pumps, pipes and other infrastructure as it involves significant capital investment to bring water to their fields
- Setting up of a standard for micro irrigation equipment so as to reduce risk that sub standard system are delivered to farmers.
- Quality control of irrigation equipment (pump) is established to provide quality testing certificate to ensure that sub-standard irrigation material are not put on the local market
- Demonstration of the technology are conducted on at least 0.5 ha in a strategic location for maximum farmers to benefits
- Institutional collaboration is reinforced to properly coordinate and improve overall effectiveness of promoting MI as an adaptation technology in drought prone area
- Adequate financial and human resources to plan, implement campaigns and demonstrations
- A multidisciplinary team with broad spread of skills to support the promotion of this technology for at least 5 years to ensure take-off of the technology and give a chance for sustainability of the technology and the market chain
- Sufficient supplier of basic irrigation components on the local market
- need to identify donor organisation to invest in establishing supply and demand market for MI to overcome problem of water shortage which is likely to amplify in the future
- Adequate skilled workers trained in design and installation of MI system is available locally
- The water delivery system needs to be designed such that where possible surface

water is delivered in farmers field under pressure ant that the latter can directly connect the source to their distribution system.

- Price of irrigation water is increased to encourage farmers to invest in water saving
- Farmers have rainwater harvesting or water storage facilities on their fields to ensure reliable water supply
- Power supply is available to boost the adoption of pressurised irrigation system
- Extra land is available for area expansion of irrigated area
- Government consider investing in development of water supply infrastructure to mprove farmers access to water as a priority
- The technology is promoted through advertisement by suppliers.

Besides those measures directly related to promote the adoption of micro irrigation, there are several other complementary adaption options that need to be deployed at national level to enhance food security under water stress conditions. These include:

- Rainwater harvesting
- On farm storage for supplementary irrigation
- Sustainable extraction of underutilized water resources
- Conservation agriculture (including water conservation practices, crop residue management, and in situ soil moisture conservation measures such as use of cover crop , mulch, minimum tillage and maximizing plant water uptake by timely operations, crop management and soil fertility management)
- Designing landscape to collect rainwater and help to inject it (naturally or via engineered structures) into aquifers which unlike lakes and reservoirs are less prone to loss due to evaporation.
- Shifting to crops/ varieties or livestock species /breeds with greater drought and heat tolerance and improved pest and disease resistance
- Intensify food production through fertigation to optimize fertiliser use and use of improved seeds
- Practicing deficit irrigation to maintain crop in period of severe water shortages
- Using treated waste water as an alternatives
- Integrated watershed management

2. Water Sector

Mauritius exploits both surface water and groundwater in order to cater for water demand. The island receives an average an annual rainfall of about 2500mm. However, owing to its topography, hydro-geological conditions and tropical location, Mauritius experiences high levels of rapid run off (60% its total rainfall). Table 2 summarizes the water balance for the island of Mauritius for selected years between 1999 and 2010 that demonstrates the variability in water availability.

Table 2. Water balance (Mm3) for the island of Mauritius, 1999-2010 (Source: Digest of Energy and Water Statistics – 2003 and 2010, Central Statistics Office, Port Louis).

Year	1999	2006	2009	2010
Rainfall (average)	2,184 (100%)	3,571 (100%)	4,470 (100%)	3,368 (100%)
Surface runoff	1,311 (60%)	2,143 (60%)	2,682 (60%)	2,021 (60%)
Evapo-transpiration	655 (30%)	1,071 (30%)	1,341 (30%)	1,010 (30%)
Net ground water recharge	218 (10%)	357 (10%)	447 (10%)	337 (10%)

In 2010, the total water demand was estimated at 975 Mm3. The agricultural sector accounted for most of the water utilized with 454 Mm3 despite the fact that this sector accounts for around only 4% of the country's GDP. Water utilization was followed by hydro-electric power generation (295 Mm3), domestic, industrial and tourism uses (212 Mm3), and industrial applications from private boreholes (14 Mm3).

Figure 1 shows the percentage breakdown of total water utilization by application.

Runoff is defined as that part of precipitation that flows towards the stream on the ground surface or within the soil (International Glossary of Hydrology, World Meteorological Organisation no. 385).

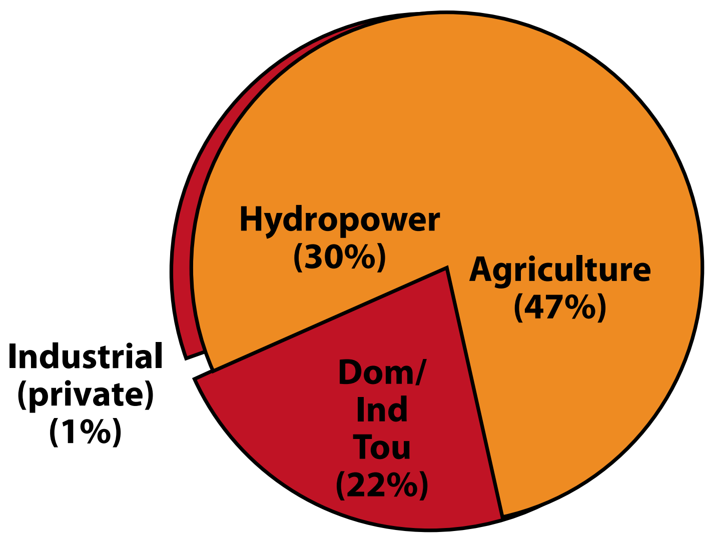

Figure 1. Final water use in 2010 (Source: Energy and Water Statistics – 2010, Central Statistics Office, Port Louis).

The extraction by source of sectoral water demand in 2010 is summarized in Table 3. Around 56% of freshwater used came from surface water (rivers and streams), 29.8% from reservoirs and the remaining 14.3% came from groundwater aquifers.

Table 3. Extraction by source of sectoral water demand in 2010 (Mm3) (Source: Table 17, Environment Statistics – 2010, Central Statistics Office, Port Louis).

	Surface Water				
	Rivers	**Reservoirs**	**Aquifers**	**Total Mm3**	**%**
Agricultural irrigation	356	80	18	**454**	47%
Hydropower	148	147	-	**295**	30%
Domestic, Industrial & Tourism	36	64	112	**212**	22%
Industrial (Private boreholes)	5	0	9	**14**	1%
Total Mm3	**545**	**291**	**139**	**975**	
Percentage (%)	55.9%	29.8%	14.3%	100%	

Fresh water availability for human use is affected by both climate and non-climate drivers. The main non-climate drivers in the water sector arise due to increasing demand from economic development, agriculture, industry, tourism and a growing urban population. These in turn result in heavy water extraction and also pollution of water resources. During the first decade of the 21st century, per capita

It must be noted that part of the water used for hydropower generation is also used for irrigation.

water consumption has increased by 7.1%, and it is expected to increase further into the future with the more affluent lifestyle of the local population. Analysis carried out in the Mauritius Environment Outlook shows that total water demand is projected at 1,200 Mm3 per year by 2040 based solely on changes in population dynamics. This demand, which does not take into account water demand in other growing sectors of the economy like tourism and Integrated Resort Schemes, is in excess of projected supplies and close to the present utilisable renewable potential of 1,233 Mm3 per year.

Groundwater-quality monitoring at 23 Interface Control Piezometers and in boreholes in use for industrial, agricultural and domestic purposes have groundwater quality in coastal aquifers is vulnerable to seawater intrusion. Sources of freshwater pollution include industrial effluents, dumping of liquid and solid waste in rivers and streams, run off from agricultural fields and untreated sewage.

Although temperature is projected to continue to increase globally, the effects of this increase on precipitation will vary from one area to another. The effect on precipitation may also vary seasonally; in some areas, precipitation is expected to increase in one season and decrease in another. Although the field of climate modeling has progressed rapidly in recent years, quantitative projections of changes in precipitation, river flows and water levels remain highly uncertain.

Nevertheless, the observed decrease in rainfall, increase in rainfall variability, increase in the occurrence of high-intensity rainfall and the shift in the onset of the summer rains, are impacting negatively on the water resources of the country. During the Technology Needs Assessment process, which also included a multi-criteria analysis approach, the following technologies have been retained in the water sector; rainwater harvesting, desalination and hydrological models. Detailed barrier analysis studies have been undertaken for all the three technologies and these are described in the sections to follow.

2.1 Preliminary targets for technology transfer and diffusion

A large volume of water is lost to the sea annually in the form of surface runoff. Over the recent years, the island has been recording high intensity long duration rainfall events, and these types of rainfall events give rise to high surface runoff, a large part being lost to the sea. The rooftop rainwater harvesting technology proposed will serve two purposes. The water collected will be used for secondary purposes such as gardening and cleaning and the second one for increasing groundwater recharge. The RWH technology is being targeted at residential levels. There are about 250,000 housing units which are being targeted, some are located in the high rainfall regions and others in the relatively drier areas. The success behind this technology will depend on the rainfall pattern in the area. The project is expected to last over 10 years, and in the first 5 years, the regions receiving higher annual average rainfall will be given priority, and each year a total of 25,000 housing units are being targeted.

Mauritius being a small isolated island, water resource management has always been very crucial. With increasing demands of water the island has to carefully manage its water resources. Long term average levels of groundwater, reservoirs and river flow rates are indicators which provide sound basis for decision making in the water resource situation at a given point in time. However, both short term and long term predictions are also key in an effective water resource management plan. By making use of hydrological models the local water resource authorities will be able to get a thorough understanding of the water resource system, as it varies over space and over time. This model can be used to forecast the impact of climate change in both the short and long term and help significantly towards a more effective water resource management policy for the country. The targeted institution is the Water Resources Unit and the key institutions which are directly concerned with water resources, such as the Central Water Authority, the Irrigation Authority, the Central Electricity Board and the large private companies involved in the production of sugar cane. The project is expected to last over 5 years. In the first year (stage 1) of the project, a dedicated unit will have to be created and provided with the logistics (computers, printers, plotter, scanner and software). The training (stage 2) will be in two parts, the first part will consist of a basic training and the second part will consist of a more advanced training. The third stage of the project, the training will be dedicated to the team involved with the use of the outputs from the model for decision making. Over the last two years, the focus will be more on providing technical support to the dedicated team and ensuring knowledge transfer.

The desalination technology is a costly technology for production of potable water supply. Furthermore the disposal of the by product, brine, can harm the environment if it is not disposed in a safe manner. Usually it is diluted then disposed in sink wells. Currently Mauritius is heavily dependent on rainwater for its water resources. Desalination provides for an alternative water resource which is independent of rainfall. About 10 hotels located near the coastal areas, have implemented the reverse osmosis desalination technology is order to address water security during the dry periods. Since 2012, the Government is encouraging more hotels located near the coast to implement the desalination technology, with a view of alleviating the pressure on the existing water resource. The present project has identified the reverse osmosis desalination technology for hotels located in the coastal areas. The project is expected to span over 10 years, targeting some 50 hotels in total. The Government has already come up with financial benefits to encourage the hotels to embark on this technology. In addition, the present project proposes that a soft loan be given to the hotels to meet part of the initial capital investments.

2.2 Barrier analysis and possible enabling measures for RWH Technology

During the workshop held in July 2012 on Barriers Analysis, the rainwater harvesting technology was taken as a case study by the participants. A brainstorming session was first conducted to list the various barriers in the local context which would be impacting on the implementation of the rainwater harvesting technology. This list of barriers was then classified as per the Reference document by UNEP/RISOE. The participants then consider one particular main barrier and decomposed this until the root cause was identified. This first analysis formed the basis for the barrier analysis for rainwater harvesting and the analysis was expanded for all the different main barriers (Annex 5).

2.2.1 General description of technology RWH

The rainwater harvesting technology is aimed at residential level, with a simple design. The main features consisting of the collection system (pipe and gulleys), the connecting pipe with an outflow for discharge of settleable solid particles, a container (500litres), and an overflow with drainage facilities in order to promote groundwater recharge.

2.2.2 Identification of barriers for technology RWH

The first step in the identification process of barriers was to classify the technology of RWH. The RWH technology falls under the category of goods which are specifically intended for the mass market, for households or for businesses. The market characteristics of RWH is as follows: it is aimed at a high number of potential consumers, there is a dense network of suppliers, distributors, maintenance and installation businesses which are involved, and this give rise to large and complicated supply chains with many actors. In the case of RWH, barriers may exist in all steps in the supply chain and demand depends to a large extent on consumer awareness and promotional efforts both from the Government and the commercial sectors. Hence, the RWH technology was classified as a market – consumer good.

As noted in Boldt et al., 2012, the transfer and diffusion of technologies are influenced by market decisions and political decisions, the extent of which is dependent of the classification category. The diffusion of consumer goods is generally dominated by market decisions, whereas non-market goods are primarily diffused through political decisions. It is worth noting that the Government has a direct influence on the diffusion of non-market goods, but only indirect influence on consumer goods. This served as a sound technical basis when considering how to overcome barriers for RWH.

The next step was to carry out a brainstorming session with the stakeholders; the topic was 'why was RWH currently not implemented at residential level?'. This was a very key step in the barrier analysis process, as it gave rise to a list of barriers specific to the local context. Once this list was drawn, the reference document by UNEP/RISOE, (Boldt et al., 2012) on barrier analysis was used to classify the barriers and these are described in the sections to follow.

2.2.2.1 Economic and financial barriers - (RWH)

A complete rainwater harvestor costs a family of 4 persons, around MUR Rs. 10,000. The cost of living in the country being high, and the salary scale for many families being not too high, people had other priorities than investing in a RWH. The benefits of a RWH are not tangible and hence many see an investment in RWH as being financially not viable. It was also noted that the Government does not provide enough financial incentives or soft loans for a family to invest in a RWH. The cost of water was found to be a deterrent in investing in a RWH, the unit cost for a residential use is around Rs. 5. To summarise, the following economic and financial barriers were noted:

- High Cost Capital
- Financially not viable
- Inappropriate financial incentives and disincentives

2.2.2.1.1 Benefit to Cost Ratio – (RWH)

A benefit to cost ratio analysis was carried out (Annex 8). The cost elements considered were the capital cost of the rainwater harvestor, the installation cost and the maintenance cost. The benefits elements considered were the savings in water bills by the consumers and the opportunity cost of the Central Water Authority who can sell this water to other consumers who pay a higher price. The benefit to cost ratio obtained was 1.37. It is important to note that additional cost and benefits elements if considered will also influence the benefit to cost ratio, and these are detailed below:

Other Cost elements

1. Preparation and promulgation of appropriate legislation and regulation
2. Setting up of a monitoring team at the level of the institution to ensure efficient implementation of the technology
3. The prices of fittings may change significantly over time.
4. The setting up of an information centre in order to ensure information to the general public
5. Government may not be able to provide 40% grant or soft loan in this project
6. The bank interest rates for loans and savings fluctuate significantly

Other Benefits

1. Possibility of job creation for plumbers and for casual workers to do regular maintenance
2. Possibility of saving more than 20m3 of water as the general public get used to adapting to water crisis
3. Decrease in cost of RWH units as local manufacturers are encouraged in the market chain.

The services such as defining a new legislation and creating an information centre will be services that are needed in order to promote sustainable consumption of water resources.

2.2.2.2 Non-Financial Barriers – RWH

2.2.2.2.1 Market Failure & Imperfection - (RWH)

RWH technology is a simple technology which can be easily adopted at residential level. However apart from cost, the general public does not seem to have a good choice. The types of rainwater harvesters available from the market reflect an underdeveloped market. Awareness to the need and type of RWH is poor in Mauritius and to the general public it appears that the market is controlled by a few companies. In addition, there is no benchmark with which the general public would be able to compare the effectiveness of using a RWH at residential level.

The following barriers were identified under this category:

- Underdeveloped competition
- Restricted access to technology
- Market control by incumbents
- Lack of reference projects in country

2.2.2.2.2 Policy, legal and regulatory - (RWH)

In order to promote RWH, there is a need for sound legislation and an institution which should enforce this legislation. Currently this is not available in Mauritius. In addition, the policy for promoting RWH at national level is not well defined. The following barriers were identified under this category:

- Insufficient and regulatory framework
- Policy intermittency and uncertainty

2.2.2.2.3 Social, cultural and behavioural - (RWH)

Habits and traditions have been identified as another main barrier likely to hinder the successful implementation of RWH technology. The general public is used to having water at a low cost and in abundance. We did not have to adapt to water scarcity and we consequently developed some bad consumer habits as far was water is concerned. The following barriers were identified under this category:

- Consumer preferences and social bases
- Traditions and habits

2.2.2.2.4 Information and awareness - (RWH)

Another important barrier that will have to be addressed is the lack of awareness about RWH, how can a RWH be set up with simple device, why should the general public be encouraged to adopt RWH, what is climate change, will it adversely impact on water resources, why should each and every one contribute to sustainable development of water resources, and how can the media contribute to promoting this awareness. The following barriers were identified under this category:

- Inadequate information
- lack of media interest in promoting technologies
- Lack of awareness about issues related to climate change and technological solution

2.2.3 Identified measures - (RWH)

RWH is a simple technology which is also relatively not costly. However, the general public needs to be encouraged to implement it. The incentives range from educating the general public about climate change impacts in the future, the RWH itself, the range of technology from simple (less costly) to more sophisticated (blend with the environment), to financial incentives in the form of soft loans. In addition, from the policy side, there is a need for a long term programme, both with regards to implementation, legislation and monitoring.

2.2.3.1 Economic and financial measures - (RWH)

- Government to provide financial incentives in the form of soft loans.
- Need to review water tariffs so as to make RWH an attractive option.
- There is a need to encourage local manufacturers in order to reduce the cost of a complete unit of RWH.

2.2.3.2 Non-financial measures - (RWH)

1. Awareness Campaigns on the impact of Climate Change on Water Resources – at all levels (General Public & Technical staff)
2. Awareness programmes to be targeted on Futuristic Scenarios to make the general public and the policy makers aware of the potential impacts of do nothing scenario.
3. Government to promote RWH through legislation & institutional support
4. Government will need to come up with appropriate legislation/regulation to ensure that RWH is well implemented.
5. More opportunities to be given to the small scale enterprises to become part of the RWH implementation process.

2.3 Barrier analysis and possible enabling measures for Hydrological Model

Hydrologic models are simplified, conceptual representations of a part of the hydrologic cycle. They are primarily used for hydrologic prediction and for understanding hydrologic processes. Hydrological model provide a sound scientific basis for decision making in water resources management. Since hydrological models involves much mathematical, statistical and stochastic processes, it is a highly specialized and of direct concern to few institution. In Mauritius the Ministry of Public Utilities & Energy and the Ministry of Agriculture and Food Security as likely to be the two Ministries directly concerned with the use of such models.

2.3.1 General description of Hydrological Model

The Hydrological model is a numerical mathematical model which processes hydrological data such as rainfall, river flows, water quality in order to predict the extreme events and futuristic scenarios of abstraction and their impacts. Hydrological models from the basis for decision making and for forecasting in many countries. These models provide scientific basis for decision making based on historical data and future trends. Hydrological models also provide for a more informed water resource management at both catchment level and on a national level.

The extent, to which a hydrological model can be a very useful water management tool, depends on availability of reliable data, on the complexity of the software and on the modeling team working with the Hydrological Models. Given the impacts of climate change on the water sector, the need to better management the water resource and the need to make long term forecast for a more informed decision making in time, the need for Hydrological Models is a most needed working tool.

2.3.2 Identification of barriers for technology Hydrological Model

The Hydrological Model falls under the category of Non-Market Public goods. This technology will contribute to the improve water resource management for the whole population in all the water demand sectors. With regards to its market characteristics, this technology will be implemented in a few Ministries, Ministry of Energy and Public Utilities and the Ministry of Agriculture and Food Security. It is characterized by a simple market chain, with few suppliers on the local market. The investment in hydrological model is usually undertaken by the Government or by private water companies. In Mauritius, the investment in Hydrological Model will come from the Government only. The beneficiaries will be the whole population.

A brainstorming session was initially carried out to identify barriers specific in the local context. These were then grouped and analysed in more detail (Annex 6).

1. The general public is not conversant with the benefits of hydrological models.
2. Even among stakeholders, hydrological model concerns a few stakeholders.
3. There are very few local experts who are familiar with the use of a hydrological model.
4. There are no local experts familiar with the development of hydrological model in order to tailor made it to the needs of the country.
5. The telemetry system which serves as a sound data input on pilot basis, and often not in working conditions, due to lack of qualified technicians.
6. The initial investment includes the software, the training to technical staff, the visits of experts for capacity building, and this is high.
7. The benefits are not tangible and cannot be readily evaluated.
8. The successful implementation of a hydrological model depends on heavy investments in logistics such as computer laboratories, accessories and dedicated staff.
9. There is a need for highly skilled technical staff and this requires training.
10. There will be high dependency on experts from abroad and this adds to the cost.
11. A few years will be needed before local technical staff can make full use of the predictive capabilities of hydrological models, as data interpretation depends on experience of using such decision making tool.
12. The issue of security of information will have to be addressed as the data will be stored within the computerized system.
13. Off shelf technologies may not always fulfill the needs for the country, but local system are non-existent.

2.3.2.1 Economic and financial barriers Hydrological Model

Cost elements are involved in several aspects of the successful implementation of a hydrological model: the initial investment in the cost of the software, the setting up of a dedicated computer laboratory and dedicated highly skilled technical staff, the initial training to be provided to the technical staff, the capacity building which may last over two years before the technical staff are able to use the hydrological model for decision making. The barriers were as follows:

- The initial investment includes the software, the training to technical staff, the visits of experts for capacity building, and this is high.
- The benefits are not tangible and cannot be readily evaluated.
- The successful implementation of a hydrological model depends on heavy investments in logistics such as computer laboratories, accessories and dedicated staff.
- There will be high dependency on experts from abroad and this adds to the cost.
- Lack of financing institutions for this particular technology.
- Price of water is very low, and investments are considered as being very high relatively.

2.3.2.2 Non –Financial Barriers – Hydrological Models

The non-financial barriers that are relevant to hydrological models are the extent and level of local expertise, the extent to which the local market is involved with this product, the level of awareness of the local water authorities and the general public about Hydrological models, and the nature of the benefits that are likely to arise following the successfully implementation of a hydrological model and an improved water resource management.

2.3.2.2 .1 Market Failure/Imperfection

- Hydrological model is not a popular technology among the general public
- Even among stakeholders, hydrological model concerns a few stakeholders.
- There are very few local experts who are familiar with the use of a hydrological model.
- There are no local experts familiar with the development of hydrological model in order to tailor made it to the needs of the country.
- Off shelf technologies may not always fulfill the needs for the country, but local system are non-existent.

2.3.2.2.2 Policy, Legal and Regulatory

- Lack of local regulations to encourage use of hydrological models for decision making in the water sector.
- The issue of security of information will have to be addressed as the data will be stored within the computerized system.
- Lack of awareness of impacts of climate change on the water sector.

2.3.2.2.3 Institutional & Organisational Capacity

- Lack of local institution which promotes and develop tailor made hydrological models.
- Lack of interests amongst stakeholders to embark on this highly specialised technology
- Is relevant to only two main Governmental institutions which are directly concerned with water resources management

2.3.2.2.4 Human Skills

- Hydrological model is not a popular technology among the general public
- Even among stakeholders, hydrological model concerns a few stakeholders.
- There are very few local experts who are familiar with the use of a hydrological model.
- There is a need to train dedicated highly skilled staff.
- There will be need for capacity building and hence regular visits of experts to train staff in using the software for decision making.

2.3.3 Identified measures for Hydrological Model

A Hydrological model provides a very technical basis for sound decision making for water resource management. To date the implementation of hydrological models has not been very successful since this success of this technology rests of the provision of adequate logistics in terms of computer facilities, dedicated highly skilled staff, regular training and capacity building which may last over at least 5 years. There are very few institutions which are interested in implementing hydrological models. Only those institutions directly involved with water resources management have noted the need for such a system.

2.3.3.1 Economic and financial measures for Hydrological Model

- Financial incentives will be need to create a dedicated unit and this will comprise of the hardware facilities such as computers, printer, plotter, scanner and an RGB projector for ease of information sharing.
- In addition to the hardware facilities, the particular hydrological modeling software will have to be purchased, installed and tailor made to suit the local needs. This will require the services of experts.
- Financial support will be needed to organize training sessions at three different levels and for technical support and capacity building.

2.3.3.2 Non-financial measures for Hydrological Model

- Local institutions to be encourage to develop tailor made systems
- Local training institutions to partner with Government to provide regular training.
- Awareness programmes to be set up to inform all stakeholders about the importance and benefits of hydrological models.

2.3.4 Financial Analysis for Hydrological Model

The cost elements in the implementation of a Hydrological Model are as follows:

1. The cost of the software
2. Regular training programmes over 2 years
3. Setting up of a dedicated computer laboratory
4. Conversion of existing historical data into acceptable format
5. Setting up of a dedicated unit for decision making using hydrological models
6. Capacity building through collaboration with experts from abroad
7. The cost of a hydrological model may vary from as small as US$1,000 to more than US$ 30,000 depending on the complexity of the system and the extent to which it has been tailor made for the local situation. In this present project it would not be wise to start with too complex models. The hydrological model including basic training, cost for technical support and regular updating, would cost around US$ 30,000.

The benefits of hydrological models are of an intangible nature, as follows:

1. Sound decisions taken well in advance of extreme events such as drought events or flood events.
2. Improved water resource management
3. Monitoring and improvement of water quality in both surface water and groundwater.
4. Improve allocation of water to different users.

Since the benefits are intangible, a cost benefit analysis was not undertaken for Hydrological Models and the same situation was encountered while working on the multi criteria analysis for technology selection.

2.4 Barrier analysis and possible enabling measures for Desalination

The potential for re-use of brackish water is being addressed in many countries. Desalination of brackish water has been implemented in Mauritius by a number of hotels located along the coastal areas. Government is encouraging hotels to implement desalination technology in order to help alleviate the pressure on water demands. Cost, energy and lack of adequate know-how are a few of the main barriers that are preventing the wider spread of this technology. Location of a hotel with respect to the sea and the cost of potable water are also factors which are preventing some hotels from adopting this technology.

2.4.1 General description of Desalination

The desalination technology considered in this study is the desalination of brackish water by reverse osmosis.

2.4.2 Identification of barriers for Desalination

A brainstorm session on the barriers for the desalination of brackish water noted the following.

1. High capital, operational and maintenance cost.
2. Highly energy intensive and no regulations to impose on conditions of renewable energy
3. By-product, brine, has to be disposed of in a safe manner but no regulation specific to disposal of brine exists so far
4. Lack of local experts involved in the manufacture of desalination plants
5. Lack of technical experts for the operation and maintenance of the plants
6. Lack of appropriate legislation governing safe exploitation of brackish water
7. Lack of appropriate legislation/regulation governing the monitoring of the impact of exploitation of brackish water and disposal of brine on the groundwater.
8. Lack of awareness of the development of desalination in the world.
9. Lack of technical know-how locally, need to rely on external support.
10. Social impact of this technology as viewed by coastal villagers.

These ideas were grouped in different categories and analyzed in detail as explained in Annex 7.

2.4.2.1 Economic and financial barriers for Desalination

The cost of desalination plant, involves both a high initial investment cost and a high operational and maintenance cost. In addition, this technology is energy intensive. These two factors contribute to the overall cost of a desalination plant. The country relies on the well-established desalination technology from abroad for the whole unit and for technical support, and these add to the overall cost of the technology.

- High capital, operational and maintenance cost.
- Highly energy intensive and no regulations to impose on conditions of renewable energy

The benefit to cost ratio was carried out for the Desalination Technology. The cost of potable water is relatively low and the analysis was based on the use of the Desalination plant during the dry periods only, for a period of 2 months. Analysis was carried out for a 300m3/day production capacity plant with a life span of 5 years. Though some 112 hotels located along the coast may have the potential of implementing a desalination plant, not all of them are located within an appropriate zone, thus the analysis targeted around half the total number, 50 hotels only. Over a period of 10 years, each year around 5 hotels will take the initiative of implementing a desalination plant. More details of the benefit to cost ratio analysis is given in Annex 9.

2.4.2.2 Non-financial barriers for Desalination

2.4.2.2.1 Market Failure/Imperfection

- Lack of local experts involved in the development of desalination plants
- Lack of technical experts for the operation and maintenance of the plants
- Lack of technical known-how locally, need to rely on external support.

2.4.2.2.2 Policy, Legal and Regulatory

- By-product, brine, has to be disposed of in a safe manner but no regulation specific to brine disposal exists so far
- Lack of appropriate legislation governing safe exploitation of brackish water
- Lack of appropriate legislation/regulation governing the monitoring of the impact of exploitation of brackish water and disposal of brine on the groundwater.

2.4.2.2.3 Social, Cultural & Behavioral

- Lack of awareness of the development of desalination in the world.
- Social impact of this technology as viewed by coastal villagers.

2.4.2.2.4 Institutional & Organisational Capacity

- No local institution to monitor the impacts of this activity on the environment and the country's resources.

2.4.3 Identified measures - Desalination

2.4.3.1 Economic and financial measures - Desalination

- Provide financial incentives to encourage the hotel sector to adopt this technology.
- Encourage local manufacturer to get involved with the objective of lowering the capital cost.
- Provide technical know-how on some parts of the system – maintenance aspects so as to lower part of the operational cost.

2.4.3.2 Non-financial measures - Desalination

- Get collaboration from abroad, for the development of local expertise
- Try various energy efficient systems for the island.
- Promulgate appropriate legislation – safe exploitation of brackish water, safe disposal of brine, monitoring of impacts of both brackish water exploitation and brine disposal.
- Create awareness as to the need for desalination

2.5 Linkages of the Barriers Identified

For all the three adaptation technologies discussed, it has been noted that there are some barriers which are common to all three.

Low cost of treated piped water

About 99.6% of the population has accessed to piped water supply at a relatively very low cost, and this is one of the reason why technologies such as RWH and Desalination are not considered an attractive option. In order to encourage both RWH and the Desalination technology, the emphasis should not be on the cost of the water, but rather on the need to optimise the use of treated water and the need for an alternative source, a rainfall independent source in this case.

Lack of Adequate Legislation

Mauritius has promulgated legislation to control to exploitation of both surface and groundwater in terms of quantity (Rivers & Canals Act, 1863 and the Groundwater Act, 1970). Legislation also exist in order to ensure that landuse activities do not impact on water quality (Effluent Discharge Regulations, 2008 and the Environmental Protection Act, 2011).

Legislation that is need to promote effective use of treated water is yet to be implemented. The new Building Act (2011) stresses on the need for sustainable consumption of water, but no detailed regulations have been formulated yet. Clear regulations are needed with regards to the design and type of the RWH that can be financed, this will ensure that the consumers get reliable products. While the EPA (2011) does require an EIA report for any project of desalination, there is also need to monitor the long terms impacts of this activity on the groundwater resources, given that these activities will occur along the coastal zones. Hydrological Models constitute a useful working tool that can provide sound technical information for improved decision making. In order to encourage relevant institutions to make use of this tool, legislation will have to be promulgated, as currently no such legislation exist in Mauritius.

Financial incentives & Institutional Support

Financial constraints have been identified as a common barrier to the implementation of the RWH and the Desalination technologies. In order to encourage the implementation of these technologies, financial grants or soft loans that would cover part of the cost of the technology will be needed as an incentive. This will have to be done under the aegis of a particular institution which will be responsible to monitor the progress of the project and at the same time safeguarding the interest of the consumers.

Training

The RWH is a simple technology, but it does require the services of plumbers and cleaners. Such training needs will need to be addressed in order to ensure success of this technology. The Desalination technology is in contrast more complex and it will require skilled workers to ensure good and safe operation of the system. Though the Desalination technology is normally bought offshelf, the daily operation and maintenance require skilled workers, and hence this need will have to be looked into. With regards to the Hydrological models, the success behind this particular technology is very much dependent on the skills of the user. This particular technology will require highly skilled technicians. There will be a need to set up a team with graduates having scientific background in order to ensure that the training sessions on the HM software are effective.

Awareness

In order to ensure the success of any new technology or policy, awareness is important. Apart from an aggressive campaign on the particular technology, RWH, Desalination or HM, there will be a need to create the awareness of the impacts of climate change on the water resources in both the short and long term.

2.6 Enabling Framework for Overcoming the Barriers in Rainwater Harvesting

In order to successfully implement Rainwater Harvesting at residential level, the following factors will serve as enabling framework:

1. Skilled workers (plumbers)
2. Availability of products such as plumbing, fittings, accessories, storage tanks.
3. Financial support schemes from the Government.
4. Regulations and legislation to protect consumers from frauds
5. Institutional support for monitoring of products being sold to the general public.
6. Government commitment towards promoting sustainable development.

2.7 Enabling Framework for Overcoming the Barriers in Hydrological Model

The success behind the Hydrological Model project will depend to a large extent on the following enabling factors:

1. Training of highly skilled technical staff.
2. Existence of Hydrological monitoring stations
3. Government policy to promote sustainable development of the water resources.
4. Institutional support and commitment to a more informed decision making process.
5. Legislation/policy that encourages the use of Hydrological Models for decision making.

2.8 Enabling Framework for Overcoming the Barriers in Desalination

In order to successfully and safely implement the desalination technology, the following factors are considered as the key enabling framework:

1. Skilled technical workers;
2. Government policy to alleviate stress on potable water;
3. Government policy to promote alternative sources of water;
4. Institutional support responsible for monitoring the impacts of brine disposal and exploitation of brackish water on groundwater quality; and
5. Appropriate legislation that will ensure protection to groundwater resources following exploitation of brackish water and disposal of brine in the environment.

3. Coastal Zone

The TNA for the Coastal Zone sector has retained four technologies, namely; Restoration of coastal vegetation, Wetland protection, Dune restoration and Rock revetment. Mauritius with its varied coastline ranging from sandy beaches to rocky shores and cliff is very much affected by coastal erosion. The causes of erosion as identified by several studies including the Study on Coastal Erosion in 2003, were from the direct interaction of the sea with the shoreline, mainly during extreme events such as cyclones and storm surges. The extent of erosion is however exacerbated in certain places because of the negative anthropogenic impacts on the health of lagoons, beaches and dunes.

Three of the four technologies retained, Restoration of coastal vegetation, Dune restoration and Rock revetment are applicable directly on the shoreline and would provide direct benefits to the location where they are applied. In contrast, wetland protection would act indirectly in mitigating the erosion impacts on an adjacent coast. Wetland, through their hydrological services they provide, contribute to improve the water quality of the lagoon around Mauritius and thus a healthy marine environment which in turn would contribute to the stability of the shoreline.

Dunes are present along a major part of the shoreline of Mauritius. Along the public beaches the dunes are vegetated mainly with grass and Casuarina trees while in other places they have been exploited for building purposes. Dunes which are natural wind-formed sand deposits acting as erosion buffers during extreme events and the vegetation play an intrinsic part in maintaining the stability of the dunes. Because of the close interaction of dunes and the vegetation found thereupon and their simultaneous and coherent processes in controlling the stability of the shoreline, the two technologies identified by the TNA, restoration of coastal vegetation and dune restoration, have been merged to the single technology of Dune and Vegetation Restoration. In practice, following dune restoration it is recommended that the dune be vegetated and likewise prior to the undertaking of vegetation restoration it is recommended that the dunes are restored. The merging of the two technologies into one has been approved during the Coastal Sector stakeholders meeting of 29 November 2012 which comprised among others, the Ministry of Environment, Ministry of Fisheries, Beach Authority, National Parks and Conservation Service and Mauritius Oceanography Institute. Hence the technology of Dune and Vegetation restoration has been worked upon as one single technology.

Several Rock Revetment projects are underway in Mauritius and a few others are in the pipeline. Rock revetment is being used in areas where there is severe erosion and where infrastructures like roads and buildings are at stake. In Mauritius it is now common to use rock as the medium for undertaking shoreline revetment, however, revetments can also be of concrete or using some latest geotextile technology.

All the, now, three retained technologies are important for adaptation to climate change for the coastal sector as they form an integral part of the coastal management approach to the problem of erosion either directly or indirectly.

3.1 Preliminary targets for technology transfer and diffusion

The Technology identified by the TNA are targeted towards the main stakeholders of the coastal sector which remain the Government of Mauritius through its several Ministries like the Ministry of Environment and Ministry of Fisheries as well as various departments and parastatal bodies, like the Beach Authority, having responsibilities over the shoreline and the public beaches around Mauritius. The technologies are also targeted at the general public and private entities, including hotels and bungalow owners who are present along the coastal zone of Mauritius.
The barriers and measures have been worked out following the stakeholders meeting of November 2012 and through informal bilateral meeting mainly with the ICZM division of the ministry of Environment.

3.2 Barrier analysis and possible enabling measures for Dune and Vegetation Restoration

3.2.1 General description of Dune and vegetation Restoration

The Study of coastal erosion around Mauritius, commonly known as the Baird Report 2003 has put forward Shore and beach management as a potential approach to comprehensively deal with the problem of erosion and it includes such actions as controlled access for vehicles and pedestrians, onshore grading, restoration of native coastal vegetation, enhancement and dune protection and restoration.

Sand dunes are an important component of the lagoon-beach ecosystem. Naturally occurring sand dunes are wind-formed sand deposits representing a store of sediment in the zone just landward of normal high tides (French, 2001). Dunes effectively store excess beach sand and serve as natural erosion buffers for shorelines during extreme events such as cyclones and storm surges. However, dunes remains fragile features that are easily altered by the actions of people e.g., trampling by pedestrians, destruction by vehicular traffic, levelling for development, mining for construction, introduction of inappropriate invasive or exotic species. Sand dunes also provide a valuable coastal habitat for many highly specialised plants and animals. As such, sand dunes may be considered important both ecologically and recreationally.

Historically in Mauritius, most of the natural sand dunes have been exploited for building purposes. At many public beaches, crowding and uncontrolled vehicle accesses have damaged the dune area.

Many sandy beaches had naturally occurring sand dune complexes prior to coastline development; as such, the initiation of artificial dunes may even restore a degree of natural character to the site. Artificial dunes are engineered structures created to mimic the functioning of natural dunes. Dune rehabilitation refers to the restoration of natural or artificial dunes from a more impaired, to a less impaired or unimpaired state of overall function, in order to gain the greatest coastal protection benefits. This technology is aimed at reducing coastal erosion and can also be used at controlling flooding in adjacent coastal areas.

Vegetation planting may be used to stabilize natural or artificial dunes. This promotes the accumulation of sand from wind-blown sources around their stems – over time, this causes dune growth. Over time, dune vegetation root networks also help to stabilise the dune. Planting can be achieved by transplanting vegetative units from nursery stocks or nearby intact dunes (USACE, 2003). One advantage of vegetation planting over dunes is that it can be undertaken at the community level using widely available tools and thus a major reduction in cost.

Endemic plants have adapted over time and can withstand sand accumulation, flooding, salt spray, sandblast, wind and water erosion, temperature fluctuations, drought and low nutrient levels (Woodhouse 1978). Their growth reduces the wind velocity near the ground where most of the wind-blown sand transport occurs. The plant stems and leaves close to the ground greatly reduce the movement of sand by saltation and surface creep (Woodhouse 1978).

Coastal dune with mixed vegetation

It would be most appropriate to consider the two previously identified technologies, namely dune and vegetation restoration, in conjunction as they are usually intrinsically linked and would provide a more comprehensive approach to the problem of coastal erosion. This is moreover in line with good shore and beach management practice which was one of the technologies outlined in the Baird report of 2003.

3.2.2 Identification of barriers for Dune and vegetation Restoration

The barriers for Dune and vegetation restoration have been worked out by firstly listing the main barriers from personal experience and then decomposed to give the root causes hindering the implementation of this particular technology. This first analysis formed the basis for the barrier analysis for the technology. The barriers were then discussed during a coastal stakeholders meeting in December 2012 at the Ministry of Environment.

3.2.2.1 Economic and financial barriers for Dune and vegetation Restoration

3.2.2.1.1. Lack of appropriate space for implementation

The major barrier in the implementation of the dune restoration technology in Mauritius is the inappropriateness and unavailability of space along the shoreline. The Pas Géométriques around Mauritius comprises of Hotels, the public beaches and also the Campement site.

The Dunes in Mauritius were originally located within the Pas Géométriques area which is as per the Pas Géométriques Act of 1982 to be area from the high water mark to 81.21 m inland. While these areas are in great demand and of high value, they have undergone major transformation to accommodate the hotels and bungalows. As such the dunes have been flattened out and eventually lost its effectiveness at controlling beach erosion and at acting as a sink or storage of sand for the seasonal dynamics of the beach.

Over a few wide public beaches, the dune shape can still be observed e.g. at Belle Mare whereas on other public beaches the dunes have been flattened out due to over use and trampling e.g. Flic en Flac.

Dune at Belle Mare under Filao and grass plantation

The *Pas Géométriques* area is still seeing development whereby old plots are being parceled for construction of new buildings, areas without buildings but with sea frontage are being sought after for hotel and bungalow construction, old buildings being renovated for new modern type.

Considering the above and the development that has been effected along the shoreline and in the Pas Géométriques, it would be a major challenge to restore the dune to the original height because of the constructions and buildings that now exist in these areas. In certain areas though, it is still possible to restore the seaward face of the dunes especially where adequate setback has been left.

3.2.2.1.2. High cost involved in terms of materials required

Dune restoration requires large quantity of sand and availability of such material is very limited in Mauritius given that only inland quarries are allowed to supply these. Moreover there is a high cost associated with dune restoration as the material itself along with the transport of same to the site is costly with a return or around MUR 800 to 1000 per ton (pers. comm. from St Felix sand quarry). Information obtained from the ICZM division of the Ministry of Environment shows that the cost for dune restoration at Rs 2500 per m3 of sand refilled on site. It was further estimated that a stretch of 1 m would cost an average of Rs 75,000 to implement. It should be pointed out that the figure is highly site specific.

The cost involved for vegetation restoration, based on practical experience from the Beach Authority in undertaking such work, along with the appropriate labour and fencing cost, would be Rs 444 for a stretch of 1 m length x 15 m wide. The cost for removing the existing filaos trees should also be added.
Another barrier for this technology is the limited amount of sand that can be acquired from the land quarries. Another source of sand might be from off-reef sandy patches but these would require a dredger and assorted equipment for proper pumping of sand to shore and thus may have a higher cost. It should be noted that around Mauritius, sand mining is not permitted within the lagoons and that since October 2001.

3.2.2.2 Non-financial barriers for Dune and vegetation Restoration

3.2.2.2.1. Inadequate legislative / regulatory framework

The dunes in Mauritius do not have per say a legislative or regulatory framework for it specific protection. The setback requirement of having no hard construction within 30 m from high water mark is more of a measure to control erosion than the actual protection of the dunes. When a leasee or owner of sea frontage area obtains his development and Building and Land Use Permit, with or without an EIA license depending upon the nature of the undertaking, there is the condition that the no hard construction is to be undertaken within a distance of 30 m from the high water mark. However the said development can include beach reprofiling, including flattening of dunes or other works as long as there are no hard constructions within this distance. Beach reprofiling for the upgrading of the beach is an undertaking requiring an EIA license.

In 2009, the study of Environmentally Sensitive Areas around Mauritius and Rodrigues (ESA Study 2009), had identified the beach and sand dunes system as an ESA and more so they have categorized the various types of beach and sand dunes.

The ESA Study (2009) has proposed a Bill for the protection of all ESA including dune and beach system but the bill has still not been enacted. The delay in the promulgation of such bill is mainly due to the long process of enacting a legislation and also probably due to lack of political will.

3.2.2.2.2. Lack of information to concerned stakeholders

Given the limited area that is available as public beaches and for dune restoration it is difficult to convince the public and the officials of the need and usefulness of dune restoration as this measure may appear to hinder access to the beaches.

Conflicts of interest may also arise, especially if dune construction takes place in an area primarily used for residential or tourism purposes, where local landowners or lease owners may be concerned about maintaining sea views.

The local population is usually familiar with static defenses which do not react to the local conditions. The drastically different way in which dunes react to storm events may cause communities to object to their use, especially in communities where coastal stabilization has been the long-term goal.

3.2.2.2.3 Lack of awareness for benefits of Dune vegetation

The local population has been accustomed with the Casuarina sp. trees, which can be found on most public beaches, and the local population tends to see these trees as appropriate for these areas as they provide good shade and thus are usually most appropriate for recreational purposes. Removal of these trees to be restored with native species may find public opposition as they are not familiar with the specifics of both.

In Mauritius the native vegetation would comprise among others creepers and shrubs. These when placed anywhere along the shoreline will take up space which is already very limited. The public is more inclined at having an appropriate space for recreational use rather than having plants all around. The benefit of these native vegetation remains largely unknown to the public. Unfortunately, native plants are more often perceived as being house to various little animals, insects and reptiles and thus their limited popularity.

The propagation of the native plant will require the setting up of an implementation programme as the availability of plants is limited and thus the setting up of nursery would be important for such purpose and thereafter the transplanting to the appropriate areas.

3.2.3 Identified measures for Dune and vegetation Restoration

The measures identified for dune and vegetation restoration have been worked out from personal experience starting from the identified barriers and thereafter putting forward measures that would directly address the problem.

3.2.3.1 Economic and financial measures for Dune and vegetation Restoration

3.2.3.1.1. Participatory and Cost Sharing

One measure that can be put forward in view of implementing dune and vegetation restoration despite the high cost that can be involved especially if sand has to be replenished would be to share such cost between neighbors and also with the government as most of the area along the shore are under lease. This participatory and cost sharing approach would ensure that the technology is being implemented thus providing for some protection to the shoreline from erosion.

This participatory and cost sharing approach has been adapted from the usual practice of the Government to initiate projects under a Built-Operate-Transfer basis whereby a technology or project is implemented with the government as partner in the venture and eventually following an agreed period of operation, the assets are transferred to the government.

Moreover if the technology were left to either the lessee or the lessor individually, the process may not even kick start, but the synergy between the two stakeholder could be a solution for the proper implementation of the technology.

3.2.3.1.2. Provide incentives

The Government should provide incentives that would encourage the lessee of the plot of land adjacent to the shore to undertake such appropriate measure to protect and restore the dunes and vegetation within their plot. Such incentives could be a decrease in their rent upon completion of works or facilities at attractive rates for the implementation of works.
It should be pointed out that both lessee and lessor have the responsibility towards ensuring that the dunes are kept and maintained in a satisfactory status with regards to erosion.

3.2.3.2. Non-financial measures for Dune and vegetation Restoration

3.2.3.2.1. Setting up of the legislative / regulatory framework

The proper legislative or regulatory framework for the implementation of the technology should be promulgated in an Act that is closely related to the coastal zone. Usually the best candidates for amendments would be the Pas Géométriques Act of 1982 and the Environment Protection Act of 2002. These should be amended so that the implementation of the technology becomes feasible and also the dunes become appropriately protected especially from developments.

3.2.3.2.2 Information and awareness

A three tier approach can be envisaged for the proper dissemination of the information regarding the benefits and use of dune and vegetation restoration. The approach would have to touch different level of stakeholders including official and Authorities, the lessee as the direct beneficiary and the public at large.
The information and awareness campaign could further be merged into a larger programme which aims at providing appropriate information with regards to climate change and coastal erosion to the stakeholders and the public at large.

The most pertinent information to be disseminated would be to explain how such measures can help in controlling erosion, any alternatives that can be used and also the benefits of the use of such technology especially in terms of being environment friendly with little negative impacts on the surroundings.

3.3 Barrier analysis and possible enabling measures for Rock Revetments

3.3.1 General description of Rock Revetments

Revetments are hard engineered structures with the primary function to prevent further erosion of the shoreline. They are built usually with stone, concrete or other durable materials and are shaped in a slope facing the sea and they aim at holding or preventing a scarp or embankment against erosion by wave action (UNFCCC, 1999). Revetments are to be differentiated with seawalls which are vertical or near vertical shoreline protection works separating the land and water areas.

Revetments are frequently used in locations where further shore erosion will result in excessive damage, e.g. when roads and buildings are about to fall into the sea.

Newly installed rock revetment in Grand Bay, 2012

Slipway and access to the sea over the rock revetment

A revetment relies on the underlying embankment for support. Revetments can be considered as flexible or rigid. Flexible revetment structures are those made of stone and pebbles that would have some freedom to move under the wave attack and would eventually endure some settlement or other movement without the structure failing. The size of the material would depend on the severity of the wave attack.

Revetments made of armoured concrete slabs are rigid structures. These rigid revetments require a firm embankment to rest upon. Usually settlement or movement of these rigid structures under severe wave attack will result in cracking and possibly structural failure.

The design of revetments should consider and accommodate the scouring effect at the toe and also lowering of the bed. The crest or top of the structure must incorporate wave overtopping protection. In low-lying areas, a wave screen at the top of the revetment may be necessary.

Revetments aim at controlling erosion of the land behind the structure due to direct wave attack. They act by blocking the dynamic removal and return of dune and beach material during and following an extreme event such as cyclone or storm surges.

It should be emphasized that Revetments do not address the root causes of erosion and therefore the erosion processes will persist unabated and any beach that is present will gradually diminish in width and height eventually creating escarpments and severe damages to the beach and dunes. Revetments do not preserve or enhance beaches. In addition beach may be lost is surrounding areas due to wave reflection and refraction from the structure. It should be noted that sloping stone revetments result in less wave reflection than smooth, impermeable, vertical seawalls.

Continued beach erosion with visible escarpment at the end of rock revetment in Grand Bay

Along the toe of the revetment or seawall, scouring which results from wave reflection may increase the natural erosion. Scour along the toe of a structure can undermine the structure, resulting in its collapse. Wave reflection will vary depending on the slope and permeability of the shoreline or protection work. To put it simply, steeper, smoother and less permeable features result in more reflection than flatter, rougher and more permeable features.

3.3.2 Identification of barriers for Rock Revetments

The barriers for rock revetments have been worked out by firstly listing the main barriers from personal experience and then decomposed to give the root causes hindering the implementation of this particular technology. This first analysis formed the basis for the barrier analysis for the technology. The barriers were then discussed during a coastal stakeholders meeting in December 2012 at the Ministry of Environment.

3.3.2.1 Economic and financial barriers for Rock Revetments

3.3.2.1.1. High cost for implementation of rock revetment

One of the main barriers to the implementation of a well-designed rock revetment is cost. The design of an effective rock revetment requires good quality, long-term environmental data such as wave heights and extreme sea levels and requires a combination of engineering and oceanographic expertise and experience.

The construction of a rock revetment would usually require several thousand tons of massive boulders, large excavators and other specialized equipment to put these in place and the cost of these together with the time required for such construction thus becomes very high of the order of Rs 10 M for 100 m of revetments (cost estimates from Beach Authority). It should be pointed out that the cost is variable depending on site and design specifics. Other figures from the Ministry of Environment give the cost at Rs 40,000 per meter.

3.3.2.2 Non-financial barriers for Rock Revetments

3.3.2.2.1 Policy intermittency and uncertainty

Rock revetments have been implemented in Mauritius more frequently during the last 5 years. Examples of rock revetment works can be observed at Trou Aux Biches and Grand Bay while it is planned to have other rock revetment structures in areas like Poudre D'or and Grand River South East.

The use of rock revetments have been mainly following severe erosion of the shoreline and where buildings or infrastructure are being left exposed to damages.
These rock revetments are usually implemented following tender for specific site. The use of this technology is being implemented on an ad-hoc basis without due consideration to it appropriateness and usefulness. In Mauritius, there are no specific plan for the control of erosion and implementation works are usually done when the need arise for certain site and also when funds are available.

The viability and effectiveness of such structure has never been assessed in Mauritius. While the Baird report of 2003 has provided a good insight of the erosion problem in Mauritius and the methods for controlling these, the intricacies of the report seems not to have been pondered upon sufficiently as the use of rock revetment may not be the most appropriate technology to be used.

Rock revetments do not address the source or cause of the erosion and this implies that erosion will persist unabated in those areas and at times the significant impacts on the region could be more damaging following the placement of these structures.

3.3.2.2.2 Limited capacity and experience

The rock revetments are frequently exposed to high wave loadings and their design must be highly robust, requiring good design, significant quantities of raw materials and potentially complicated construction methods. In locations of high energy waves, additional cost must be expended on other protective measures so as to protect the structure's toe.
The design of the rock revetments in Mauritius are left to civil engineers who have civil structural experience and thus the design do not usually include consideration of coastal dynamics, sediment transport and the hydrodynamics. This has for effect that erosion, to various degrees, occurring at the end of the structure is exacerbated because of the mere presence and design of the structure.

In addition it should be considered that the use of this technology might entail additional environmental cost especially in the case of wrong design and implementation of works.
The availability of experience, materials, labour and specialized machinery is usually the barrier to the implementation of this technology.

3.3.2.2.4 Lack of awareness and information to coastal communities

The use of rock revetment may provide an erroneous sense of protection against erosion. It will usually control the erosive forces at specific location whereas adjacent areas remain or can become more vulnerable. Also the use of this technology largely affects the aesthetics of our beaches and may be regarded as an eyesore especially for a country which is betting a large portion of its economy on the tourism industry. Moreover the use of rock revetment may limit the accessibility to the sea.

3.3.3 Identified measures for Rock Revetments

The measures identified for rock revetments have been worked out from personal experience starting from the identified barriers and thereafter putting forward measures that would directly address the problem.

3.3.3.1 Economic and financial measures for Rock Revetments

3.2.3.1.1 Participatory and Cost Sharing

Rock revetments are usually associated with high cost of the order of MUR 10 M for around 100 m (figures from implemented projects and from Beach Authority). Up till now most major works in the implementation of rock revetments have been made by the Government. In view of decreasing the load on the government, it can be contemplated that hotels or other private bodies contribute to the cost of the rock revetment. This contribution should not be in the form of tax but rather as a social contribution for the benefit of the area.
This participatory and cost sharing approach would assist in the implementation of the technology and thus providing for some protection to the shoreline from erosion. Several projects have been undertaken under the Corporate Social Responsibility (CSR) by private institutions and implementation of rock revetments could fit in well under this scheme.
In very rare cases would a hotel come forward with a rock revetment project and that will only be in the event that it is required on its own beach frontage.

3.2.3.1.2. Alternatives to Rock revetments

As mentioned before, revetments can be made from different materials and the use of other materials in lieu of rock to form revetments should be studied as it can have major impacts on the cost of the structure. Geotextile bags with sand could be a possible alternative whereby the cost is reduced to one third of conventional rock revetment (www.geofabricsinternational.com).

3.3.3.2 Non-financial measures for Revetments

3.3.3.2.1 Proper planning

A national plan for the control of erosion would be most appropriate for Mauritius in as much as it would give the various methods which can be most appropriately used upon consideration of the individual characteristics of the eroded site. This national plan would identify the measure or technology to be used for the various locations and it would have the added advantage that works would be done following a schedule plan and thereafter the monitoring of the works shall be undertaken.

3.3.3.2.2 Information and awareness

An information and awareness campaign on the problem of erosion along the shoreline and the various methods that exist to control the erosion would be most appropriate for Mauritius. The benefits and disadvantages of each method should be given. This campaign should be targeted towards the public at large and the authorities and this would ensure early detection of erosion. Whilst several degree of erosion exists if dealt with at its very early stage, the effort and cost incurred in controlling it could be consequential.

The most pertinent information to be disseminated with regards to climate change and coastal erosion to the stakeholders and the public at large, would be to explain how such measures can help in controlling erosion, any alternatives that can be used and also the benefits of the use of such technology especially in terms of being environment friendly with little negative impacts on the surroundings.

3.4 Barrier analysis and possible enabling measures for Wetland Protection

3.4.1 General description of Wetland Protection

Wetlands contribute two major services, namely Biological and Habitat Conservation services and Hydrological services and both of which are of utmost importance to the maintenance of the ecosystem balance in the coastal areas which may have direct or indirect effect on the erosional characteristics of the shoreline.

Wetland in Mauritius, ESA survey of wetland, 2009

3.4.1.1. Biological and Habitat Conservation Services

Wetlands are unique ecosystems where aquatic and terrestrial life forms assemble. Although they exhibit some biologically similarities, lentic (e.g. marshes) and lotic (e.g. rivers) wetland communities are shaped by very different hydrological conditions. Permanent inundation

in the absence of strong currents, high dissolved organic carbon concentrations and thick organic matter accumulation in marsh/swamp wetlands requires specialized plant-forms (hydrophytic species) that can survive both inundation and low-oxygen soils. The gentle transitional zone (ecotone) along the edges of wetlands frequently supports a community composition that is distinctive and not represented elsewhere in the landscape. The transitional zone is where terrestrial and aquatic species overlap, and it is often both rich in species and biologically productive.

In addition to the unique community composition, wetlands also provide crucial habitats for terrestrial species that have an aquatic life-stage or require water for survival, particularly amphibians, water-birds, snails and other invertebrates. Many migratory birds require some form of wetland habitat in order to successfully overwinter.

3.4.1.2. Hydrological Services

In addition to the significant biological values of wetland ecosystems, they also have a wider role in the natural hydrology of the landscape. Lotic wetlands, such as rivers, integrate the surface hydrology across the watershed. River networks drive landform evolution, acting as the fastest transfer route of dissolved and particulate matter from terrestrial to marine environments. Changes to this rate as a consequence of human land use alter the biogeochemical mass balance, with consequent ecological adjustments in both source and sink habitats. Lentic wetlands, such as coastal marshes and swamps, capture surface flows, slowing down water movement and buffering these rate changes. This allows large particulate matter to settle to the wetland bottom, reducing the export of terrigenous sediment and anthropogenic nutrient pollution to the surrounding coastal lagoons. Thus, wetlands function as natural “sediment and pollution traps” that help to buffer changes in lagoon water quality as a consequence of land use change.

Unfortunately, the backfilling of wetlands along the Mauritius coast has significantly decreased the area of wetlands and significantly increased surface water flow to the sea. This has resulted in elevated levels of suspended solids, nutrients from sewage and fertilizers, and contaminants entering coastal lagoons. Declining water quality and algal growth has already been detected in several portions of the lagoon (Baird report 2003). Coral-reef ecosystems are also highly sensitive to eutrophication (such as algal blooms that rob the water of oxygen) from nutrient runoff, sedimentation, and temperature changes, and must be protected from such sources if possible.

Flooding at previous wetland after having been backfilled

In late March 2008, Mauritius was seriously affected by flooding due to heavy rainfall over three consecutive days. The flooding of homes in and around converted wetlands in Grand Baie and Flic en Flac during that period has demonstrated both weak municipal planning and limited public understanding about the risks of residential developments in wetlands. The low-lying topographical position of these properties means they have a high probability of experiencing future flooding. If such developments continue, expensive new infrastructure to reduce flooding will be needed. Even more importantly, such infrastructure will direct damaging, sediment and pollution-laden flood waters directly into the surrounding lagoons, which could rapidly degrade an ecosystem that is vital to the tourism industry and long-term economic health of Mauritius.

3.4.2 Identification of barriers for Wetland Protection

During a workshop held in July 2012 on Barriers Analysis, the wetland protection technology was taken as a case study by the participants, which included representatives from Ministry of Environment, Mauritius Oceanography Institute, Beach Authority, National Parks and conservation Services among others. A list of the barriers in the local context which would be impacting on the implementation of the Wetland Protection technology was worked out. This first analysis formed the basis for the barrier analysis for wetland protection and the analysis was expanded for all the different main barriers.

3.4.2.1 Economic and financial barriers for Wetland Protection

3.4.2.2.1. High Cost

Wetlands usually occur close to the coastal zone and as such are in areas where properties are of very high value, examples are Grand Bay and Flic en Flac. In view of offering the best protection to wetlands, it must be ascertained that the wetland is under some official control and being under private ownership does not afford wetland this protection.

3.4.2.2 Non-financial barriers for Wetland Protection

3.4.2.2.1 Inadequate legislative / regulatory framework

The ESA study (2009) had to consider the then draft Wetland bill which was under preparation in view of conserving and protecting the wetlands of Mauritius. The study eventually produced a comprehensive bill for the protection, conservation and management of all ESAs including the wetlands.

While the cabinet of Ministers was appraised the ESA study in April 2010 and the report validated by the Government, the draft ESA bill has still not been passed through the parliament for eventual enactment. This is seriously hindering the protection and conservation effort as there is an inadequate legislative and regulatory framework for all the environmentally sensitive areas including the wetlands.
Marshlands provide a particular challenge in terms of protection and management due to their location in and around coastal settlements and their perceived negative attributes (odor and insect breeding grounds).

3.4.2.2.2 Inefficient enforcement

Most coastal wetlands are found in the immediate vicinity of highly developed and built up area such as Flic en Flac, Grand Bay, Pereybere and Belle Mare. Their proximity to those high value areas makes them prone to be backfilled in view of a forthcoming development.
A proponent for a future development would usually backfill a wetland as these areas are perceived as wasteland or unimportant areas which is furthermore breeding ground for mosquitoes, with non-aesthetic plants and very commonly associated with foul odour and smell. It has been only recently that the hydrological services have been appreciated by the public and that only after flooding of houses following heavy rainfall.

Enforcement measures are limited with existing legislation and thus the pressures and threats over wetlands are constantly accruing.

3.4.2.2.3 Lack of participation and communication between Institutions

Wetlands in Mauritius fall under the responsibility of the Ministry of Agro Industry and food security through the National Parks and Conservation Services which in addition is the focal point for the Ramsar sites.

In a case of backfilling, it is usually the Ministry of Environment who would be called upon to investigate the matter and they in turn would undertake a site visit with the other stakeholders like the District Council, Police de L'Environement, NPCS and then thereafter enforcement measures would be taken and again usually by the Ministry of Environment through the Police de L'Environement.
The above is a mere example that wetlands in Mauritius are legally framed under various section of the law and different Authorities have jurisdiction over them. The proper management of wetlands is thus challenging under such situation.
Moreover, the enforcement of the present laws is limited when it comes to the protection of the wetland area.

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3.4.2.2.2 Inefficient enforcement

Most coastal wetlands are found in the immediate vicinity of highly developed and built up area such as Flic en Flac, Grand Bay, Pereybere and Belle Mare. Their proximity to those high value areas makes them prone to be backfilled in view of a forthcoming development.

A proponent for a future development would usually backfill a wetland as these areas are perceived as wasteland or unimportant areas which is furthermore breeding ground for mosquitoes, with non-aesthetic plants and very commonly associated with foul odour and smell. It has been only recently that the hydrological services have been appreciated by the public and that only after flooding of houses following heavy rainfall.

Enforcement measures are limited with existing legislation and thus the pressures and threats over wetlands are constantly accruing.

3.4.2.2.3 Lack of participation and communication between Institutions

Wetlands in Mauritius fall under the responsibility of the Ministry of Agro Industry and food security through the National Parks and Conservation Services which in addition is the focal point for the Ramsar sites.

In a case of backfilling, it is usually the Ministry of Environment who would be called upon to investigate the matter and they in turn would undertake a site visit with the other stakeholders like the District Council, Police de L'Environement, NPCS and then thereafter enforcement measures would be taken and again usually by the Ministry of Environment through the Police de L'Environement.

The above is a mere example that wetlands in Mauritius are legally framed under various section of the law and different Authorities have jurisdiction over them. The proper management of wetlands is thus challenging under such situation.

Moreover, the enforcement of the present laws is limited when it comes to the protection of the wetland area.

3.4.2.2.4 Lack of information on wetland ecosystems

Wetlands are wrongly perceived, by the general public, as being wastelands and proliferation ground for mosquitoes and other insects or pests. This misperception is directly related to lack of information on wetlands and their importance in the ecosystem and the services it provides.

This misperception over the wetlands is the main reasons for these to be at risk of being backfilled. Thus it becomes more challenging to protect the wetlands under those circumstances.

3.4.3 Identified measures for Wetland Protection

The measures identified for wetland protection have been worked out from personal experience starting from the identified barriers and thereafter putting forward measures that would directly address the problem.

3.4.3.1 Economic and financial measures for Wetland Protection

3.4.3.1.1. Acquisition of Wetlands

In view of better protecting the wetlands, the government could acquire the plots which are under wetlands or in the 30 m buffer zone. Whilst compulsory acquisition for plots of land is usually a long process, the Government may provide incentives to wetland land owners to either voluntarily give or exchange their plot for other plots which would be more appropriate for development.
The above measure has been spelled out in the ESA Study (2009) Policy Report. This measure would make the wetlands come under an official jurisdiction thereby facilitating its proper protection.

3.4.3.2 Non-financial measures for Wetland Protection

3.4.3.2.1. Proper Legislative / regulatory framework

In view of ensuring the proper protection of wetlands, it would be of utmost importance to have a dedicated law that would fulfill this gap. Up and until such law is passed, the wetlands would only be protected under ancillary laws such as under EPA 2002. The ESA bill as prepared under the ESA Study (2009) would have been most appropriate in ensuring the protection of wetlands and other ESA in Mauritius. Moreover the legislation should also contain appropriate enforcing of the laws with severe penalties.

3.4.3.2.2. Control Development

In view of controlling development especially in wetland rich areas such as Grand Bay, Pereybere and Belle Mare, there would need to have appropriate enforcing measures against the backfilling of wetlands. The Authorities should also be equipped with the appropriate materials for the accurate location of the existing wetlands.

3.4.3.2.3 Information and awareness

An information and awareness campaign on wetlands in general would be most appropriate as the importance of wetlands in the ecosystem and the services it provides remains unknown to the public at large. The ignorance of the above is usually the source for wetlands being backfilled. It is far too common for people to realize their importance following heavy rainfall causing flooding in the surrounding areas.
The most pertinent information to be disseminated would be the services provided by the wetlands, its importance and of course how to ensure that it fulfills these in the best of their capacity. It would also be appropriate to provide information on what would happen in the surrounding areas following backfilling of the wetland.

References

Alston, J.M., J.M. Beddow, and P.G. Pardey. 2009. "Agricultural Research, Productivity, and Food Prices in the Long Run." Science 325(5945):1209.

AIAEE 2003 Challenges in Implementing Integrated Pest Management (IPM) Practices:Implications for Agricultural Extension, Proceedings of the 19th Annual Conference Raleigh, North Carolina, USA, 475

Baird, W. F. and Associates, 2003. Study on Coastal Erosion in Mauritius, Ministry of Environment and NDU.

Fisheries and Marine Resources Act 1998

French, P.W. (2001) Coastal defences: Processes, Problems and Solutions. London: Routledge.Government Information Centre. (2012). Rain Water Harvesting Scheme Launched. Available: http://www.gov.mu/portal/site/Mainhomepage/menuitem.a42b24128104d9845dabddd154508a0c/?content_id=1674ac2f97a26310VgnVCM1000000a04a8c0RCRD. Last accessed 2 December 2012.

Lybbert, T. And Sumner, D. (2010). Agricultural Technologies for Climate Change Mitigation and Adaptation in Developing Countries: Policy Options for Innovation and Technology Diffusion, Geneva, Switzerland: ICTSD, Washington, DC: IPC. Available at: http://ictsd.org/downloads/2010/06/agricultural-technologies-for-climate-change-mitigation-and-adaptation-in-developing-countries_web.pdf

Inter-governmental Panel on Climate Change (IPCC). 2001. Working Group II: Impacts, Adaptations and Vulnerability. Chapter 17. Small Island States. IPCC, UNEP & WMO.

Kiss, A. & Meerman, F. (1991). Integrated Pest Management and African, Agriculture.Washington D.C.: The World Bank.

Knausenberger, W.I., Schaefers, G.A., Cochrane, J.,& Gebrekidan, B.(2001). Africa IPM. Link: An Initiative to Facilitate IPM Information Networking in Africa. Retrieved December 14, 2000, from http://www.ag.vt.edu/ail/Proceedings/usaid.htm

Kumar, M. D.; Hugh Turral; Bharat Sharma; Upali Amarasinghe and O. P. Singh (2008) Water Saving and YieldEnhancing Micro Irrigation Technologies in India: When and where can they become best bet technologies?,paper for 7th IWMI-Tata Annual Partners' Meet, ICRISAT Campus, Hyderabad, 2-4 April, 2008.

Kumar, M. Dinesh (2005), Impact of Electricity Prices and Volumetric Water Allocation on Groundwater Demand Management: Analysis from Western India, Energy Policy, 33 (1).

Mauritius Research Council. (2001). Thematic Working Group on Water. Available: http://www.mrc.org.mu/Documents/Thematic/WaterReport.pdf. Last accessed 2 December 2012.

Michaelides, G., M. Allybokus, and R.J. Young 1986. Optimised Design and Water Quality Studies of Roof

Top Rainwater Catchment Project in Mauritius. Water Supply, 4:117-122.

Ministry of Environment & NDU. 2008. ESA Study Inception Report. Prepared by NWFS Consultancy and STEM Consulting Ltd. February, 2008. 52 pp.

Ministry of Environment & Sustainable Development . (2008). National Programme on Sustainable Consumption and Production in Mauritius. Available: http://www.gov.mu/portal/goc/menv/files/SCP/scp%20final%20report%2022.08.08/Development%20of%20a%20National%20Programme%20on%20SCP%2029.08.08.doc. Last accessed 2 December 2012.

Morse, S., McNamara, N., Acholo, M., Okwoli, B. (2000). Visions of Sustainability:Stakeholders, Change and Indicators. Aldershot, England: Ashgate PublishingLimited.

Uhm, K. (2002). Integrated Pest Management. Retrieved March 15, 2002, from http://www.agnet.org/libray/abstract/eb470.html

Toness, A.S. (2001). The Potential of Participatory Rural Appraisal (PRA) Approaches and Methods for Agricultural Extension and Development in the 21st Century. Journal of International Agricultural and Extension Education, 8(1), 25-37.

Narayanamoorthy, A. (2008), Economics of Drip Irrigation in Cotton: Synthesis of Four Case Studies, paper for7th IWMI-Tata Annual Partners' Meet, ICRISAT Campus, Hyderabad. 2-4 April, 2008.

Ngigi. N. Stephen, 2009 , Climate change adaptation strategies: water resources management options for smallholders farming systems in Sub-Saharan Africa, the MGD centre, Earth Institute at Columbia University , Rockfeller Foundation, 2009.
Pas Géométriques Act of 1982

Sauer, J. (1962). Effects of Recent Tropical Cyclones on the Coastal Vegetation of Mauritius. Journal of Ecology. Volume 50.

Technical Report on Freshwater Wetland, ESA Study, Prepared for the Ministry of Environment and NDU, Government of Mauritius, Prepared by NWFS Consultancy and STEM Consulting Ltd. June 2009)

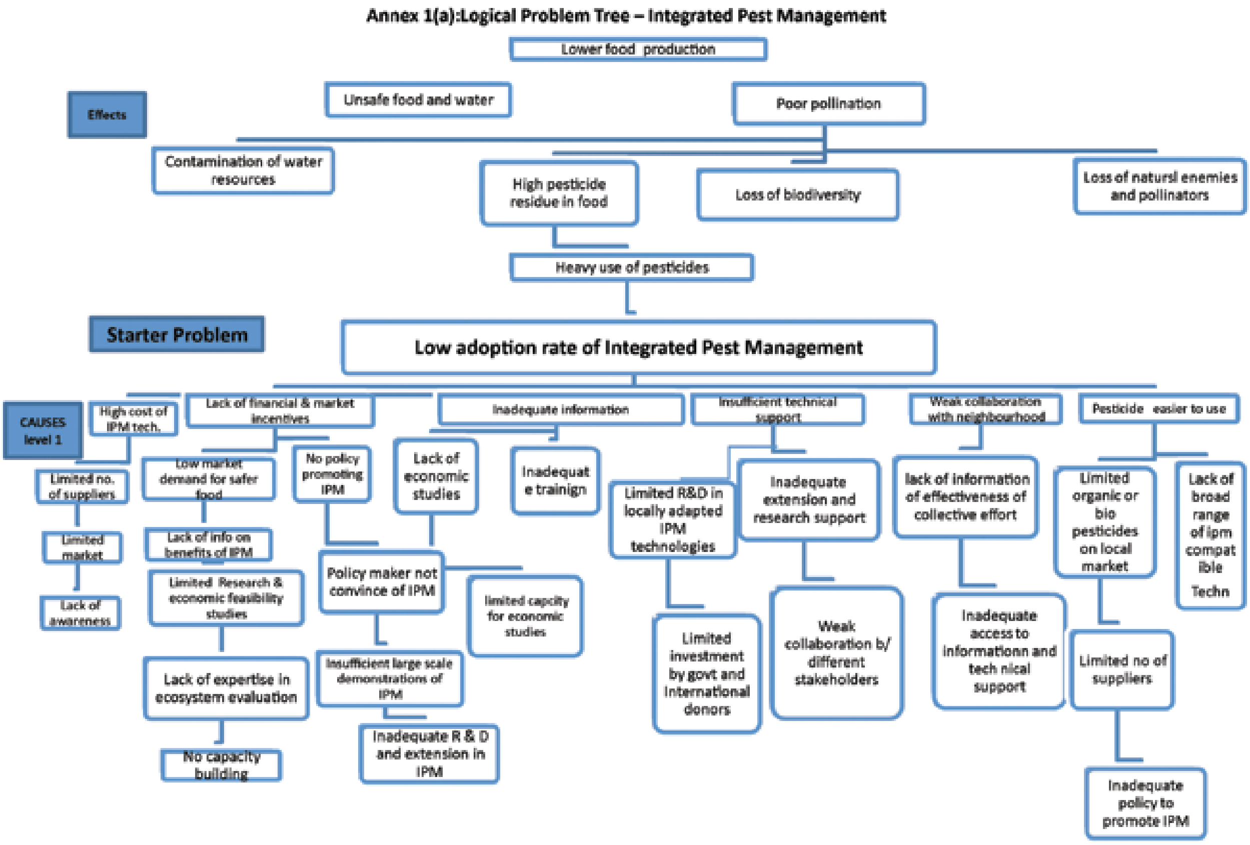
USACE (United States Army Corps of Engineers) (2003) Coastal Engineering Manual – Part V. Washington DC: USACE. Available from: http://140.194.76.129/publications/eng-manuals/em1110-2-1100/PartI/PartI.htm.

UNFCCC (United Nations Framework Convention on Climate Change) (1999) Coastal Adaptation Technologies. Bonn: UNFCCC. Available from: http://unfccc.int/resource/docs/tp/tp0199.pdf.

Woodhouse, W.W., 1978. Dune Building and Stabilization with Vegetation. U.S. Army Corp of Engineers. Vol.3: 9-104.

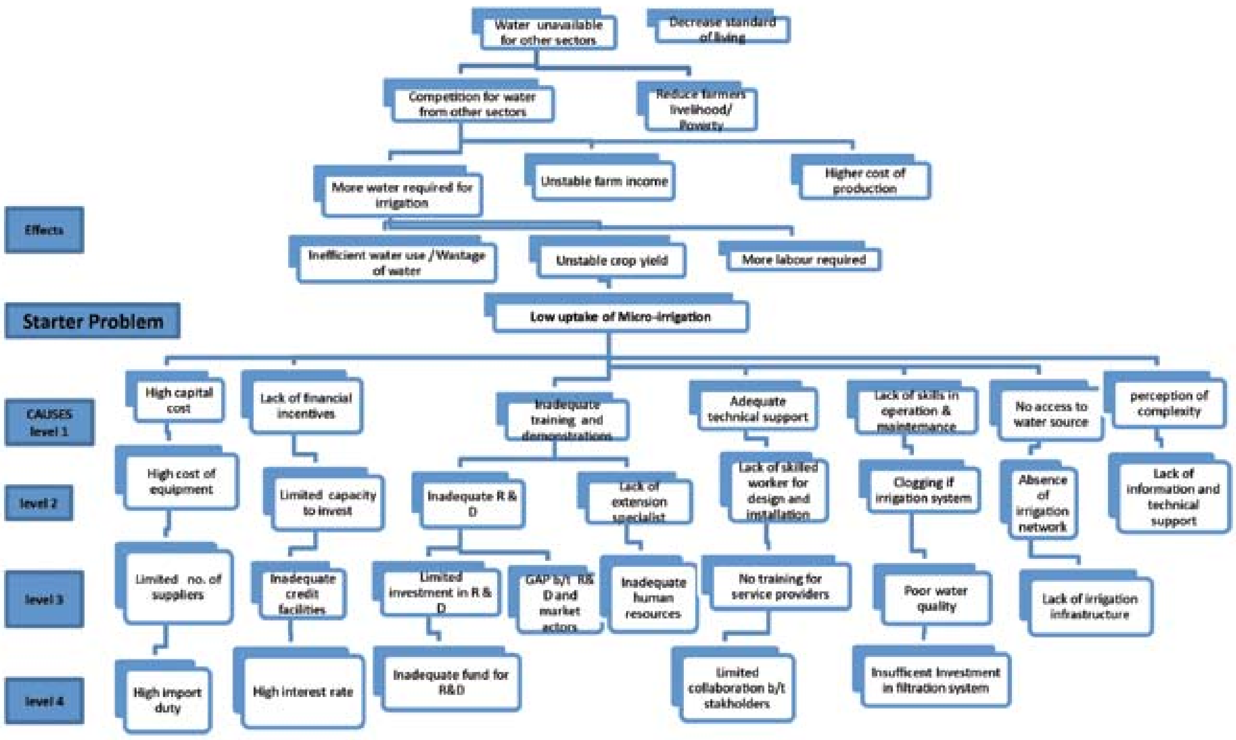
Wetland Bill (Draft) 2008

Annex 1 - Market Maps and Problem Trees – Agriculture



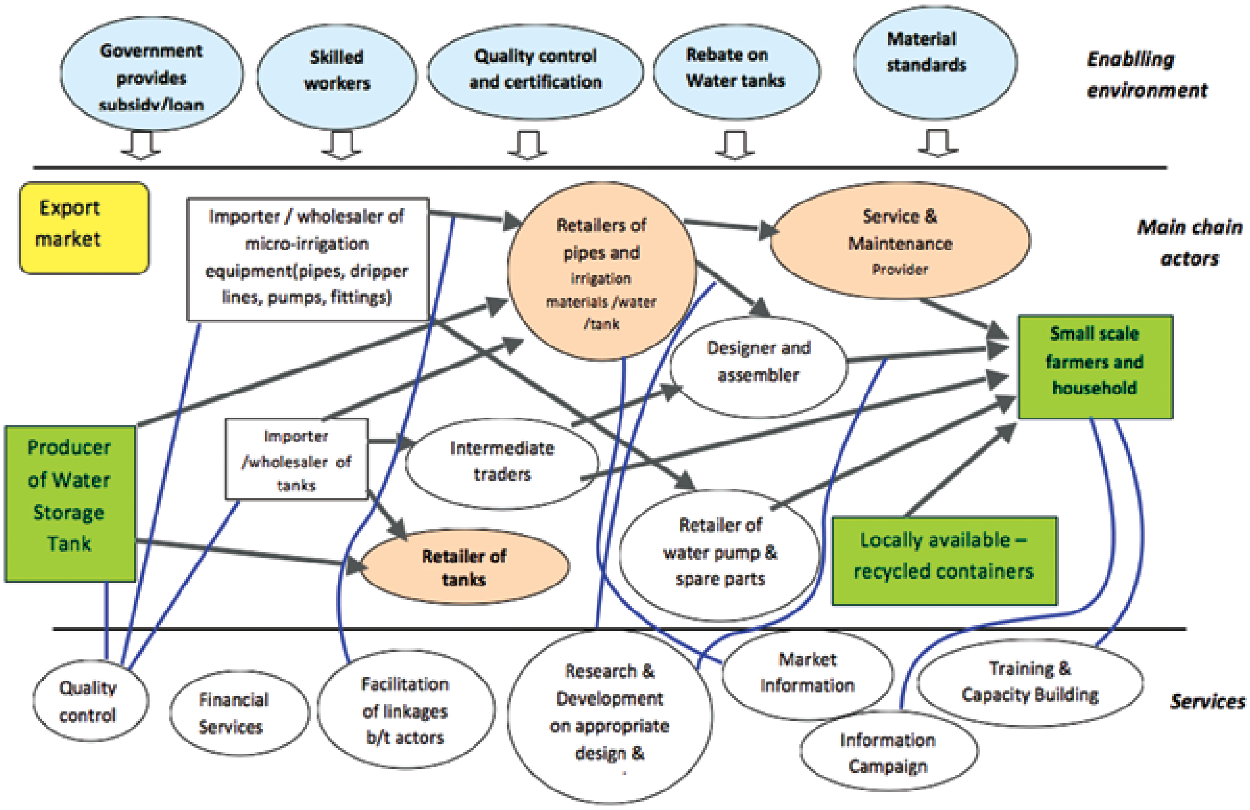
Annex 1 - Market Maps and Problem Trees – Agriculture

Annex 1 (b): Logical Problem Tree – Micro-irrigation

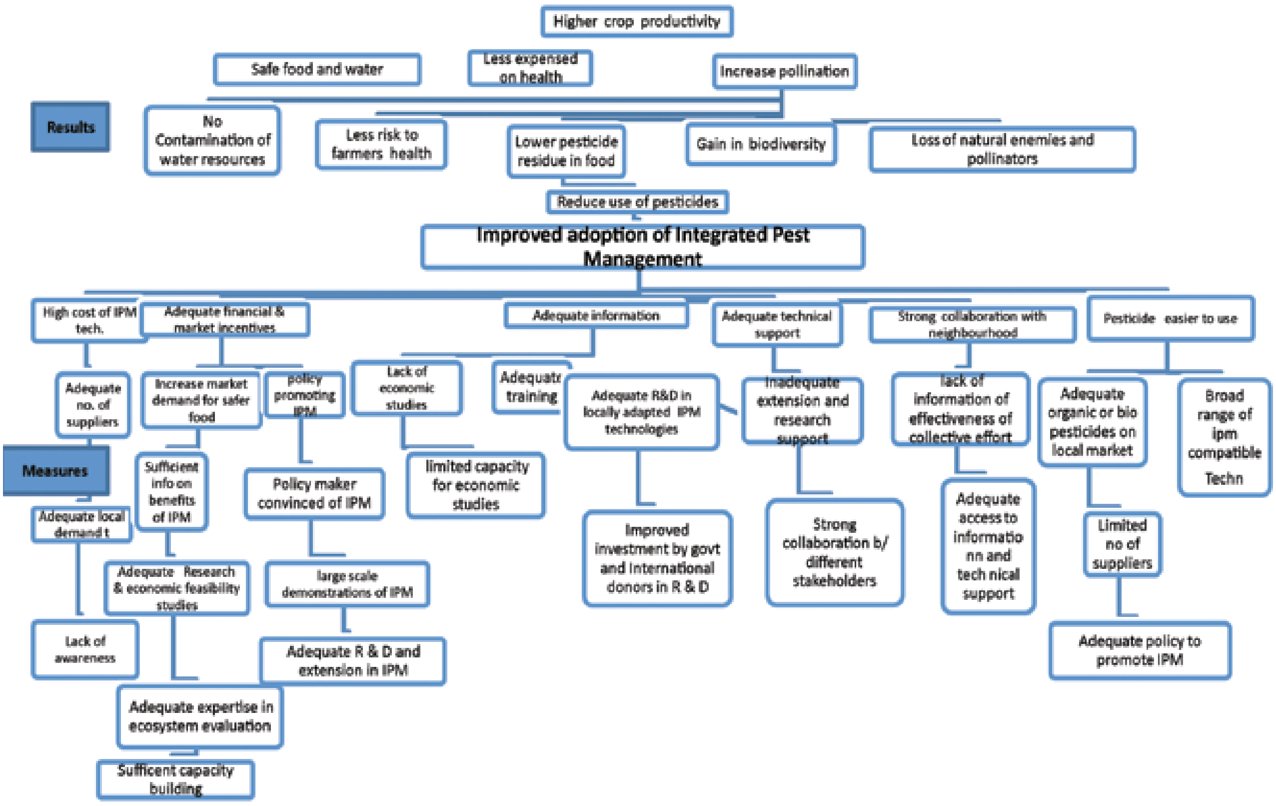


Annex 1 - Market Maps and Problem Trees – Agriculture

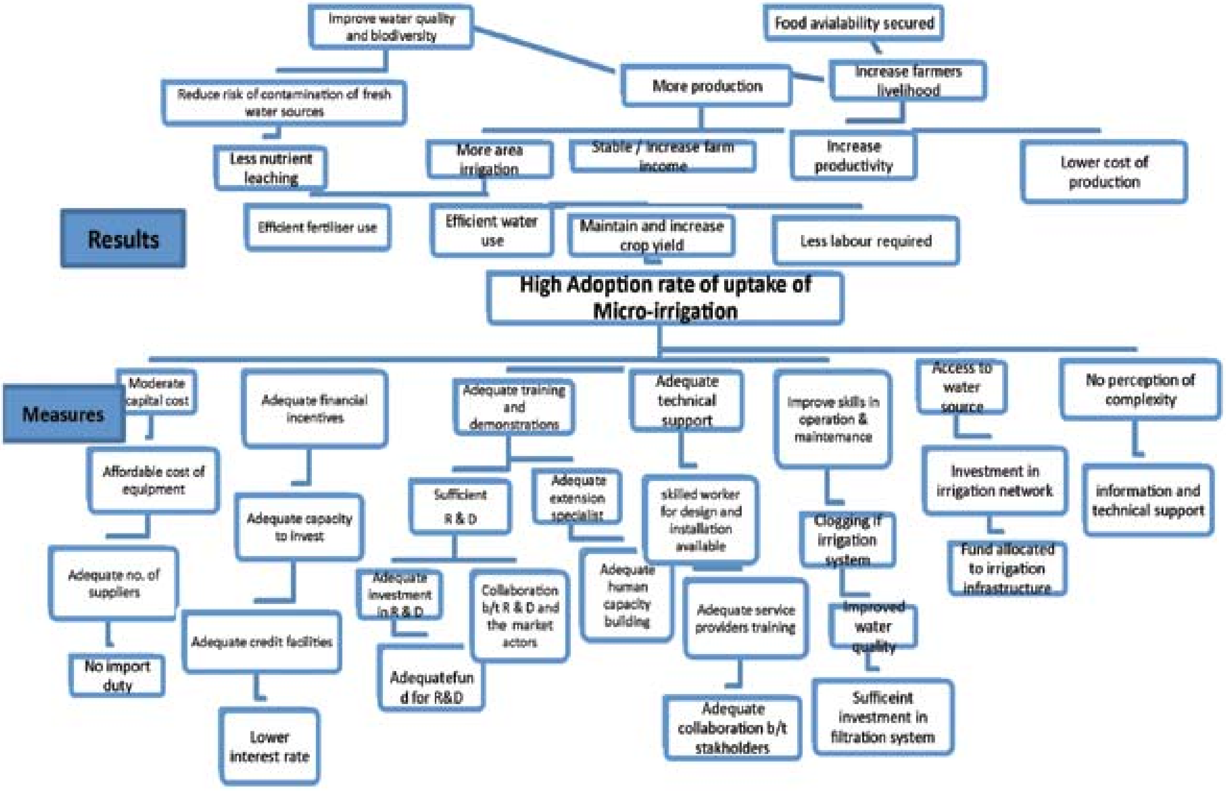
Annex 1c) –Market mapping for micro-irrigation technology



Annex 1d) Objective Tree – Integrated Pest Management



Annex 1e) Objective Tree- Micro-irrigation



Annex 2 – List of Stakeholders Involved and their Contacts - Agriculture

List of stakeholders involved in identification of barriers and development of enabling framework Sector - Agriculture				
Name(s) of contact person	**Organisation**	**Approach of consultation**	**Date**	**Topic**
Mr Gannesh	Farmers Service Cooperation	Bilateral meeting	26.08.12	Microirrigation
Mr S. Mulloo	Irrigation Authority	Bilateral meeting	August 2012	Microirrigation
Mr A. Goolaub	Agricultural Research and Extension Unit (AREU)	Informal Interview	September 2012	Microirrigation & IPM
Mr S. Benimadhu	Pathology Division< AREU	Informal Interview	12.10.12	IPM and I
Mr Dunhawor and Mrs L. Unmole	Entomology Division, AREU	Meeting / discussion	12.10.12	ntegrated Pest Management
Mr K. Permalloo and Mr Sookar	Agricultural Services	Meeting / discussion	12.09.12	Integrated Pest Management
Mr S. Seeruttun	Agricultural Services	Bilateral Meeting	04.09.12	Microirrigation & IPM
Mrs R. Brizmohun Gopaul	Faculty of Agriculture ,University of Mauritius	Bilateral Meeting	22.09.12	Microirrigation & IPM
Mr Koonjal	Mauritius Sugar Research Institute	Bilateral Meeting	27.10.12	Microirrigation
Mr S. Pandoo	Agricultural Research and Extension Unit	Bilateral Meeting	20.09.22	Microirrigation
Mr Ram Vencatasamy	Agricultural Research and Extension Unit	Bilateral Meeting	20.10..12	Microirrigation

Annex 3 – Policy Factsheets - Agriculture

Key:	
Minimum requirements	
Recommended/ good to have	
POLICY: Name of Policy	Blueprint for a 'Sustainable Diversified Agri-Food Strategy for Mauritius'(2008 – 2015)
Name of field:	**Agriculture**
Date Effective:	July 2008- 2015
Date Announced:	2008y
Date Promulgated:	Approved by cabinet (not an act of parliament)
Date Ended:	2015
Unit:	**CC|RE|EE :** CC
Country:	Republic of Mauritius
Year:	2008
Policy Status:	In force
Agency:	Ministry of Agro Industry and Food Security (MAIFS)
Funding:	Programme are funded through capital budget of MAIFS, Food Security Fund and international funding (IFAD)
Further Information:	http://www.gov.mu/portal/site/moa/menuitem.c9c2cca091f5d3b8adbea610a0208a0c/
Enforcement:	Agricultural Research and Extension Unit, Mauritius Sugar Industry Research Institute, Small Planters Welfare Funds, Small Enterprise and Handicraft Development Authority, Agricultural Services/ MAIFS
Penalty:	Not applicable
Related Policies: 2016)	Strategic Options in Crop and Livestock Sector (2007- 2015) and Multi- Annual Adaptation Strategy for Sugar Sector (2006-2015)
Policy Superseded by:	N/A
Policy Supersedes:	Non sugar Sector Strategic plan (2003- 2007)
Stated Objective:	Improve domestic food security in a competitive and sustainable manner , review marketing and distribution , Encourage regional coperation of Food Production

Evaluation:	Updating of action plan is ongoing
Policy Type:	Agriculture / Food security
Policy Target:	Crop and livestock growers
URL:	www.gov.mu/portal/goc/agroind/ www.areu.mu www.msiri.mu
Legal References:	Finance and Audit (Food Security Fund) Regulations 2008
Description:	In June 2008, in response to the global rising food prices and shortages, the Government of Mauritius adopted this Blueprint for a 'Sustainable Diversified Agri-Food Strategy for Mauritius'(2008 – 2015) in view of fostering local food production to mitigated the dependency on imported commodities. The policy also aimed to (i)Mobilize land and aquatic resources, inputs for production, human resources, technology and financial resources in order to optimize food and livestock production locally for domestic consumption; (ii)Promote the exportation of food surpluses so as to capture the maximum gains from economies of scale; (iii) Partner with countries of the region, such as Madagascar and Mozambique and such other countries where opportunities arise to produce food crops, livestock and marine products for domestic consumption as well as for regional markets; (iv) Promote both public and private joint ventures with the support of regional blocks, including India and China; (v) Undertake a sensitization campaign to promote healthy eating. To support the above measures, Government provided Rs 1 billion for a Food Security Fund and decided to set up a Food Security Fund Committee (FSFC) to administer and manage the fund, as per the Finance and Audit (Food Security Fund) Regulations 2008

Annex 4 Cost-Benefit Analysis – Agriculture

(a) Cost benefit analysis for **INTEGRATED PEST MANAGEMENT**			
COST= investment in R&D + demonstration cost+ training cost + additonal cost of IPM implementation + cost of public awareness			
BENEFITS= Benefit from increase in crop yield and quality + saving of pesticide + saving of labour for spraying			
Assumptions	**Unit**		
Total area under food crop (ha)	ha	7000	
Total No. of small planters	Number	8500	
Targeted area under IPM	ha	1200	approx 20 %
Area under IPM per year	ha/yr	50	over 6 years
Cost of investment R&D	(Rs/yr)	2000000	
Cost of technical support to IPM	(Rs/25ha/yr)	520000	
cost of demonstration	Rs/yr/ region(4)	60,000	
Training cost	Rs/ha	500	
Cost of public awareness	Rs/yr	200000	
Additional investment cost	Rs /ha	30,000	
Time frame of project	years	10	
Production of food crop	t/ha/yr	30	

COST

Year	area under IPM	cost on investment in R&D	Invest Technical support to IPM	Cost of training of farmers	Demonstra -tion cost	Cost of public awareness	Additional cost of IPM technology	Total cost
1	200	2000000	4160000	100000	240000	200000	6000000	12700000
2	400	2000000	8320000	200000	240000	200000	12000000	22960000
3	600	2000000	12480000	300000	240000	200000	18000000	33220000
4	800	2000000	16640000	400000	240000	200000	24000000	43480000
5	1000	2000000	20800000	500000	240000	200000	30000000	53740000
6	1200	2000000	24960000	600000	240000	200000	36000000	64000000
7	1200	2000000	24960000	600000	240000	200000	36000000	64000000
8	1200	2000000	24960000	600000	240000	200000	36000000	64000000
9	1200	2000000	24960000	600000	240000	200000	36000000	64000000
10	1200	2000000	24960000	600000	240000	200000	36000000	64000000
								486100000

Assumptions

	year	1	2	3	4	5	6	≥7
Crop yield increase	t/ha /yr	-2	0	1.5	2	3	4	5
Market price	Rs/t	20,000	20,000	21000	21000	22000	22000	23000
Extra Revenue with increase in yield and quality	Rs/ha	-40000	0	31500	42000	66000	88000	115000
Saving of pesticide	Rs/ha /yr	6000	8000	10000	15000	20000	30000	40000
Saving in pesticides increase gradually over years								

Saving of labour for spraying	mandays/ha /year		52
Cost per mandays	Rs/ mandays		325
Saving on labour	Rs/ha /yr		16900

BENEFITS

Year	area under IPM (ha)	Increase in revenue from increased in yield and quality	Benefit from pesticide savings	Benefit from labour saving	Total benefit	Net Benefit	Discounting factor	NPV
1	200	-8000000	1200000	3380000	-3420000	-16120000	1.00000	-16120000
2	400	-8000000	3200000	6760000	1960000	-21000000	0.90744	-19056261
3	600	-1700000	6000000	10140000	14440000	-18780000	0.82345	-15464376
4	800	6700000	12000000	13520000	32220000	-11260000	0.74723	-8413828
5	1000	19900000	20000000	16900000	56800000	3060000	0.67807	2074889.9
6	1200	29142200	36000000	20280000	85422200	21422200	0.61531	13181235
7	1200	57900000	36000000	20280000	114180000	50180000	0.55836	28018255
8	1200	68500000	48000000	20280000	136780000	72780000	0.50667	36875752
9	1200	91500000	54000000	20280000	165780000	101780000	0.45978	46796103
10	1200	1.08E+08	54000000	20280000	182480000	118480000	0.41722	49432286
					786642200			

Benefit / cost ratio	1.6183

Other benefits

1. Environmental benefits such as increase in natural enemies, pollinators and soil microorganisms
2. Health benefits through safer produce (less pesticide residue) and less exposure of workers to pesticides
3. Increase market access due to safer production methods

(b) Cost benefit analysis – for MICROIRRIGATION TECHOLOGY (MI)

COST=cost of subsidy+ cost of capacity building +cost of investment + cost on interest on capital + cost of maintenance

BENEFITS= revenue increase with yield increase + saving on water + saving on labour

Assumptions	**Measures** - 40% subsidy on investment cost and low interest rate on capital
Area under food crop (ha)	7000
Present area under MI (ha)	167
Additional area under MI by 2017	250
Present area under MI (ha)	167
Additional area under MI by 2017	250
Targeted area under MI /year (ha)	50
One farmer owns (Ha)	0.5
Cost of technology (Rs/ha)	300000
Assuming 40 % subsidy /ha	120000
Capacity building /beneficiary (Rs/yr)	500
Maintenance cost (5%of investment cost)/yr	9000
Life expectancy of micro irrigation 10 years	
Interest rate 8%of investment cost	0.08
Payback period years	10

COST

Year	New area under MI(ha)/yr	New area under MI(ha)	cost on subsidy	Cost of CB	Investment	Cost of interest	cost of maintenance	TOTAL COST
1	50	50	6000000	50000	9000000	720000	0	15770000
2	50	100	6000000	50000	9000000	1440000	450000	16940000
3	50	150	6000000	50000	9000000	2160000	900000	18110000
4	50	200	6000000	50000	9000000	2880000	1350000	19280000
5	50	250	6000000	50000	9000000	3600000	1800000	20450000
6			0	0	0	5076000	2250000	7326000
7			0	0	0	5076000	2250000	7326000
8			0	0	0	5076000	2250000	7326000
9			0	0	0	5076000	2250000	7326000
10			0	0	0	5076000	2250000	7326000
								127180000

	Baseline						Assumption 10 % decrease in yield due to decreasing trend in rainfall			
	2012						2022			
Crop /cycle /yr	Crop yield without MI. (t/ha)	Crop Yield with MI (t/ha)	increase in yield (t/ha) with MI	% increase in yield with MI	Price Rs/t	Benefit from increase yield (Rs/t)	Est. yield (t/ha)	Est. yield increase with MI (t/ha)	Est. yield increase (t/ha)	Est. Additi. revenue from yield increase (Rs/ha)
Tomato	20	25.2	5.2	0.26	20000	104000	18	22.68	4.68	93600
Bean	6	7.6	1.6	0.27	30000	48000	5.4	6.84	1.44	43200
potato	25	29.8	4.8	0.19	26000	124800	22.5	26.82	4.32	112320
Total (per year)						276800				249120

Assumptions - saving of 2 mandays /ha/week		Micro irrigation save 35% water	
Cost of labour (mandays)	300		Estimated Cost of water or irrigation Rs/ha /yr 15000
			Saving on water

BENEFITS

Yr	New area under MI (ha)	Additional benefit from yield increase with adaptation (Rs/ha)	Benefit from yield increase	Benefit from water savings	benefit from labour saving	Total benefit	Net Benefit	Discounting factor	Net Present value
1	50	276800	13840000	262500	1560000	15662500	-107500	1.00000	-107500
2	100	273724	27372444	525000	3120000	31017444	14077444	0.90744	12774450
3	150	270649	40597333	787500	4680000	46064833	27954833	0.82345	23019385
4	200	267573	53514667	1050000	6240000	60804667	41524667	0.74723	31028542
5	250	264498	66124444	1312500	7800000	75236944	54786944	0.67807	37149306
6	250	264498	66124444	1312500	7800000	75236944	67910944	0.61531	41786096
7	250	258347	64586667	1312500	7800000	73699167	66373167	0.55836	37059791
8	250	255271	63817778	1312500	7800000	72930278	65604278	0.50667	33239999
9	250	252196	63048889	1312500	7800000	72161389	64835389	0.45978	29809821
10	250	249120	62280000	1312500	7800000	71392500	64066500	0.41722	26729858
						594206666.7			
							Benefit /cost ratio		4.67217

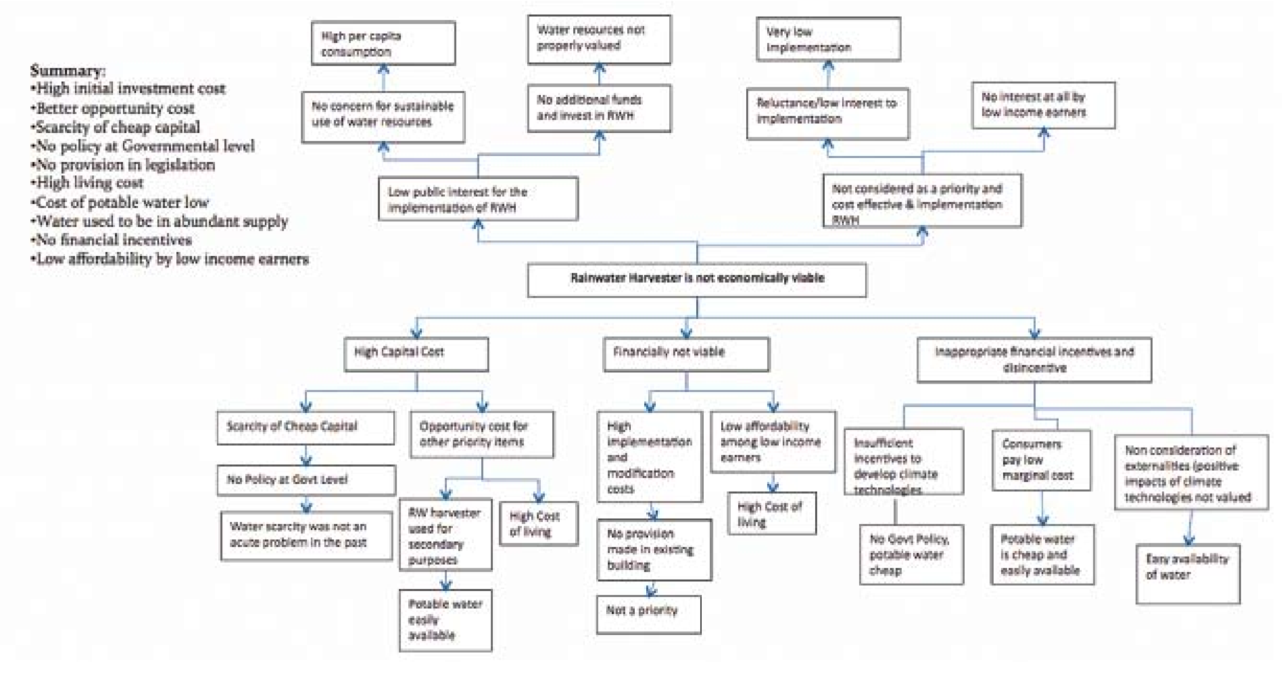
Other benefits

1. Opportunity to use water save to irrigate additional cropland
2. Creation of jobs (for irrigation design , installation and maintenance)
3. This technology will improve yield , food security and farmers livelihood
4. Efficient use of water will reduce nutrient leaching and risk of water contamination

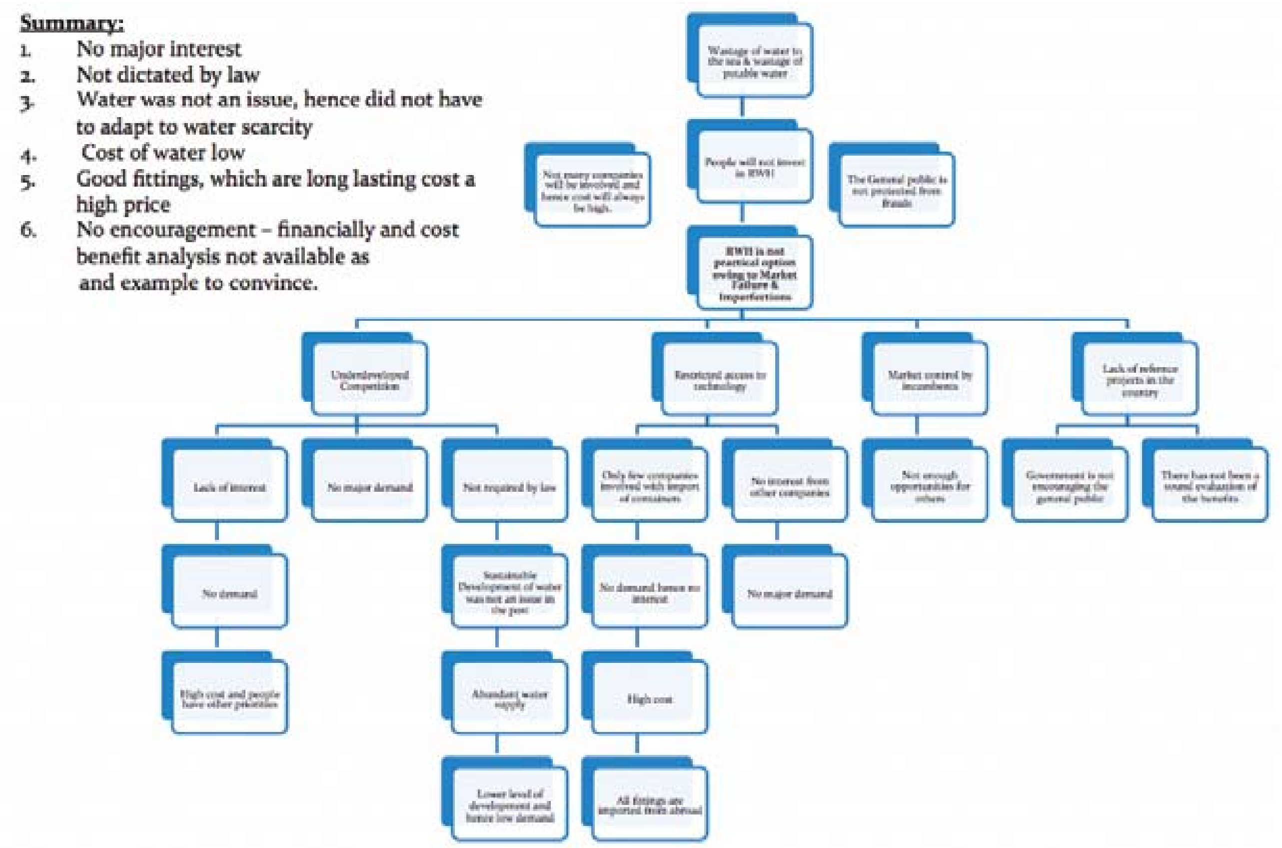
Annex 5 – Market Maps and LPA - Rainwater Water Harvesting

Problem Tree

Economic & Financial



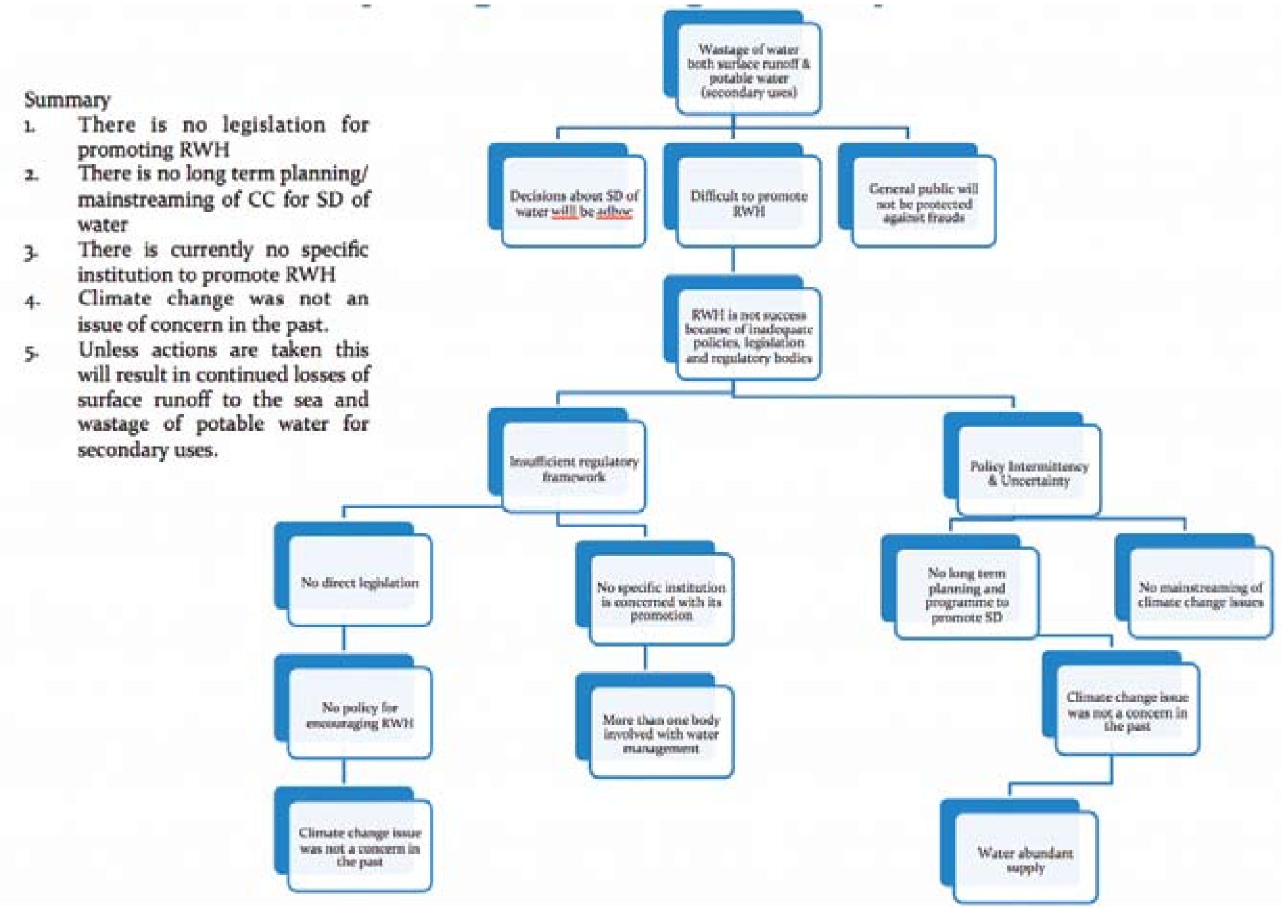
Market Failure & Imperfections



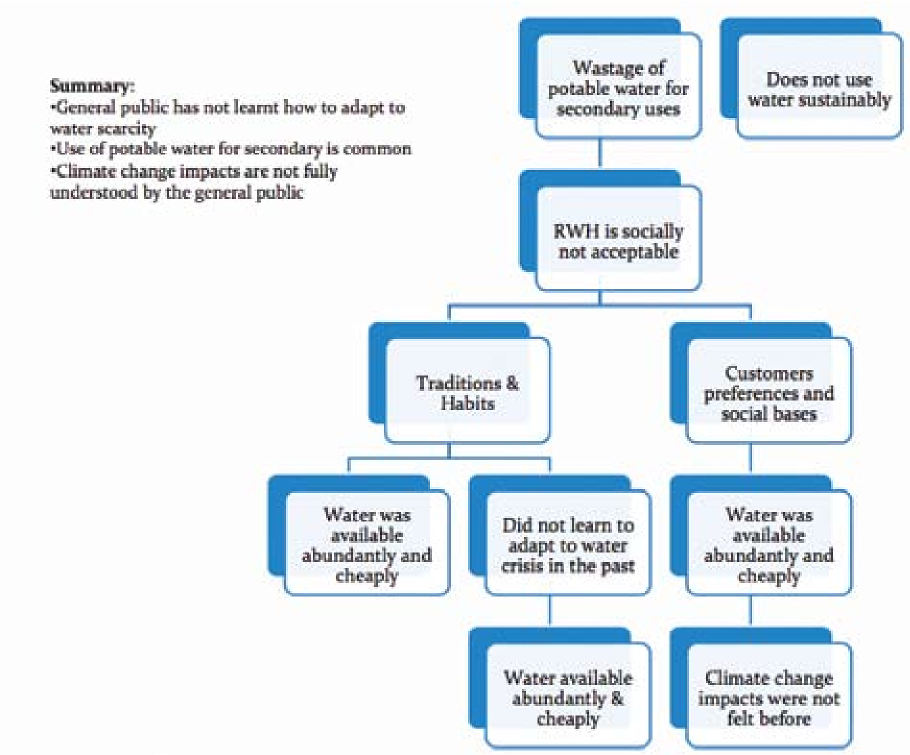
Annex 5 – Market Maps and LPA - Rainwater Water Harvesting

Problem Tree

Policy, Legal & Regulatory



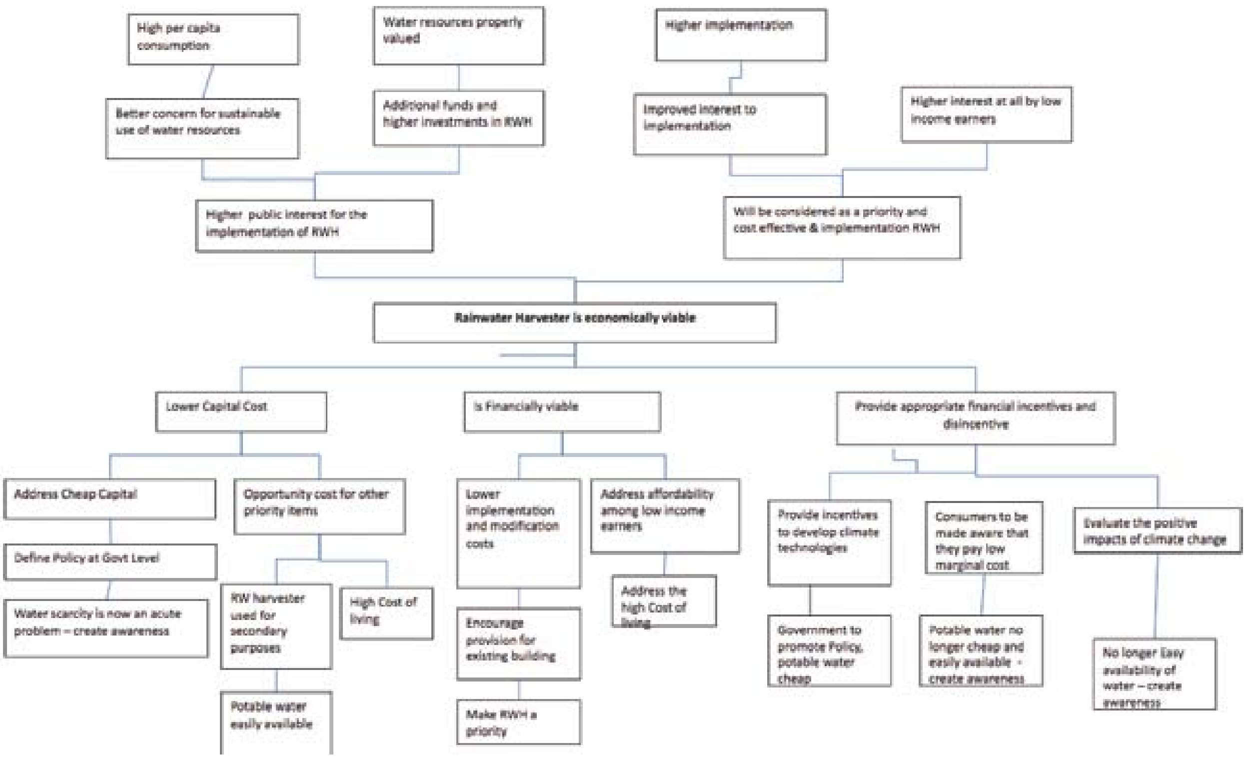
Social , Cultral & Behavioral



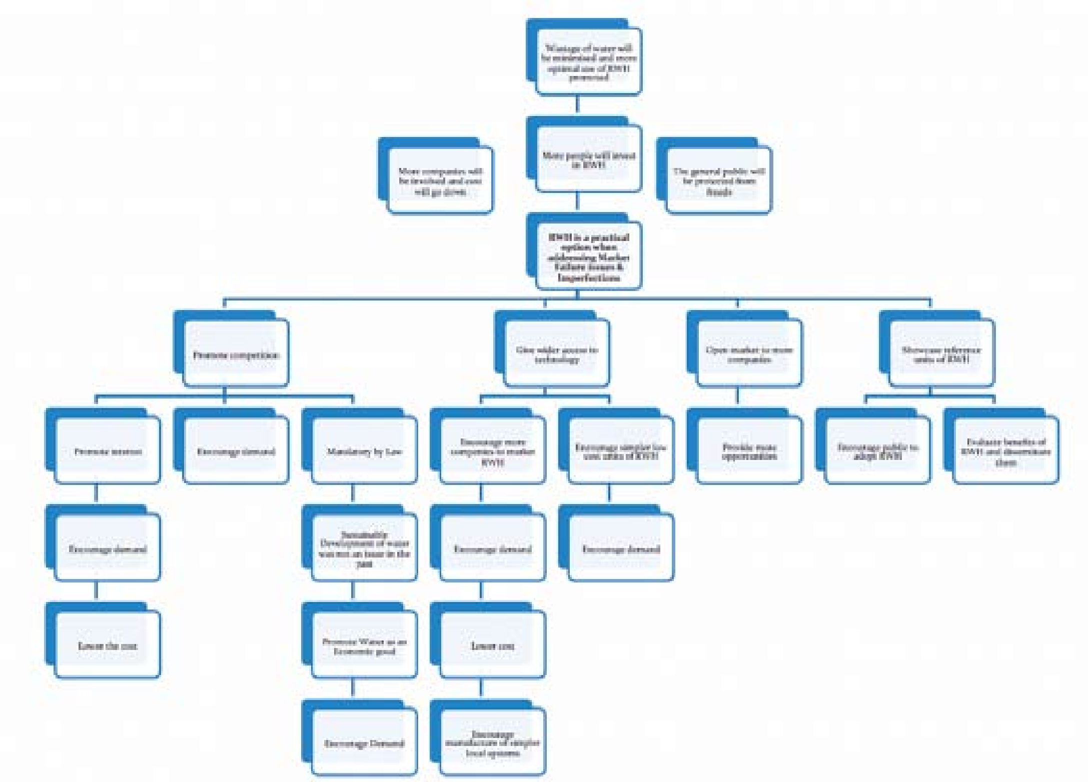
Annex 5 – Market Maps and LPA - Rainwater Water Harvesting

Objective Tree

Economic & Financial



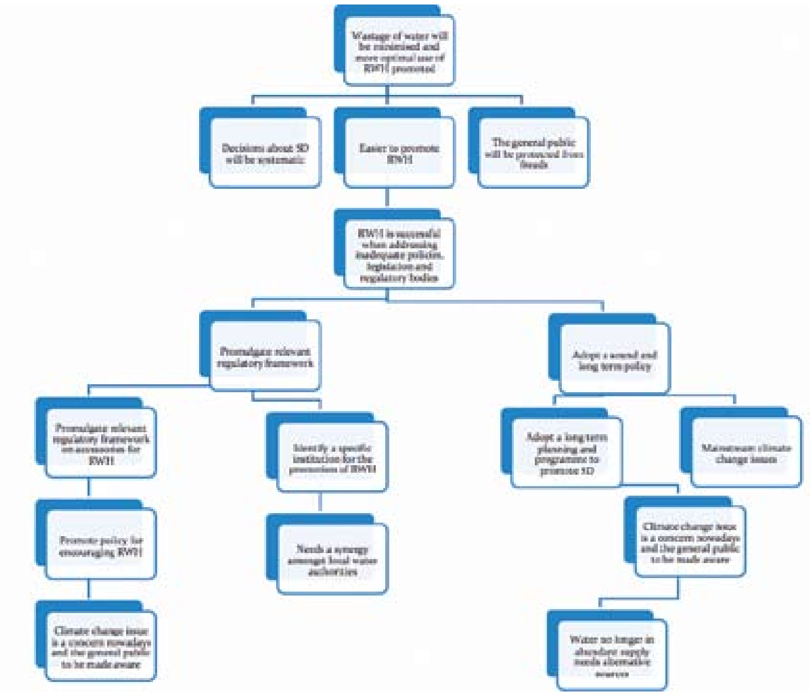
Market Failure & Imperfections



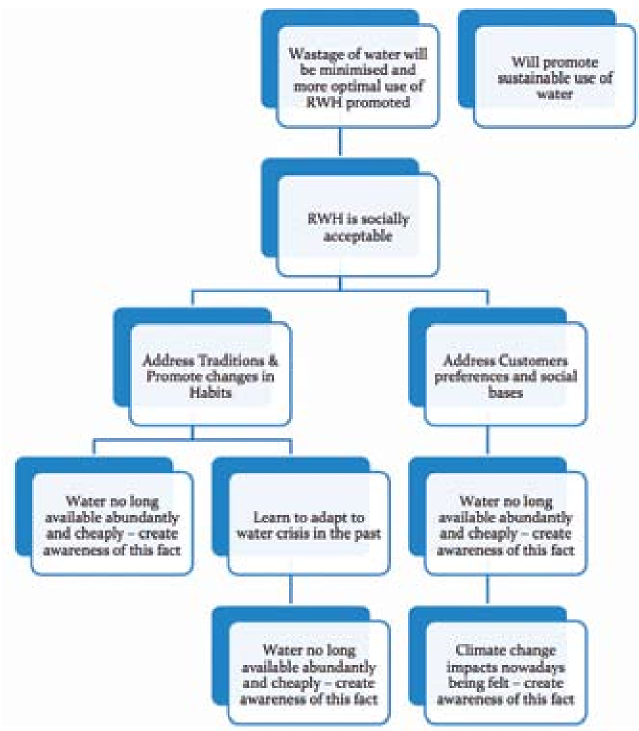
Annex 5 – Market Maps and LPA - Rainwater Water Harvesting

Objective Tree

Policy, Legal & Regulatory

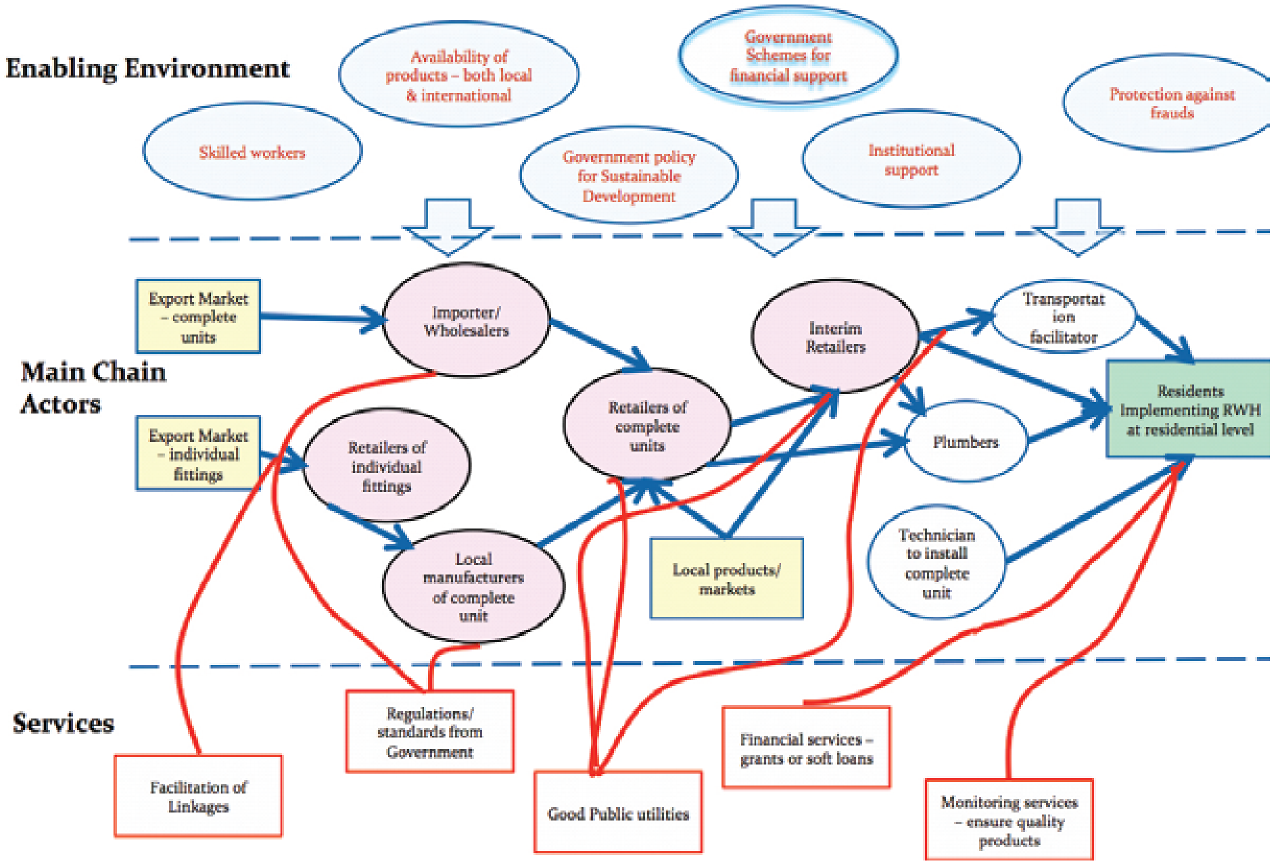


Social , Cultral & Behavioral



Annex 5 – Market Maps and LPA - Rainwater Water Harvesting

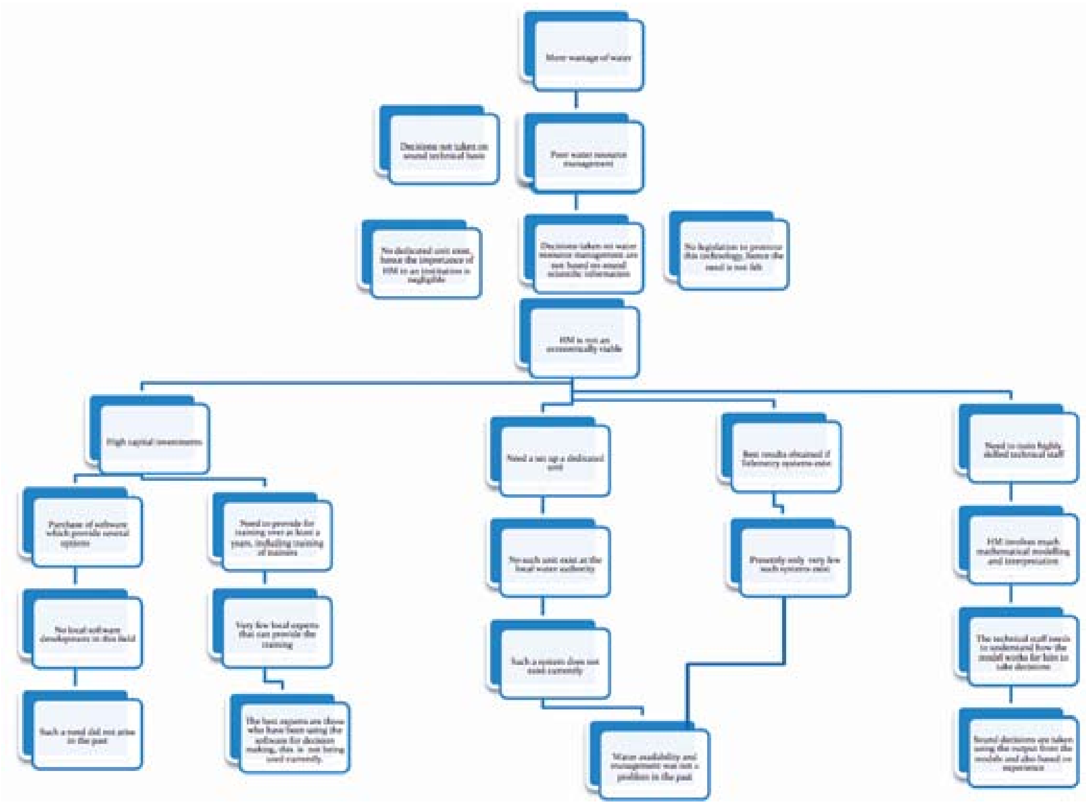
Market Mapping



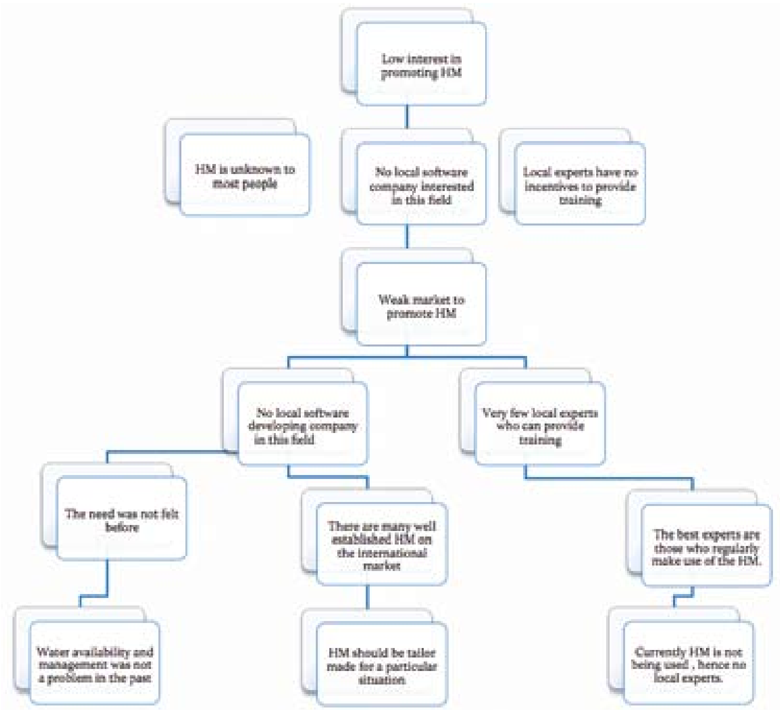
Annex 6 – Market Maps and LPA - Hydrological Model

Problem Tree

Economic & Financial



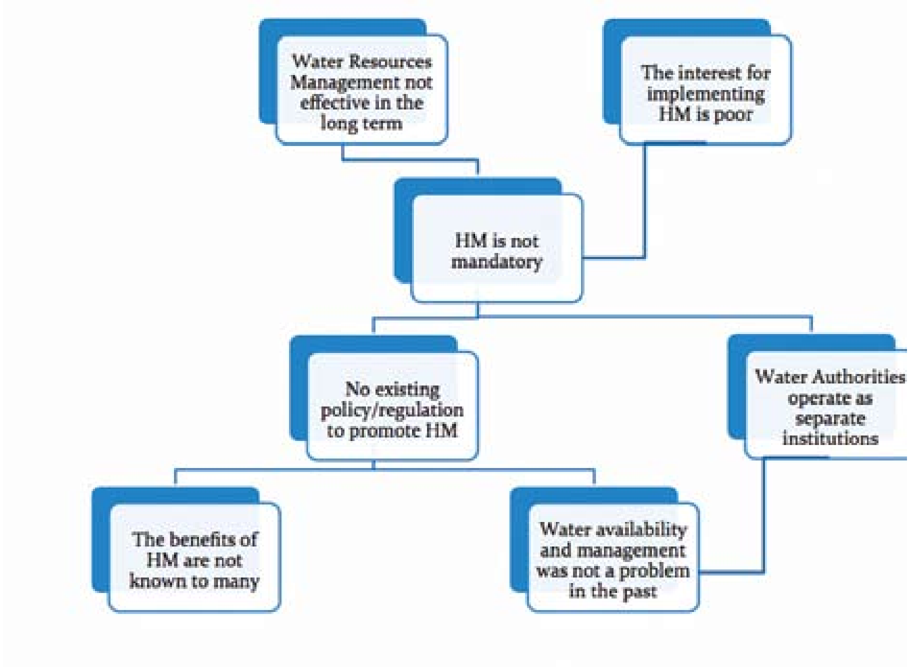
Market Failure & Imperfections



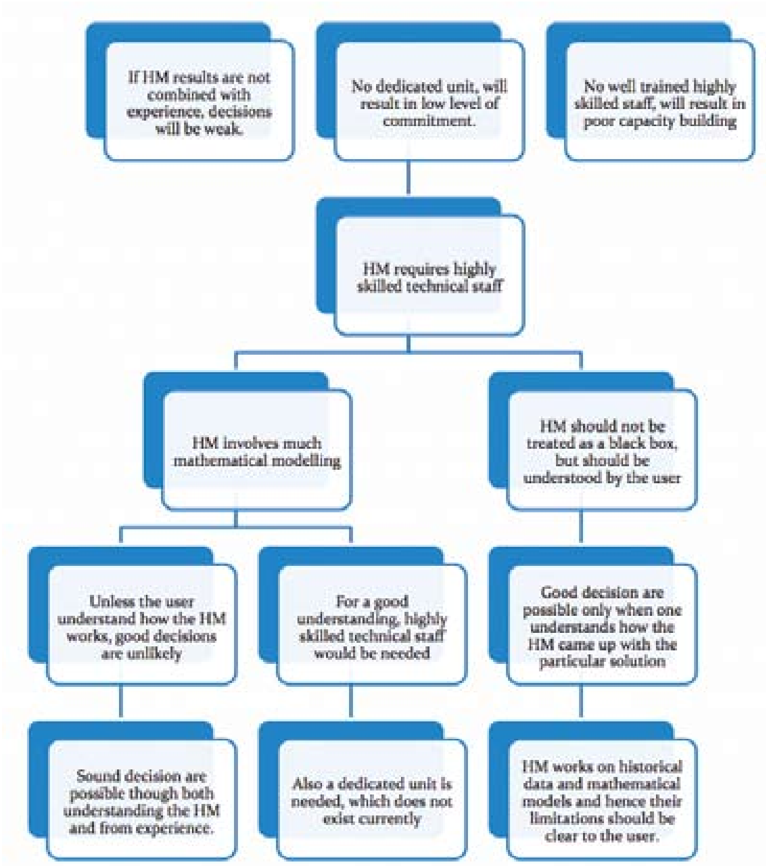
Annex 6 – Market Maps and LPA - Hydrological Model

Problem Tree

Policy, Legal & Regulatory



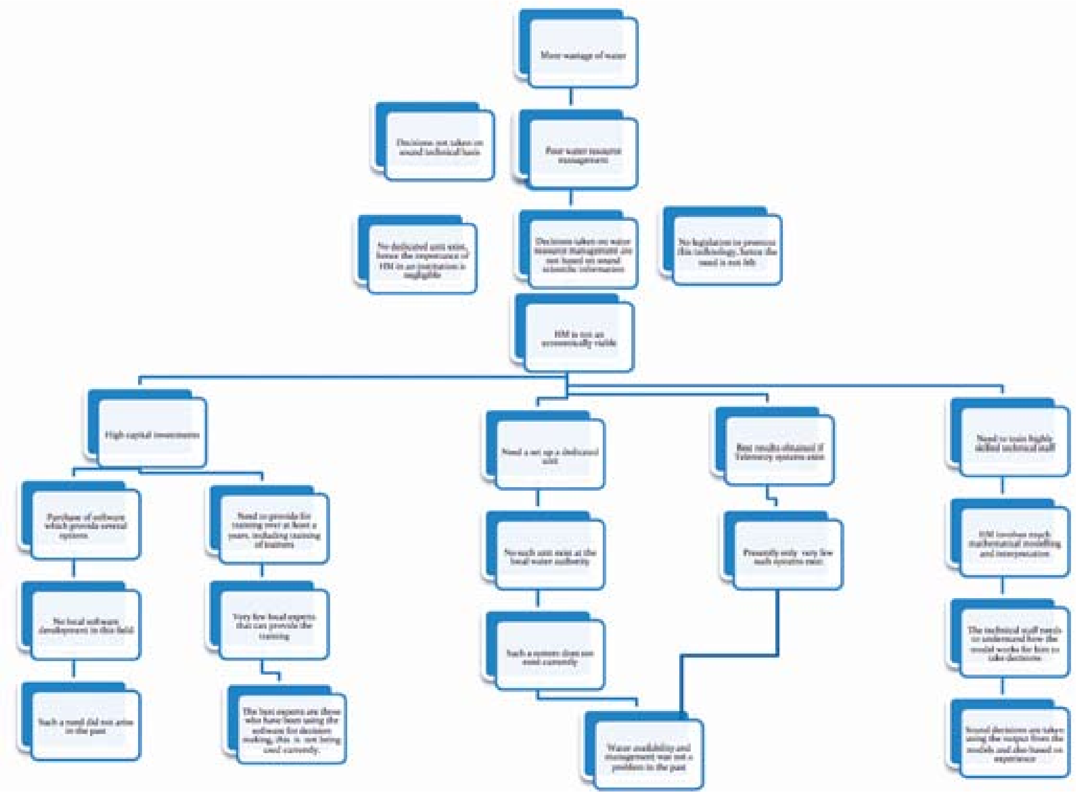
Human Skills



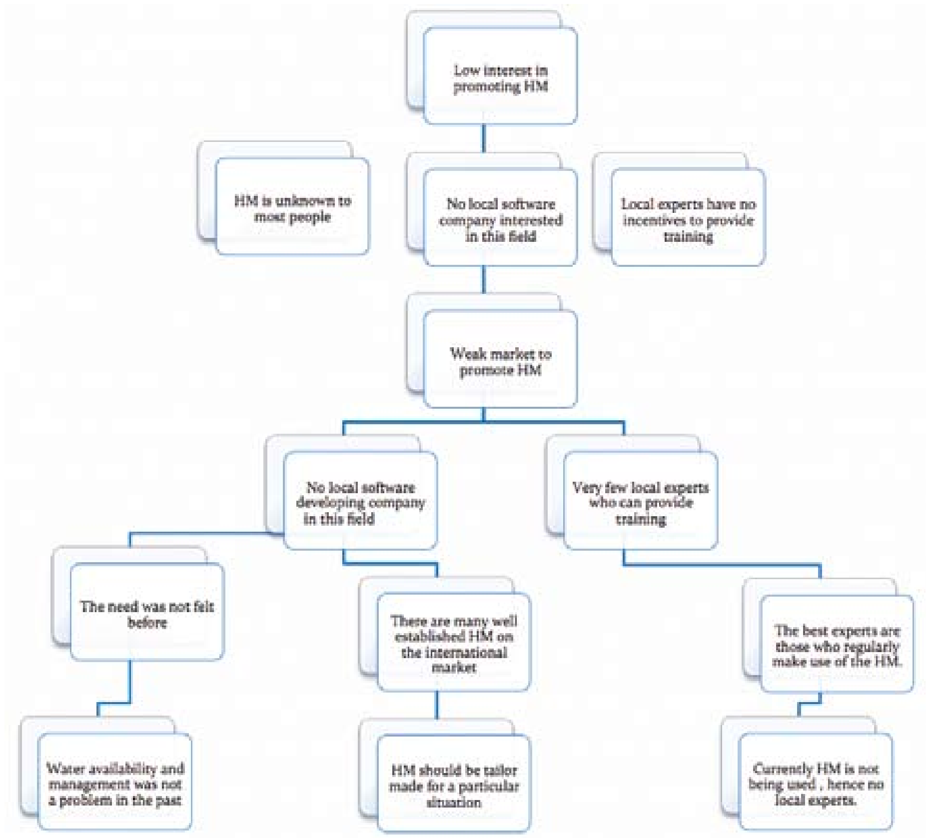
Annex 6 – Market Maps and LPA - Hydrological Model

Objective Tree

Economic & Financial



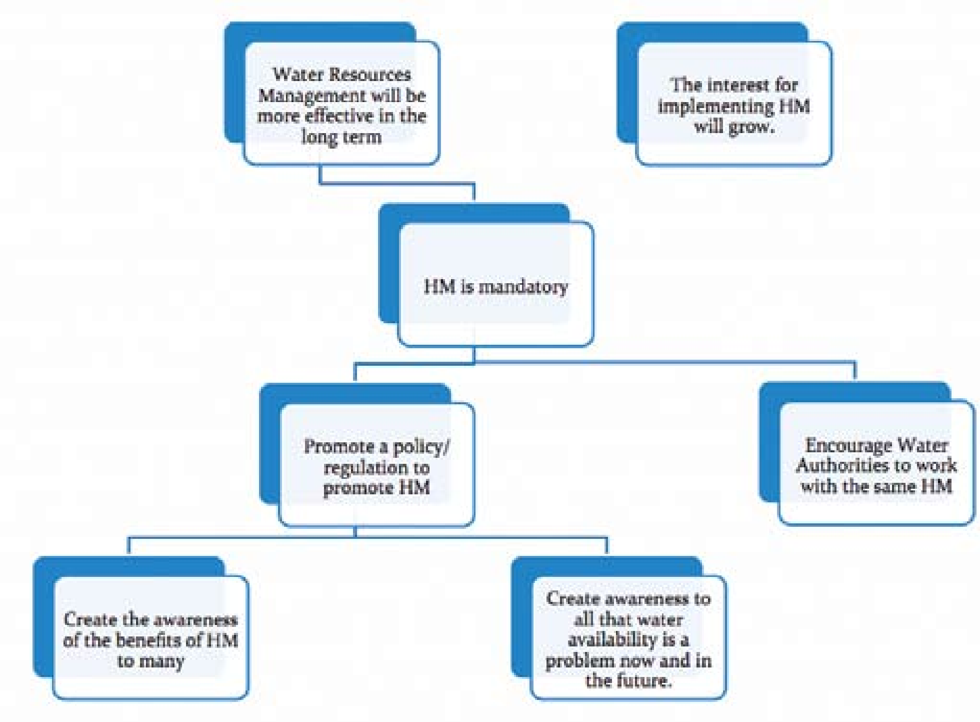
Market Failure & Imperfections



Annex 6 – Market Maps and LPA - Hydrological Model

Objective Tree

Policy, Legal & Regulatory



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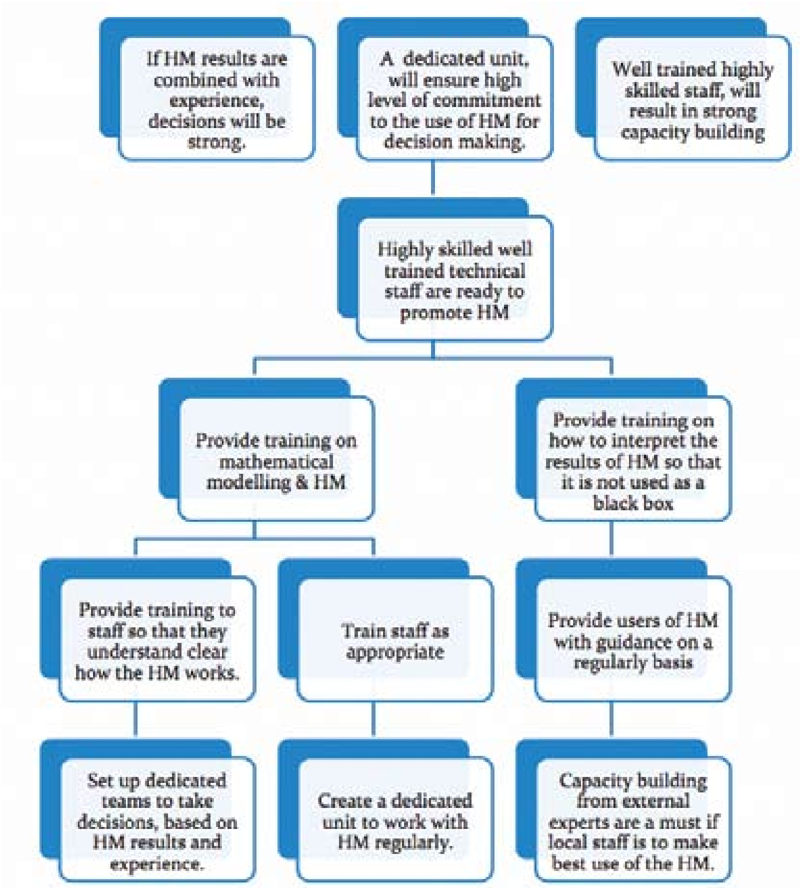
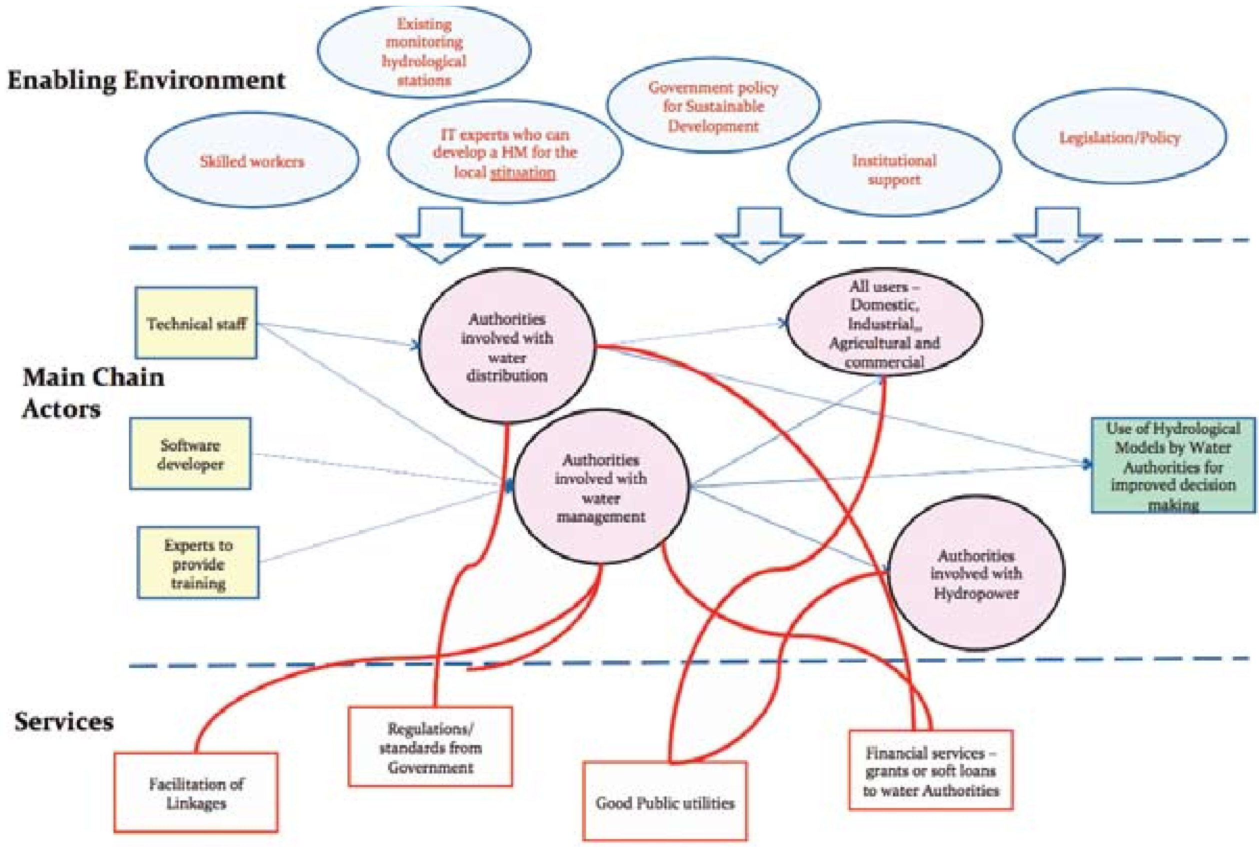


Annex 6 – Market Maps and LPA - Hydrological Model

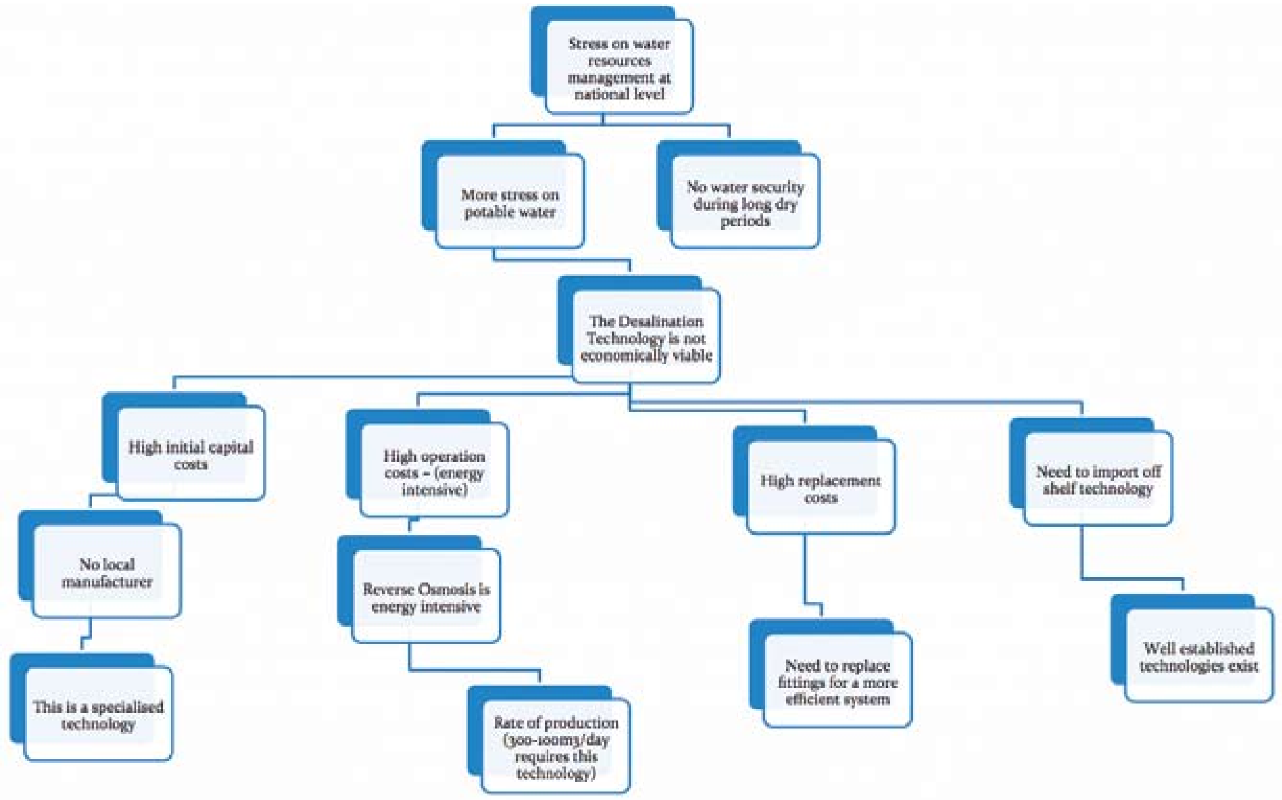
Market Mapping



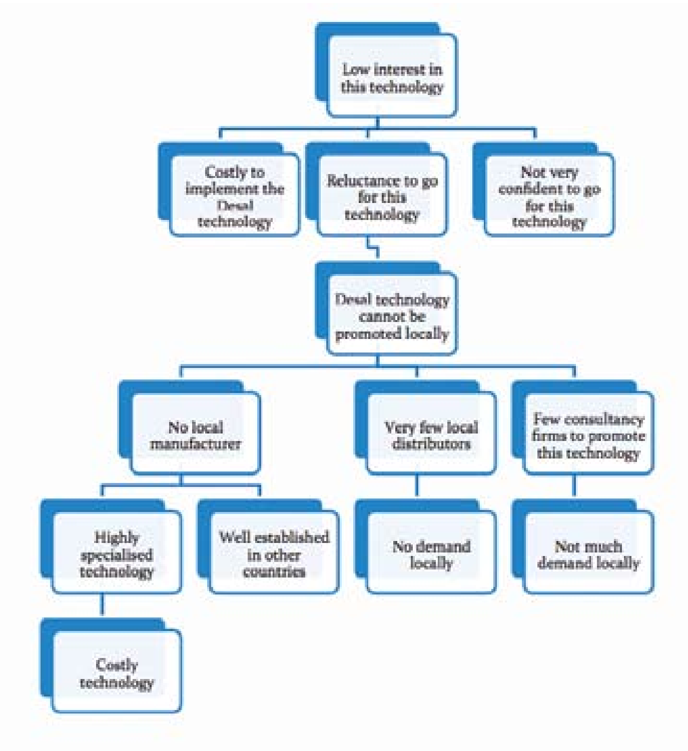
Annex 7 – Market Maps and LPA - Desalination Technology

Problem Tree

Economic & Financial



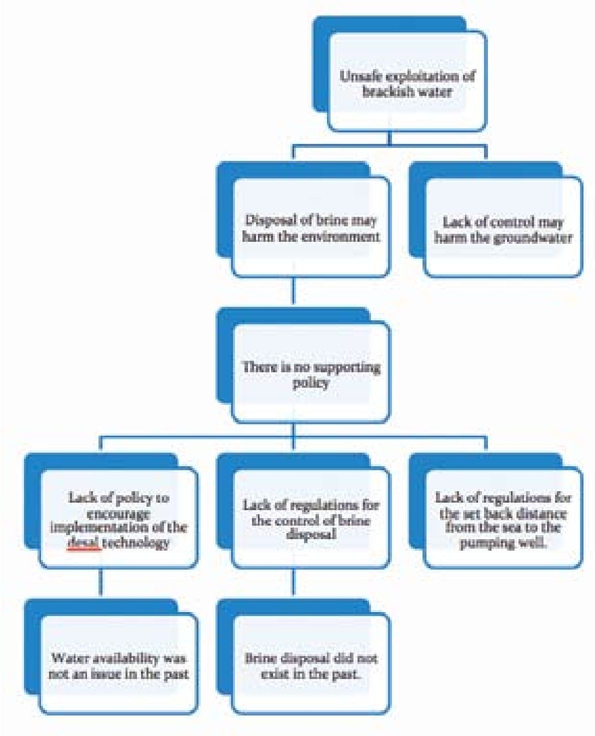
Market Failure & Imperfections



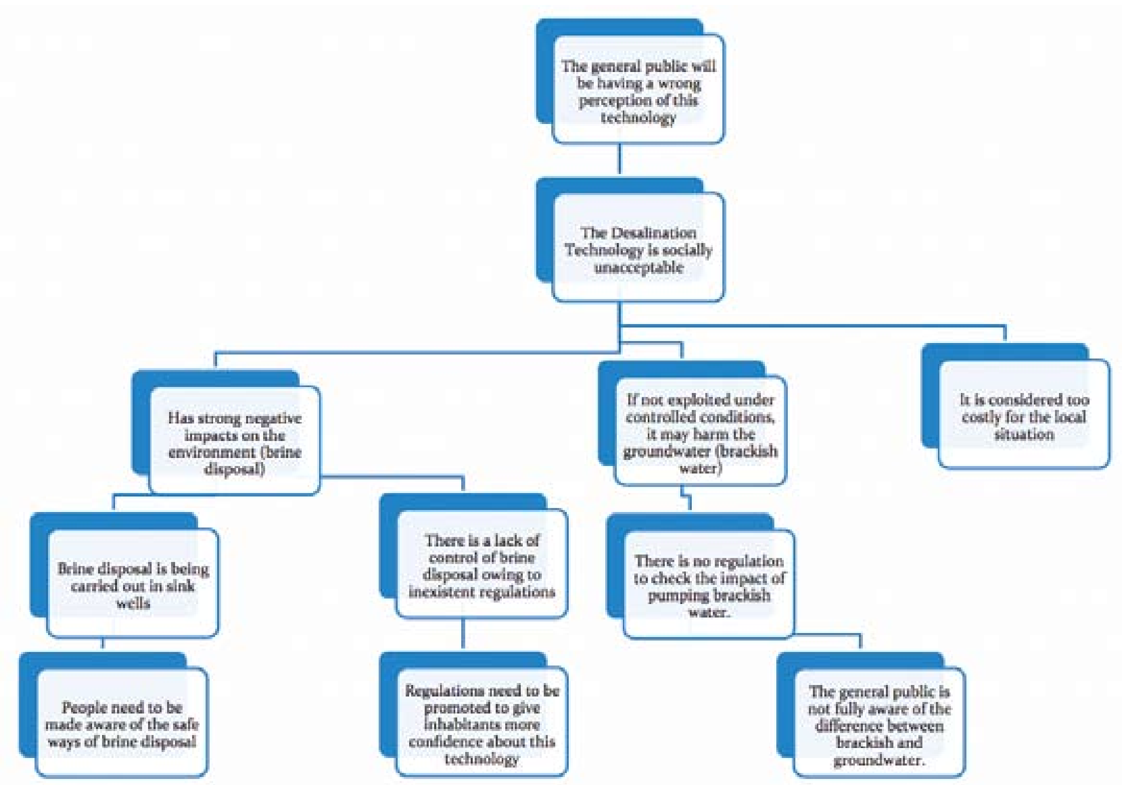
Annex 7 – Market Maps and LPA - Desalination Technology

Problem Tree

Policy, Legal & Regulatory



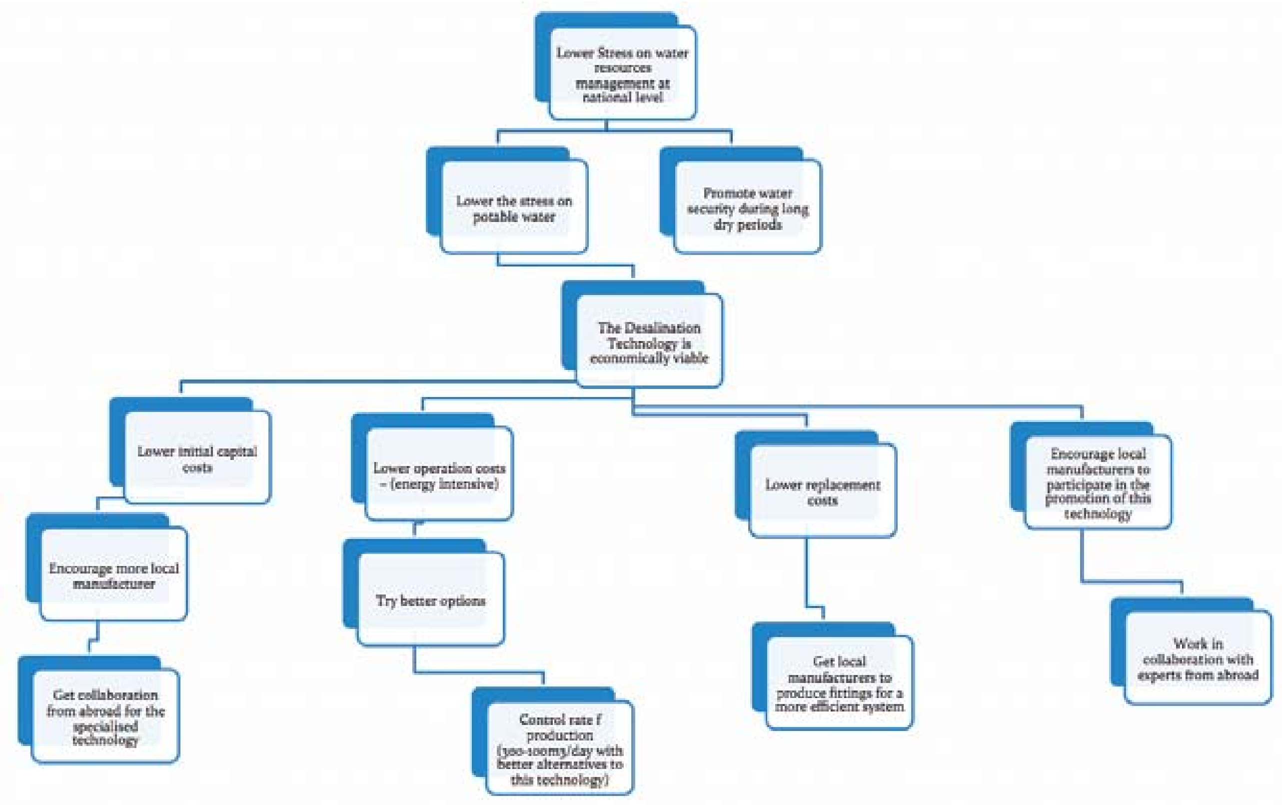
Social , Cultral & Behavioral



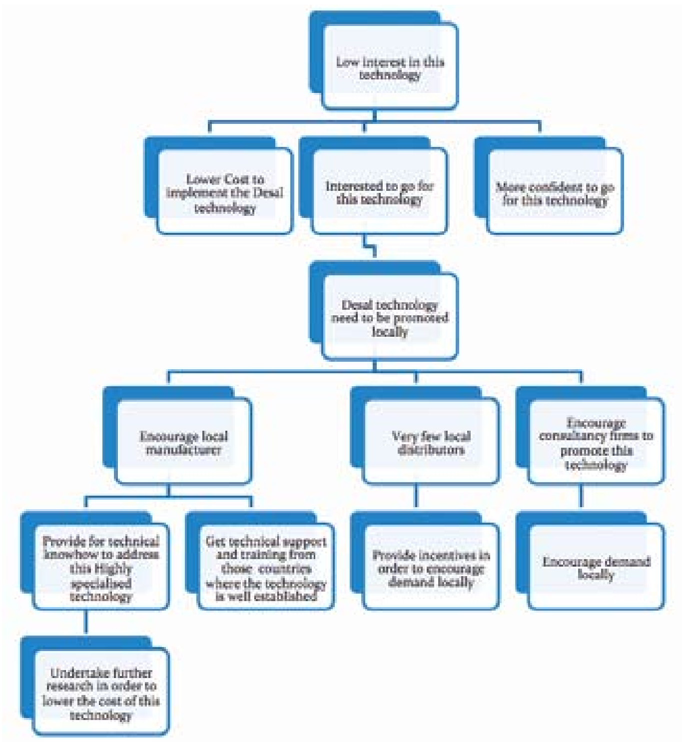
Annex 7 – Market Maps and LPA - Desalination Technology

Objective Tree

Economic & Financial



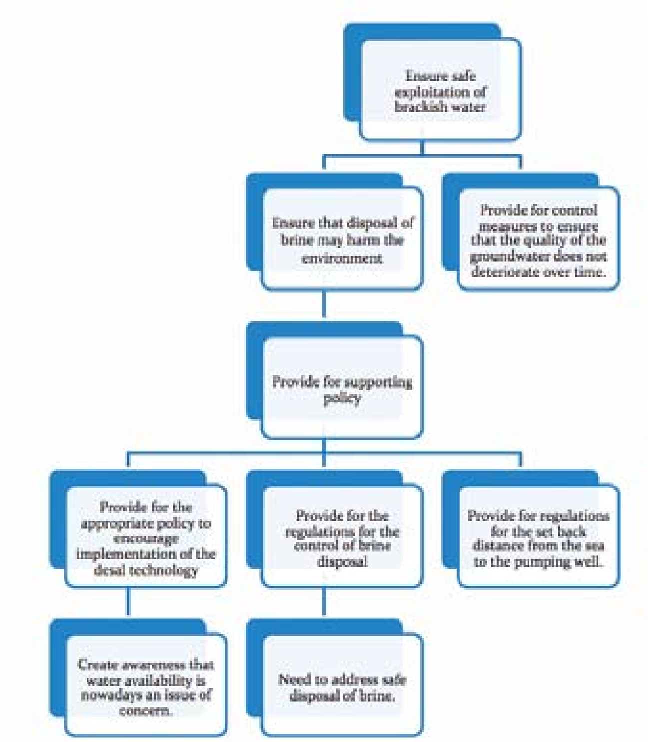
Market Failure & Imperfections



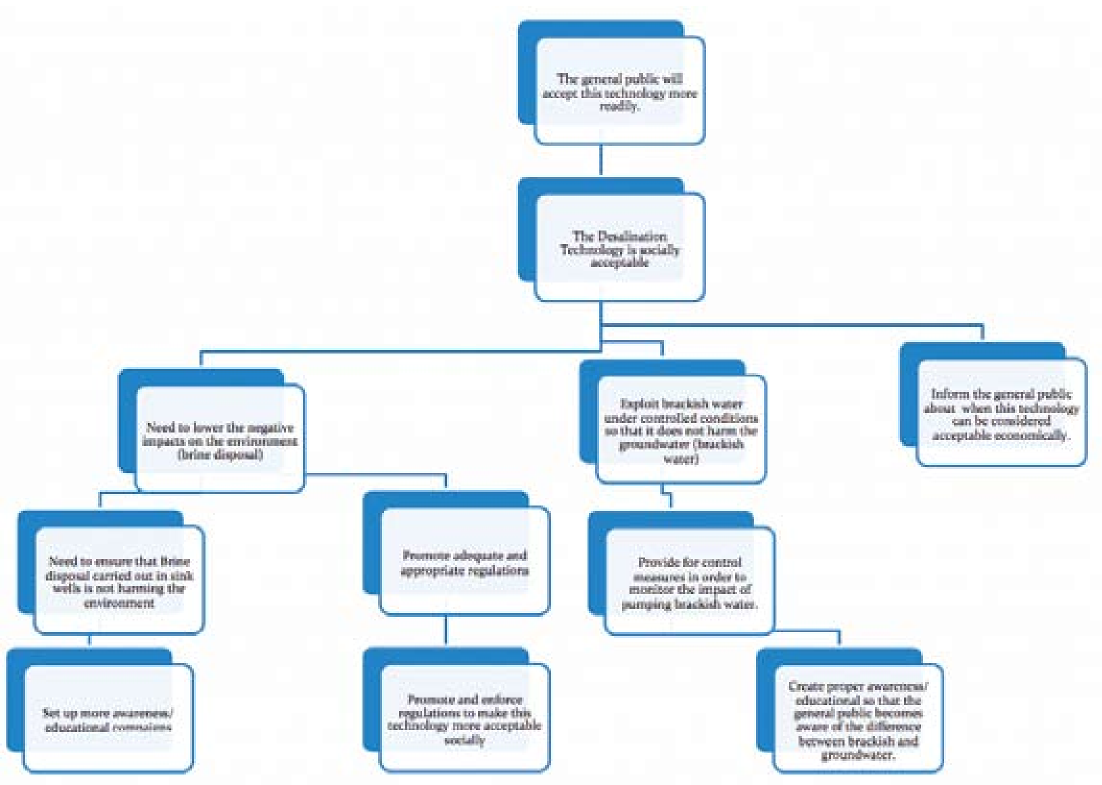
Annex 7 – Market Maps and LPA - Desalination Technology

Objective Tree

Policy, Legal & Regulatory

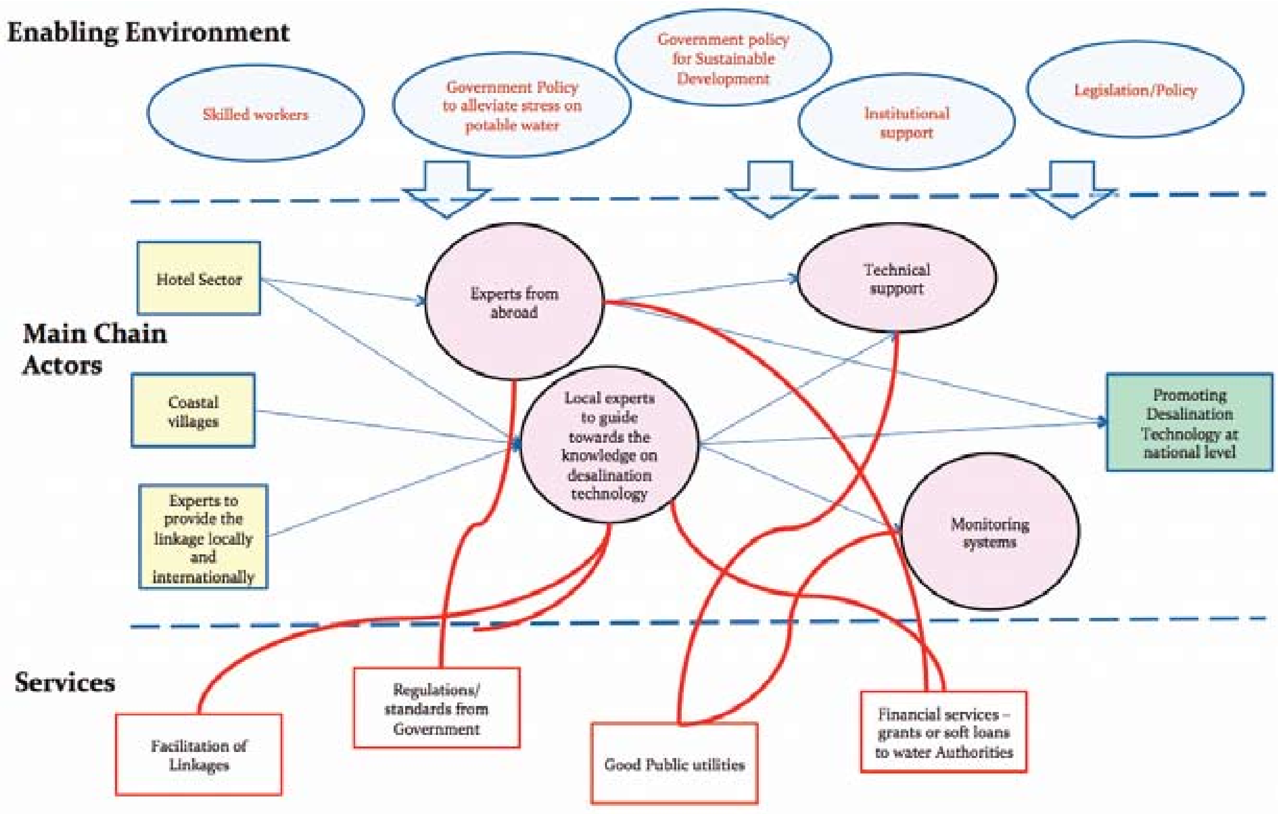


Social , Cultral & Behavioral



Annex 7 – Market Maps and LPA - Desalination Technology

Market Mapping



Annex 8 – Cost Benefit Analysis – RWH

RAINWATER HARVESTING TECHNOLOGY								
Cost elements = Cost of complete unit + Installation cost + Maintenance cost+ cost of awareness campaigns								
Benefits = savings in water consumption + opportunity cost by CWA								
Assumptions								
1. No. of families targeted =			250000					
2. **Awareness campaigns** to be provided over the first 10 years at the rate of Rs 200,000 per year =			200000					
3. **Government to subsidise** 40% of the total cost of each unit								
4. The **Weighted Average Cost of Capital**(WACC) calculated as indicated below - to be used for the discounting factor =			10.20%					
WACC	10.200	(Weighted Average Cost of Capital)						
Debt	70%	12%						
Equity	30%	6%						
Total	100%							

Year	Number of units targeted	Cost of individual units (Rs.)	Installation costs	Maintenance Cost (Rs)	Awareness Campaigns over 10 years	Total Cost (Rs)	Discounted Factor	Present Value (Rs.)
1	25000	150000000	25000000		200000	175200000	1	175200000
2	25000	150000000	25000000		200000	175200000	0.907441016	158983666.1
3	25000	150000000	25000000	2500000	200000	177700000	0.823449198	146326922.5
4	25000	150000000	25000000	5000000	200000	180200000	0.747231577	134651130.2
5	25000	150000000	25000000	7500000	200000	182700000	0.678068582	123883129.9
6	25000	150000000	25000000	10000000	200000	185200000	0.615307243	113954901.4
7	25000	150000000	25000000	12500000	200000	187700000	0.55835503	104803239.1
8	25000	150000000	25000000	15000000	200000	190200000	0.506674256	96369443.48
9	25000	150000000	25000000	17500000	200000	192700000	0.459777002	88599028.24
10	25000	150000000	25000000	20000000	200000	195200000	0.41722051	81441443.5
11				22500000		22500000	0.378603003	8518567.577
12				25000000		25000000	0.343559894	8588997.355
13				25000000		25000000	0.31176034	7794008.489
14				25000000		25000000	0.282904119	7072602.985
15				25000000		25000000	0.256718802	6417970.041
16				25000000		25000000	0.23295717	5823929.256
17				25000000		25000000	0.211394891	5284872.283
18				25000000		25000000	0.191828395	4795709.876
19				25000000		25000000	0.174072954	4351823.844
20				25000000		25000000	0.157960938	3949023.452
							TOTAL COST	**1.29E+09**

BENEFITS

Year	Volume of water saved per year (m3) per household	Volume of water saved by whole population (m3)	Savings in water bills (Rs.)	Opportunity cost for CWA - sell water at a higher price (Rs)	Total benefits (Rs.)	Discounted Factor	NPV (Rs)
1	20	5000000	40000000	150000000	190000000	1	190000000
2	20	5000000	40000000	150000000	190000000	0.907441016	172413793.1
3	20	5000000	40000000	150000000	190000000	0.823449198	156455347.6
4	20	5000000	40000000	150000000	190000000	0.747231577	141973999.7
5	20	5000000	40000000	150000000	190000000	0.678068582	128833030.6
6	20	5000000	40000000	150000000	190000000	0.615307243	116908376.2
7	20	5000000	40000000	150000000	190000000	0.55835503	106087455.7
8	20	5000000	40000000	150000000	190000000	0.506674256	96268108.63
9	20	5000000	40000000	150000000	190000000	0.459777002	87357630.33
10	20	5000000	40000000	150000000	190000000	0.41722051	79271896.85
11	20	5000000	40000000	150000000	190000000	0.378603003	71934570.65

12	20	5000000	40000000	150000000		190000000	0.343559894	65276379.9	
13	20	5000000	40000000	150000000		190000000	0.31176034	59234464.52	
14	20	5000000	40000000	150000000		190000000	0.282904119	53751782.68	
15	20	5000000	40000000	150000000		190000000	0.256718802	48776572.31	
16	20	5000000	40000000	150000000		190000000	0.23295717	44261862.35	
17	20	5000000	40000000	150000000		190000000	0.211394891	40165029.35	
18	20	5000000	40000000	150000000		190000000	0.191828395	36447395.06	
19	20	5000000	40000000	150000000		190000000	0.174072954	33073861.21	
20	20	5000000	40000000	150000000		190000000	0.157960938	30012578.23	
							TOTAL BENEFITS	**1.76E+09**	
							Benefit to Cost Ratio	**1.37**	

Other Cost elements
1. Preparation and promulgation of appropriate legislation and regulation
2. Setting up of a monitoring team at the level of the institution to ensure efficient implementation of the technology
3. The prices of fittings may change significantly over time.
4. The setting up of an information centre in order to ensure information to the general public
5. Government may not be able to provide 40% grant or soft loan in this project
6. The bank interest rates for loans and savings fluctuate significantly
Other Benefits
1. Possibility of job creation for plumbers and for casual workers to do regular maintenance
2. Possibility of saving more than 20m3 of water as the general public get used to adapting to water crisis
3. Decrease in cost of RWH units as local manufacturers are encouraged in the market chain.

Annex 9 – Cost Benefit Analysis – Desalination Technology

Desalination Technology - Analysis carried out for 2 months during the dry period.

Cost elements = Initial Capital cost+ Operational cost + Maintenance cost+ Replacement Cost

Benefits = Volume of water produced + savings in water consumption + opportunity cost by CWA

Assumptions

1. Initial capital cost of a 300m3/day production unit = 14 Milliion Rs.
2. Maintenance cost = Rs. 135,000 per year operated over **2 months during dry periods only**
3. Life span of a unit = 20 years
4. Potential number of costal hotels = 112
5. Islandwide Daily water demand in the hotel sector = 11000m3/day
6. Installation cost of one unit = 5 Million Rs.
7. Operational Cost: 20-25% - chemicals, 15-20% cartridges/membranes & 60-65% electricity - of the total unit cost = Rs. 135,000 per month (including replacement of membranes)
8. Target 50% of potential hotels = 50 over the next 20 years as not all hotels will have the facilities for sea water exploitation

9, Operated only during 2 months (dry season)

10. Awareness campaigns carried out over the first 10 years only

11. The **Weighted Average Cost of Capital**(WACC) calculated as indicated below - to be used for the discounting factor = 10.20%

WACC	10.200	(Weighted Average Cost of Capital)
debt	70%	12%
equity	30%	6%
total	100%	

Year	Number of Desal units targetted	Cost of individual units (M Rs.)	Operational Costs (M - Rs)	Awareness Campaings over 10 years (M - Rs)	Total Cost (M -Rs)	Discounted Factor	Present Value (M - Rs.)
1	5	95	1.35	0.2	96.55	1	96.55
2	5	95	2.7	0.2	97.9	0.907441016	88.8384755
3	5	95	4.05	0.2	99.25	0.823449198	81.7273329
4	5	95	5.4	0.2	100.6	0.747231577	75.1714967
5	5	95	6.75	0.2	101.95	0.678068582	69.1290919
6	5	95	8.1	0.2	103.3	0.615307243	63.5612382
7	5	95	9.45	0.2	104.65	0.55835503	58.4318539
8	5	95	10.8	0.2	106	0.506674256	53.7074711
9	5	95	12.15	0.2	107.35	0.459777002	49.3570611
10	5	95	13.5	0.2	108.7	0.41722051	45.3518694
11			13.5		13.5	0.378603003	5.11114055
12			13.5		13.5	0.343559894	4.63805857
13			13.5		13.5	0.31176034	4.20876458
14			13.5		13.5	0.282904119	3.81920561
15			13.5		13.5	0.256718802	3.46570382
16			13.5		13.5	0.23295717	3.1449218
17			13.5		13.5	0.211394891	2.85383103
18			13.5		13.5	0.191828395	2.58968333
19			13.5		13.5	0.174072954	2.34998488
20			13.5		13.5	0.157960938	2.13247266
						TOTAL COST	**7.16E+02**

BENEFITS									
Year	Volume of water produced per year (m3) by hotels	Savings in water bills (M - Rs)	Opportunity cost for CWA (M -Rs.)		Total benefits (Rs.)	Discounted Factor	NPV (Rs)		
1	36000	1.08	1.08		2.16	1	2.16		
2	72000	2.16	2.16		4.32	0.907441016	3.92014519		
3	108000	3.24	3.24		6.48	0.823449198	5.3359508		
4	144000	4.32	4.32		8.64	0.747231577	6.45608083		
5	180000	5.4	5.4		10.8	0.678068582	7.32314068		
6	216000	6.48	6.48		12.96	0.615307243	7.97438187		
7	252000	7.56	7.56		15.12	0.55835503	8.44232805		
8	288000	8.64	8.64		17.28	0.506674256	8.75533114		
9	324000	9.72	9.72		19.44	0.459777002	8.93806491		
10	360000	10.8	10.8		21.6	0.41722051	9.01196301		
11	360000	10.8	10.8		21.6	0.378603003	8.17782487		
12	360000	10.8	10.8		21.6	0.343559894	7.42089371		
13	360000	10.8	10.8		21.6	0.31176034	6.73402333		
14	360000	10.8	10.8		21.6	0.282904119	6.11072898		
15	360000	10.8	10.8		21.6	0.256718802	5.54512612		
16	360000	10.8	10.8		21.6	0.23295717	5.03187488		
17	360000	10.8	10.8		21.6	0.211394891	4.56612965		
18	360000	10.8	10.8		21.6	0.191828395	4.14349333		
19	360000	10.8	10.8		21.6	0.174072954	3.7599758		
20	360000	10.8	10.8		21.6	0.157960938	3.41195626		
						TOTAL BENEFITS	**1.23E+02**		
						Benefit to Cost Ratio	**0.17**		
						< 1 if operated during dry periods only			

Other Cost elements

1. Development and promulgation of appropriate legislation
2. Permission and cost implications some hotels will need to abstract sea water (if they are not vey close to the sea.
3. More operational & maintenance cost if the plant is operated over the whole year rather than 2 months only.
4. Maintenance cost will increase if there are few skilled technical staff to maintain the system.
5. Brackish water with lower conductivity may cause more hindrance than treating sea water.

Other Benefits

1. May fully alleviate pressure on water demand on treated potable water.
2. Will make the hotel fully water secured for its clients.
3. Will be beneficial if the system is operated fully.

Annex 10 – Policy Fact Sheet - Water Sector

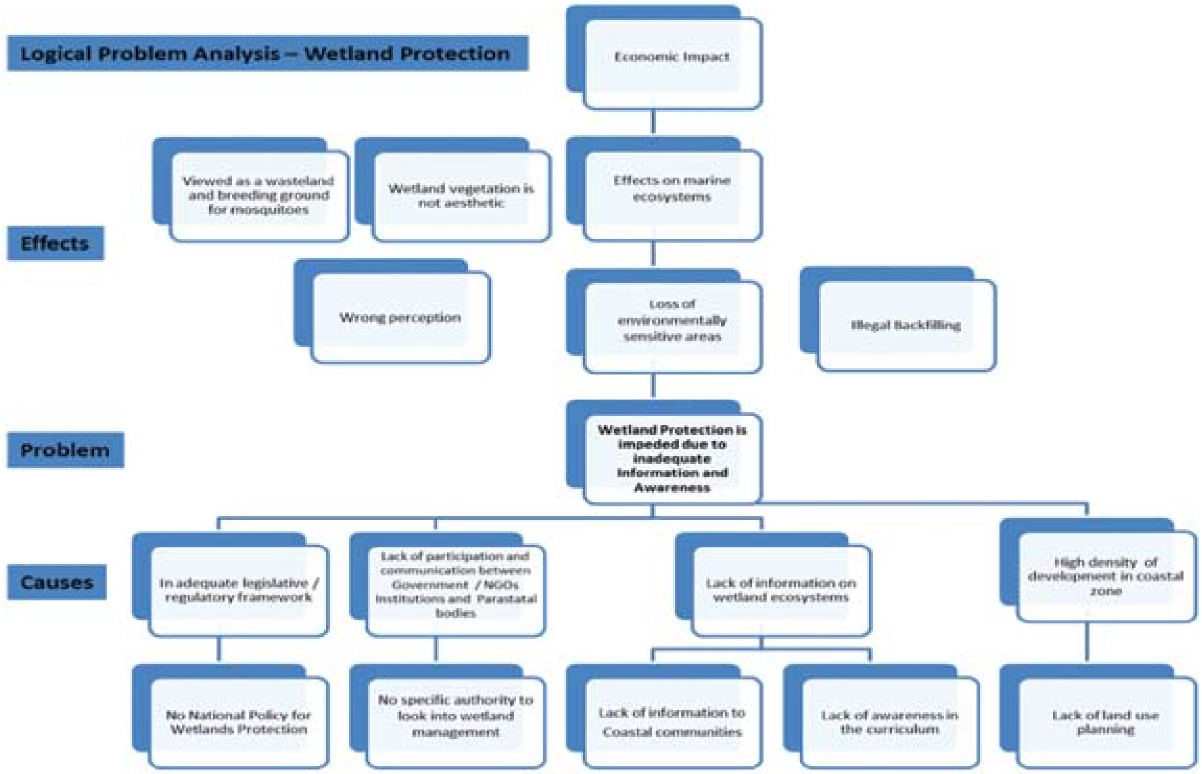
Key:	
Minimum requirements	
Recommended/ good to have	
POLICY: Name of Policy	
Name of field:	Desalination
Date Effective:	August 2012
Date Announced:	16 April 2012 (Government Programme)
Date Promulgated:	August 2012
Date Ended:	na
Unit:	na
Country:	Mauritius
Year:	2012
Policy Status:	**In force**
Agency:	Ministry of Housing and Lands
Funding:	A 50% annual allowance on a straight-line basis will be provided for desalination plant and landscaping and other earthworks for embellishment purposes undertaken in 2013 and 2014 (currently no allowance is given for such expenditure) – (Government budget 2013 highlights)
Further Information:	A number of hotels have already been using desalination technology to cater for their water demands during the dry season.
Enforcement:	Ministry of Housing and Local Authorities.
Penalty:	na
Related Policies: 2016)	na
Policy Superseded by:	New Policy
Policy Supersedes:	na
Stated Objective:	To low the pressure on potable water and to address water security during dry seasons.
Evaluation:	na
Policy Type:	na
Policy Target:	na
URL:	http://www.gov.mu/portal/goc/housing/file/desal.pdf
Legal References:	na
Description:	na

Annex 11 – List of Stakeholders - Water Sector

List of stakeholders involved in identification of barriers and development of enabling framework Sector - Water				
Name(s) of contact person	**Organisation**	**Approach of consultation**	**Date**	**Topic**
Sales Manager	Supermarkets	Informal Interview	28.04.2012 & 11.11.2012	Rainwater Harvesting – whole unit
Mrs. R. Ramrekha	Water Resources Unit	Meeting / discussion	11.05.2012	Rainwater Harvesting & Desalination
Mr. D. Jahajeeah	Water Resources Unit	Meeting / discussion	18.05.2012	Rainwater Harvesting & Desalination
Mr. A. K. Gopaul	Central Water Authority	Meeting / discussion	15.06.2012	Rainwater Harvesting
Mr. Caullychurn	Water Resources Unit	Bilateral meeting	8.08.2012	Rainwater Harvesting & Hydrological Models
Sales Manager	Retailers	Informal Interview	25.08.2012 & 30.08.2012	Rainwater Harvesting – Storage tanks
Mr. R. Bissessur	Water Resources Unit	Meeting / discussion	9.11.2012	Rainwater Harvesting & Desalination
Mr. R. Pokun	Water Resources Unit	Bilateral meeting	12.11.2012	Hydrological Models
Mr. E. Seenyen	Scene-Ries Consult Ltd	Informal Interview	10.12.2012	Desalination

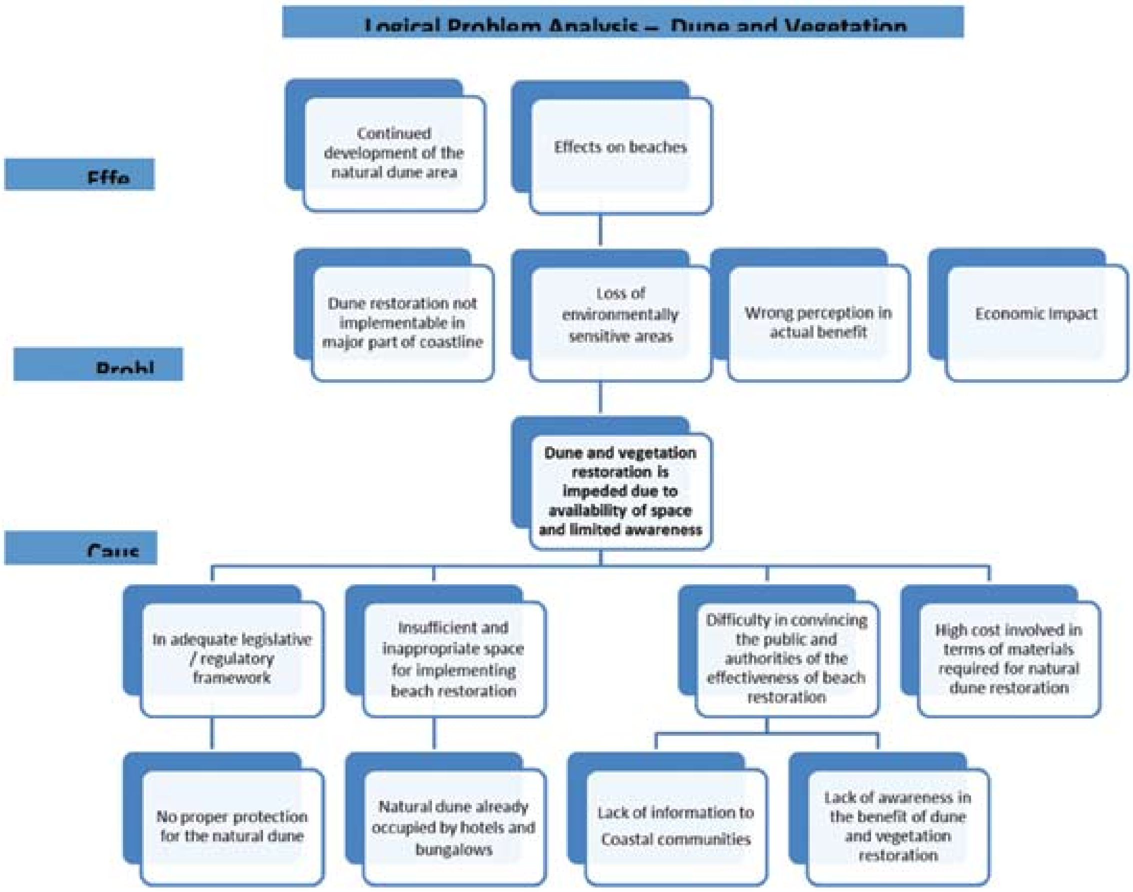
Annex 12 - Market Maps and Problem Trees – Coastal Zone

a) Problem tree – Wetland protection



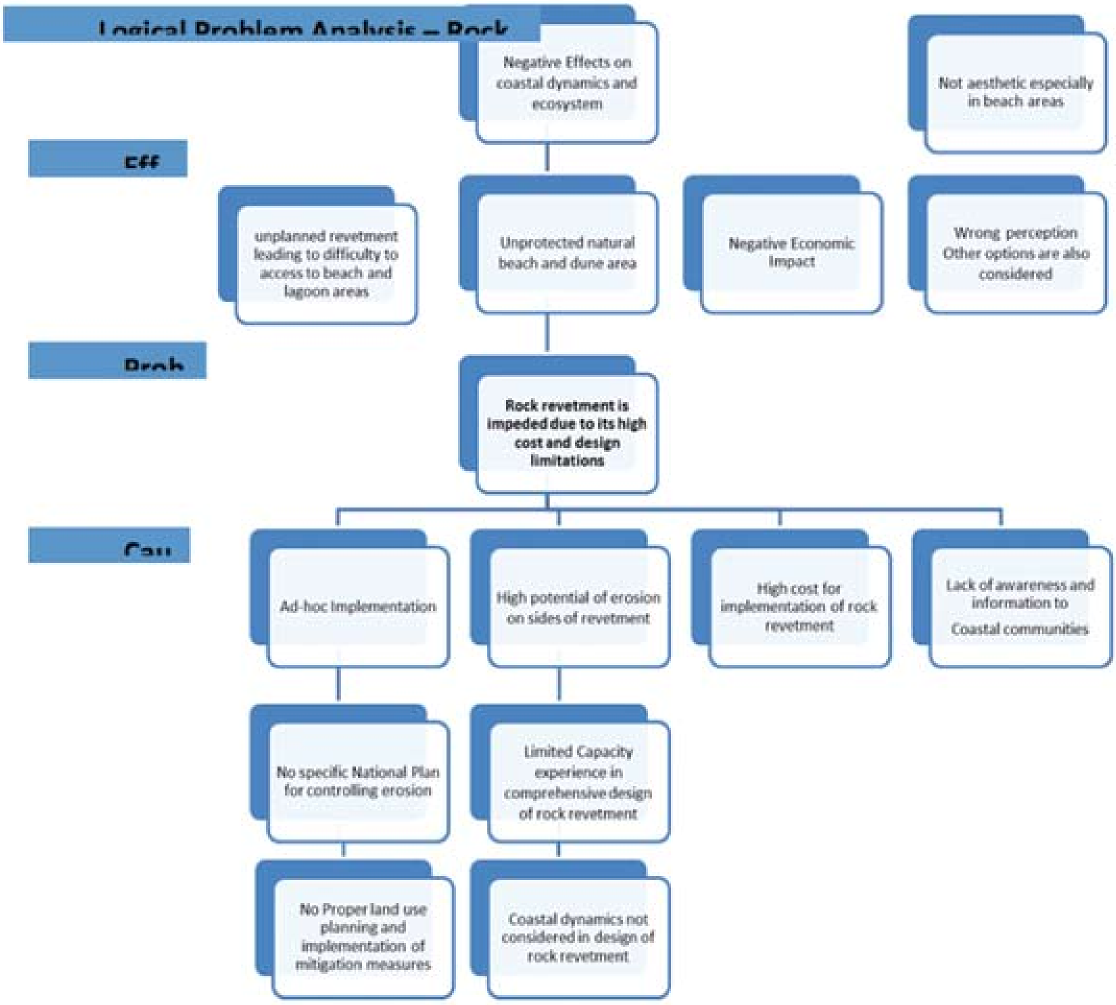
Annex 12 - Market Maps and Problem Trees – Coastal Zone

Annex 12b) Problem tree – Dune and Vegetation Restoration



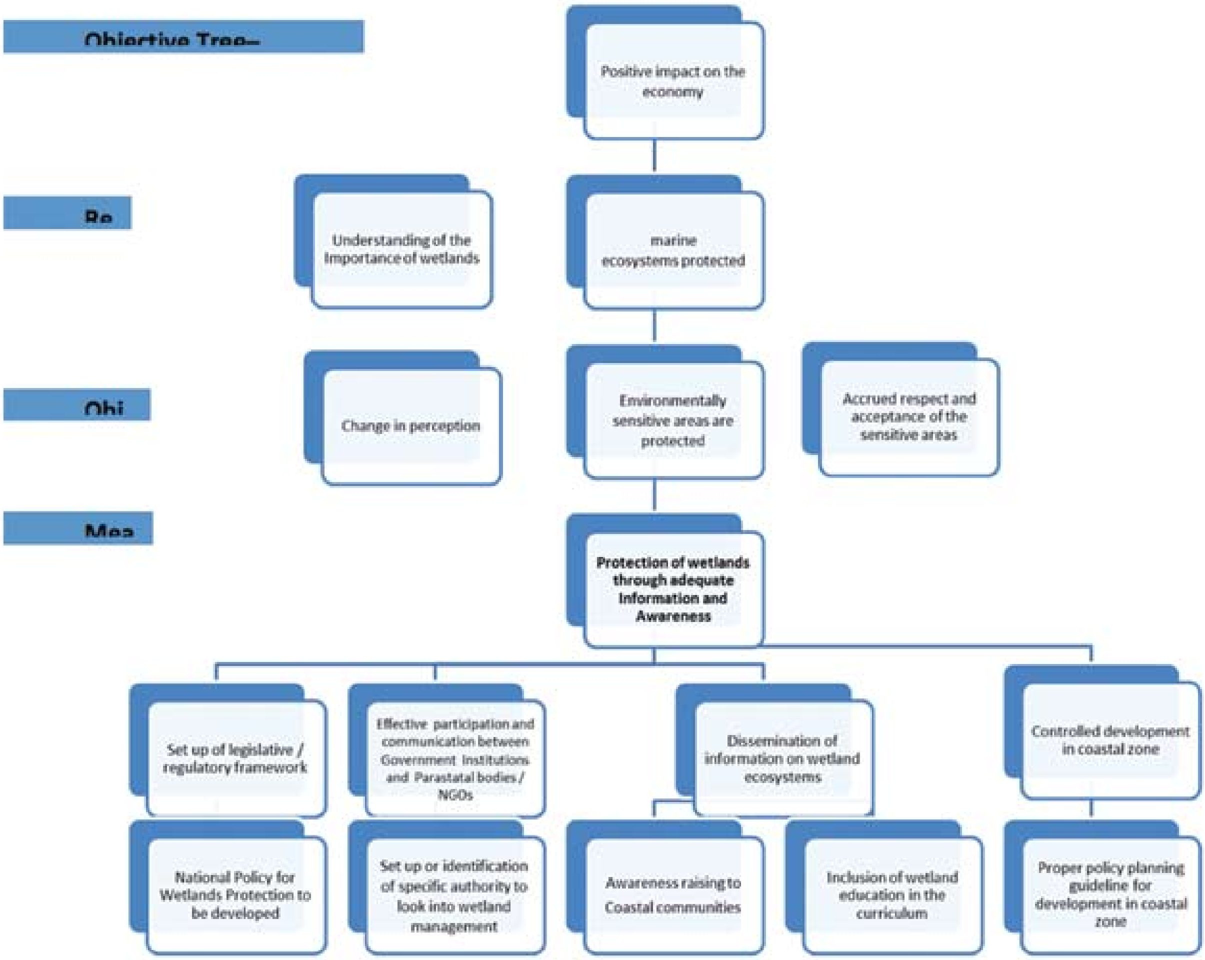
Annex 12 - Market Maps and Problem Trees – Coastal Zone

Annex 12c) Problem tree – Rock Revetment



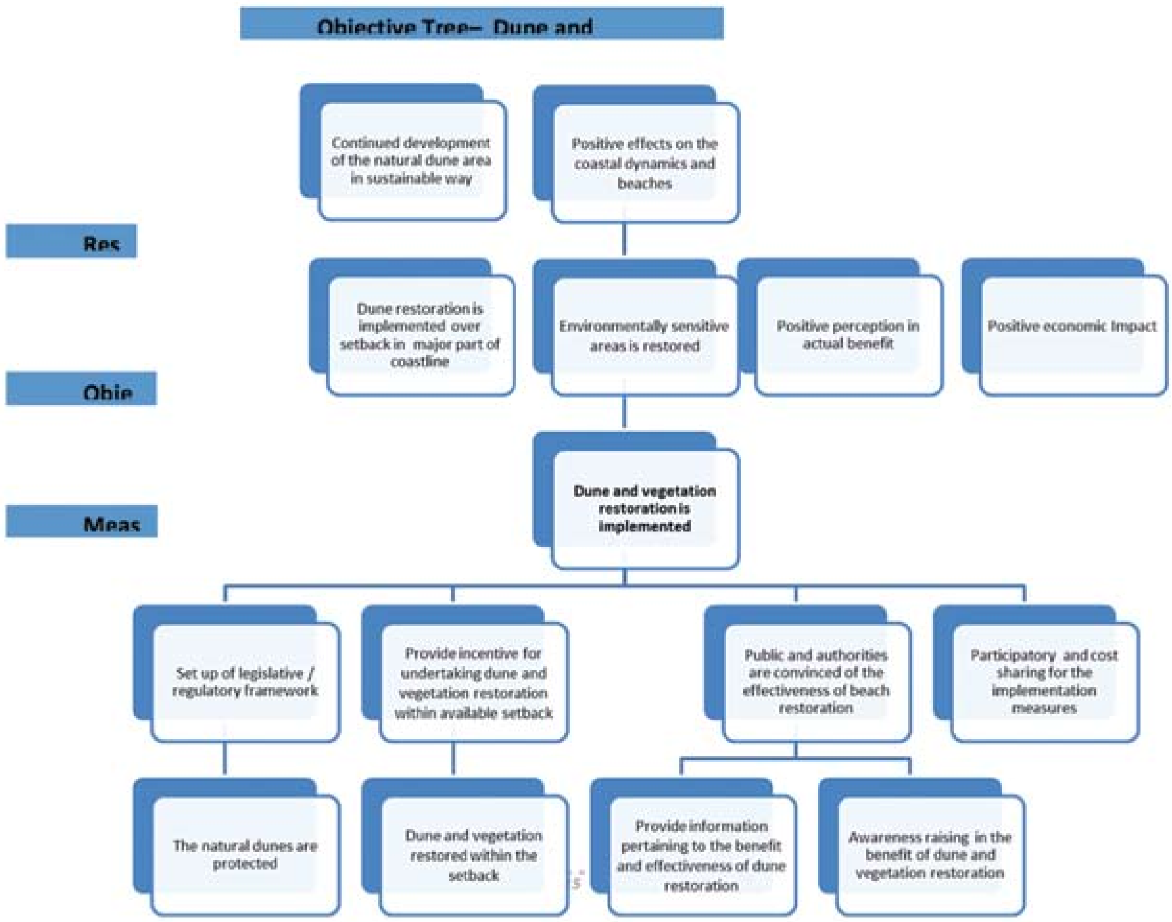
Annex 12 - Market Maps and Problem Trees – Coastal Zone

Annex 12d) Objective tree – Wetlands Protection



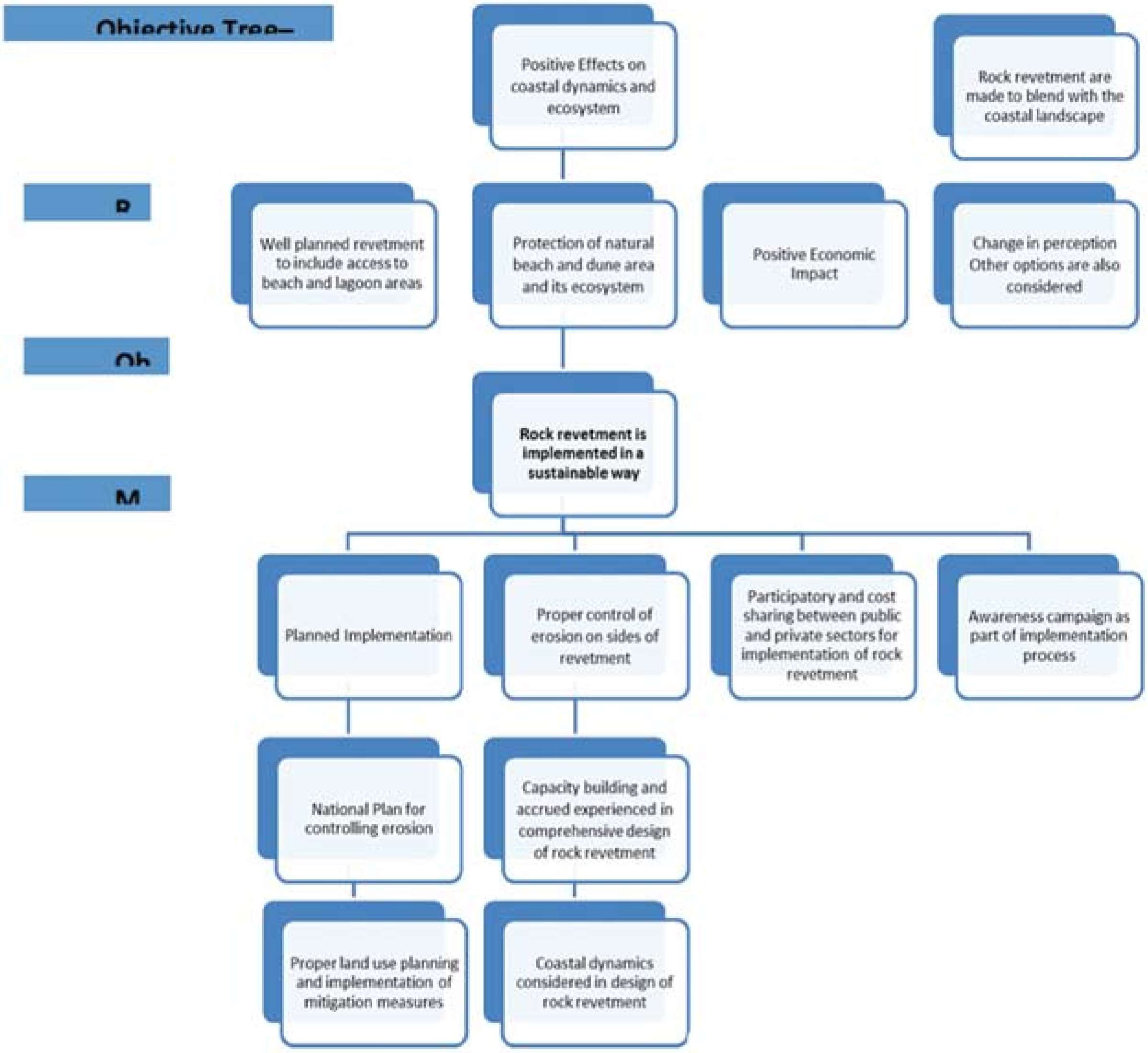
Annex 12 - Market Maps and Problem Trees – Coastal Zone

Annex 12e) Objective Tree – Dune and Vegetation Restoration



Annex 12 - Market Maps and Problem Trees – Coastal Zone

Annex 12f) Objective Tree – Rock Revetment



(I) Central Statistics Office (2009), Mauritius in Figures – 2009, Central Statistics Office, Port -Louis.

(II) Government of Mauritius (2010) Second National Communication under UNFCCC (Mauritius Meteorological Services, Vacoas, 2010), pg. 79.

(III) Government of Mauritius (2010) Mauritius Environment Outlook (Government of Mauritius, Port Louis, Mauritius, 2010), pg. 47.

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URL : http://environment.gov.mu