United Republic of Tanzania

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION

Barrier Analysis and Enabling Framework Report

AGRICULTURE AND WATER SECTORS

2017

DISCLAIMER

Report II

BA&EF Report

Executive Summary

In Part I of the TNA report, Tanzania prioritized two sectors of agriculture and water to address the technology gap in adaptation. The priority sectors chosen in the TNA project for adaptation were consistent with national development priorities, while taking into account the vulnerabilities of climate change impacts in the country. The sectoral consideration in the climate-development nexus of Tanzania was clearly revealed, the TNA project brings complementarities in terms of nationally appropriate technology options. The processes of prioritized technologies involved review of the existing literature, involvement of stakeholders, sector working groups and technical expertise in consultation with national TNA coordination office. The same actors also influenced the criteria and decision for sector and technology identification and prioritization. The identified sectors relevant for climate change adaptation were agriculture and food security, water, energy, forest and health. Agriculture and Water sectors were prioritized and were therefore analysed further in the TNA for adaptation.

The TNA adaptation report identified three adaptation technologies for agriculture sector namely improved seed varieties, system of rice intensification and drip irrigation. The report further identified three technologies for water sector namely rain water harvesting, smart water meters and waste disposal ponds to address recycling and reuse of water for the development of the technology action plan (TAP).

This report is second in the series of reports generated under TNA project. This report on Barrier Analysis and Enabling Framework covers adaptation technologies for two sectors, namely: (1) agriculture and (2) water. 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, literature review, market mapping linking all the market actors and the Logical Problem Analysis involving barrier decomposition and root causes analysis

- Investigating, assessing and categorizing 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.

Agriculture in Tanzania is dominated by small scale farmers who depend on rain and use rudimentary technologies for farming. Taking account of vulnerability assessment done in various policy development processes, this study focused on the food crop production and irrigation. In view of likely impact of climate change on the sectors, adaptation technologies were selected and prioritized to ensure that they are effectively transferred to improve resilience. In the development of the TNA, three prioritized adaptation technologies that best suit needs of small scale farmers were retained. They included (1) Promotion of use of improved seed varieties which are characterized by early maturing, and tolerance to pests and drought to enhance resilience of crops to climate change hazards, particularly drought, extreme heat and shorter rain seasons. The technology reduces the risk of total crop failure and provides the producers with chances of dealing with the uncertainty created by climate change because they require relatively little rainfall, (2) System of Rice intensification which is a technology aimed at increasing the yield of rice produced under constrained water availability and (3) drip-irrigation in order to optimize use of water which is likely to become scarce in the future while enhancing food production.

The main barriers identified were low capacity in accessing loans and credits, inadequate training and awareness, limited demonstration and technical support, weak inter institutional collaboration, gap between R&D and market. A range of measures required to overcome the barriers were identified including supportive policy, economic incentives, research and institution support and public awareness.

The following tables summarises the barriers that may hinder diffusion of the selected agriculture technologies for adaptation and the corresponding measures to solve them

Barriers to and measures to overcome Barriers to Improved Seed Varieties		
Barrier Category	Barriers	Measures
Financial Barriers	a) Improved seeds are expensive compared to traditional available seeds.	i. Reduce cost of release of seeds by regulating processes at Tanzania Official Certification Institute (TOSCI). ii. Simplifying the variety release procedures by reducing the number of institutions that a variety has to go through before it is released. iii. Strengthen the capacity of TOSCI by addressing the financial, human and infrastructural challenges
	b) Difficulty to access finance	i. Deliberate efforts to increase knowledge of available financial services such as information on credit acquisition to farmers. ii. The government can support the formation of lending groups or associations which will reduce MFI cost of reaching rural clients and operating in remote areas.

Barriers to and measures to overcome Barriers to Improved Seed Varieties		
Barrier Category	**Barriers**	**Measures**
		iii. Promote initiatives that will support rural and agricultural populations to create alliances with other actors (NGOs, governmental entities, producer organizations, etc.) to set up complementary services like training and technical assistance (TA) on management or financial advisory services to farmers, capacity building on entrepreneurial skills and use of agricultural produce to repay back the loans.
	c) Economic viability to guaranteed market	i. Government to Increase farmers' Market access- processing and distribution channels by supporting and building long-term relationships for the different actors in the agriculture value chain. This will enable farmers to have information of available markets for their produce to decide on investment and use of technology.
Non-Financial Barriers		
Awareness and information	Poor awareness and information	i. Strengthen information sharing of farmers through improving extension services such as farmer field schools. ii. Reorient ASA funding to promote the development of new seed companies in under-served regions of Tanzania through private sector services in marketing, business planning, and internal quality control mechanisms, as well as increasing farmers' understanding of the importance of certified seed.
Human Skill	Inadequate human capacity	Engage with the private sector in public private partnerships (PPP) so as to strengthen extension agents and farmer capacity to utilize improved seeds. Such capacity of training on use of seeds properly through proper agronomic practices at village level and funds to build capacity of extension agents.
	Inability to distinguish genuine and fake seeds	Educate farmers to identify genuine seeds through selection of seeds in the value chain. Certification seal by Tanzania Bureau of Standards (TBS) should be mandatory for all seeds.

Barriers to and measures to overcome Barriers to Improved Seed Varieties

Barrier Category	Barriers	Measures
Technical	Complexity of the technology	Strengthen the research and development to provide necessary support to farmers to be able to address technical issues of the adopted technology.
	Delayed release of ISV	Reduce time for release of improved seed varieties: This involves reducing the time required for seed variety registration and release, and revising the committee process for variety release.
Policy, legal and regulatory barriers	Non recognition of farmer managed seed system by the seed policy	i. Establish a seed quality control programme: Tanzanian government should develop strategies that explicitly recognize farmers' rights and support flexible and adaptive seed quality control processes appropriate to local conditions. ii. Funding support for the development of an inclusive seed R&D programme. Public resources through programmes and budgets should be channeled towards experimentation and development in farmers' existing seed systems through the improvement and development of farmers' varieties.
Social cultural and behavioural barriers	Convenience to and acceptability by small scale farmers not evaluated	i. Demonstration of improved seeds: The release of new varieties needs to be accompanied by establishment of demonstration fields which can be used for the learning purpose where all technical issues can be resolved. Through observation and learning, farmers will have information that will enable them to make informed decisions. These fields will promote the released varieties and fast track adoption. ii. Establish networks: Government to address the value chain actor coordination challenge through consultation with all key stakeholders in seed management. Relevant government institutions should develop communication strategy, awareness materials and promotional strategies to ensure public acceptance of ISV.

Barriers to and measures to overcome Barriers to System of Rice Intensification		
Barrier Category	Barriers	Measures
Economical and Financial Barriers	Inadequate financial resources	i. Support to establishment of informal savings and credit groups at community level: Social networks in village economies could potentially play an important role for agricultural technology adoption and social acceptability needed for SRI to diffuse quickly. ii. Encourage private public partnership to initiatives such as SACGOT at the small scale level iii. Enhancing producer price support mechanism, facilitate market access and avail information on markets to small scale farmers.
	Lack agriculture credit and loans	i. Establish small holder credit facilities: Initiatives from banks such as TIB and TAIB should focus on majority farmers who are small scale farmers. ii. Relevant state institutions such MAFL, research institutions, academia etc should conduct economic and financial feasibility studies and make the study findings available to the public and to the decision makers to support investment on the technology
Non Financial Barriers		
Information and awareness	Access to information and extension services	i. Establish SRI demonstration plots and on farm trials. ii. Exchange visits of rice scientists, extension officers, processors and farmers to share experience and encourage network of technology adopters.
	Perceptions of climate change among the farmers	Increase campaigns of climate change awareness and how to reduce risk exposure where adoption of SRI should be emphasized. Understanding of the contribution of technologies to yield variability is important.
Human Skill	Limited human capacity	i. Strengthening of farmer field schools and training institutions to train farmers and to learn on what works in practice. ii. Training of early adopter farmers,

Barriers to and measures to overcome Barriers to System of Rice Intensification		
Barrier Category	Barriers	Measures
		processors, extension officers and other stakeholders in rice technologies at the Ministry of Agriculture Training Institutes/centers iii. Increase management skills of increased production, introduce/ adopt supporting technologies to complement the realized gain from SRI. For instance, the development and availability of improved post-harvest processing technologies and value addition processes.
Policy , legal and regulatory	Inadequate regulations and bylaws	Relevant authorities should work together to advocate the harmonization of principals of SRI and existing policy regulations.
Institutional and Organizational Capacity	Poor institutional coordination	i. Strengthen water user associations (WUAs) on use of water for irrigation. ii. Ministry of Agriculture Fisheries and Livestock (MAFL) and Ministry of Water and Irrigation (MoWI) to coordinate farmers to manage the canal collectively to increase their likelihood of adoption of SRI.
Social, Cultural behaviour	Poor acceptance	Enhance use of farmer field schools and deliberate identification of champions within the community who can influence the community on decisions.

Barriers to and measures to overcome Barriers to Drip Irrigation		
Barrier Category	Barriers	Measures
Economic and financial	a) High capital cost	i. Government taxes on importation to be reduced or eliminated ii. Attract more private sector involvement in the market chain of the same. Such an initiative would improve the financial viability of the deploying technology and increase uptake
	b) Difficulty to access finance	i. Government to engineer provision of credit facilities, grants, and subsidies as instruments to support farmers to invest in drip irrigation (DI) equipment. ii. Establish an appropriate land tenure system to enable farmers to own the land legally and enhance their capacity of collateral for accessing loans. iii. Local governments Authorities (LGAs) should consider establishing a fund to provide low interest credits/loans for drip irrigation

Barriers to and measures to overcome Barriers to Drip Irrigation		
Barrier Category	Barriers	Measures
		projects. The fund source can be through imposing a levy on establishment of commercial farms. iv. Development institutions with a mandate to promote these technologies could consider providing required funds on agreed terms.
Non-Financial Barriers		
Information and awareness	Low level awareness of the technology	Consistent awareness creation
	Farmers mindset	With the aim of transforming their farming practices, provide knowledge to farmers through demonstration farms on off season harvest, train them on diversification of crops, marketing and record keeping.
Technical	Insufficient understanding of the use of the kits and functionality	Drip irrigation systems should be viewed as a tool toward increased productivity, not as a stand-alone solution. Effective utilization of drip irrigation needs to be tied to technical assistance to ensure farmers are maximizing the benefits of the system and applying other required and complementary good agricultural practices.
	Inadequate pest and disease control	Promote technical assistance in partnership with development institutions, NGOs, or government agencies to provide irrigation management, crop production, agronomic training and advice, and market access support.
Policy, legal and regulatory barriers	Government policy and incentives	Reduce or remove VAT and duties for drip irrigation equipment to enable local private sector to supply irrigation equipment to small scale farmers at affordable cost. Local standards for drip irrigation equipment and vetting systems need to be developed for quality control to check if equipment on sale is of required standards.
Institutional and organizational capacity barriers	Weak link between research extension and farmers	Strengthen the collaboration among the stakeholders through training, regular 'sharing' meetings and developing system of communications
	Limited institutional capacity for research and development	Development partners and the government in their joint programmes, should aim to increase budget for R&D institutions, increasing

Barriers to and measures to overcome Barriers to Drip Irrigation		
Barrier Category	Barriers	Measures
		numbers of skilled/ technical people, strengthen south south collaboration to enable sharing of new knowledge
Social, Cultural behaviour	Resistance to adopt the technology , and Fear of unknown	Provide extensive awareness programme through media to ensure a large section of the population become familiar with the technology.
	Community conflicts	Deliberate efforts to solve land conflicts by strengthening coordination of village and LGAs are important.

The primary focus of water resource sector in the face of accelerated climate change phenomenon is the development and adoption of technologies that result in efficient water use. For this purpose, the prioritized technologies included (i) rainwater harvest from roof top, (ii) leakage reduction programme using smart water meter and (iii) water recycling and reuse through waste stabilization ponds. The main barriers identified for the water technologies were the high cost of installation and maintenance, especially when considered for small farms and the lack of technical staff for designing and maintaining such systems, inadequate training and awareness, limited demonstration and technical support, weak inter institutional collaboration, gap between R&D and market chain. A number of enabling measures like financial incentives to farmers, training and capacity building were conceived to help in the diffusion of these technologies in Tanzania. 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 following tables summarises the barriers that may hinder diffusion of the selected water technologies for adaptation and the corresponding measures to solve them

Barriers to and measures to overcome Barriers to Rainwater Harvest		
Barrier Category	Barriers	Measures
Economic and financial	Cost of materials and equipment	iii. Tanzania's government should offer incentives and subsidies to support individual efforts to address their water supply challenges with RWH. A 50% subsidy on rainwater harvesting equipment is recommended, these financial measures can support the purchase of materials and equipment for the system iv. Attract more private sector involvement in the market chain of the same. Such an initiative would improve the financial viability of the deploying technology and increase uptake.

Barriers to and measures to overcome Barriers to Rainwater Harvest		
Barrier Category	Barriers	Measures
	High initial costs for individuals investment	i. Deliberate initiatives to promote provision of credit facilities, grants for demonstration sites, as instruments to support investment in RWH. ii. Individuals, at the community level can establish the microfinance schemes leading to self-funding initiatives such as the saving and credit systems (VICOBA). ii. Local governments Authorities (LGAs) should consider establishing a fund to provide low interest credits/loans for RWH projects.
Non-Financial Barriers		
Information and awareness	Limited awareness towards climate change and adaptive solutions	i. Consistent awareness creation in promoting knowledge regarding climate change and the connected environmental and socio-economic impacts through media involvement, training, and inclusion of technology basics in the education system. ii. It is essential to establish demonstration or pilots projects on RWH which will create an opportunity to run training and capacity building to local engineers, technicians as well as beneficiaries.
Technical	Quality and quantity aspects	i. Introduction of dual water usage system where rooftop rainwater can be used for drinking only while surface and groundwater can be used for other purposes. ii. Strengthening of the Programme on Monitoring and modeling of water quantity and quality
	Limited accessibility of data on rainfall and weather	Government should develop and implement a programme on measuring local weather data
Human Skill	Develop and improve skills on workmanship	Establish local training institute that would develop a number of local artisans coupled by strengthening of water institutions with water research centers.
Policy, legal and regulatory barriers	Absence of policy tools	i. Develop supporting Policy and regulatory instruments for RWH technology which will guide, encourage, and enforce the adoption and diffusion of the RWH technology. ii. Establishment of enabling policies including cost-sharing strategies, provision of subsides along with technical know-how and capacity building for promotion of RWH. iii. Promote urban water harvesting, through

Barriers to and measures to overcome Barriers to Rainwater Harvest

Barrier Category	Barriers	Measures
		policies which include a mix of incentives and penalties, and that such policy initiatives should be strengthened further through legislation
Institutional and organizational capacity barriers	Poor management skills of harvested water by consumers	Programmes should be introduced to enhance local water management skills such as purification, proper collection and use suitability, and organization capacities.

Barriers to and measures to overcome Barriers to Smart Water Meter		
Barrier Category	Barriers	Measures
Economic and financial	i. High Cost of Capital Investment and system maintenance	Private sector involvement through the public private partnership (PPP) can be one of the mechanisms to overcome the high initial investment cost as well as system maintenance costs.
	ii. Mobile payment tariffs	The government can introduce subsidized tariffs to the telecommunication firms for the service. But on the other hand, the telecommunication firms can regard this as giving back service or as corporate social responsibility (CSR).
Non-Financial Barriers		
Information and awareness	Limited awareness among water users (consumers)	Development of a comprehensive awareness programme through audio and visual media as well as printing media to enable adoption of the meters. The programme should benefit authorities through capacity building, workshops, exchange programmes and gear towards making consumers feel in control of their water consumption by publicizing that smart metering gives back the control to the consumer
	i. Insufficient information and data	utilities could do the following: • Undertake customer mapping in the network • All customers to be metered • Undertake regular monitoring of the water distribution system • Establish and update the customer database
Technical	i. Poor Infrastructure	Government to embark on private sector involvement through the public private partnership (PPP) can be adopted.
	ii. Lack of relevant experience and expertise	Partnership with technology providers can be one of the opportunities for utility staff to create awareness (which could be through remedial courses, demonstration projects or both) or get educated about smart water networks, the impacts on the utilities performance as well as cost benefit analysis of the SWM investment.
Policy, legal	Absence of Standards and	Establish a governing regulatory framework that

Barriers to and measures to overcome Barriers to Smart Water Meter		
Barrier Category	Barriers	Measures
and regulatory barriers	Guidelines	will address the relevant technical standards and guidelines.
Social/ cultural behaviour	Social Acceptance	The government has to develop a regulatory mechanism aiming at cyber security focusing on public privacy aspects for personal consumer information. On the other hand, the technology providers together with utilities have to undertake communication campaigns regarding customer data protection. The campaign should address system operation aspects, assurance about technical as well as managerial measures in place to protect the customer data or privacy.

Barriers to and measures to overcome Barriers to Waste Water Stabilization Pond		
Barrier Category	Barriers	Measures
Economic and financial	Poor access to affordable financing for WSPs construction	Government to invest on attracting external support through bilateral and multilateral agreements; Subsidize cost of construction to at least 50 %.
	High investment costs	Enable municipalities to access loans and grants to meet costs of construction
Non-Financial Barriers		
Technical	Limited research on wastewater treatment technologies, WSPs	• Government should develop relevant standards and specifications that can reflect the local situation. In depth studies that can address area specific conditions for the ponds construction should be conducted. • Support research institutions through regular monitoring of the operational WSPs in order to determine the trends on operational efficiency with the objective of wastewater reuse and recycling.
Policy, legal and regulatory barriers	Absence of Policy instruments: (financial incentives, regulations and awareness programme) targeted on wastewater recycling and reuse.	• Develop supportive Policy and regulatory instruments to promote WSPs targeting economic incentives, for instance tax exemptions or subsidies to the private operators interested in investing in this sector. • On the other hand, the government can

Barriers to and measures to overcome Barriers to Waste Water Stabilization Pond

Barrier Category	Barriers	Measures
		impose strict and elevated tax for those operators discharging or disposing waste water.
	ii. Weak implementation of the land policy	The government has to strengthen and enforce urban planning laws and regulations. Urban residents who happen to reside close to the WSPs have to be resettled and compensated appropriately for their reallocation.

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AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
ARIs	Agriculture Research Institute(s)
ASA	Agriculture Seed Agency
CWSS	Community/Commercial Water Supply and Sanitation
CWSSP	Community/ Commercial Water Supply and Sanitation Programme
EWURA	Energy and Water Utility Regulation Authority
GDP	Gross Development Product
LGAs	Local Government Authority (s)
MALF	Ministry of Agriculture, Livestock and Fisheries
MLHSD	Ministry of Lands, Housing and Human Settlements Developments
MFI	Micro Finance Institute
MIT	Ministry of Industry and Trade
MoHCDEC	Ministry of Health, Community Development, Gender, Elderly and Children
MOF	Ministry of Finance and Planning
NAWAPO	National Water Policy
NRW	Non Revenue Water
NWSDS	National Water Sector Development Strategy
PORALG	Presidents' Office Regional Administration and Local Government
RWH	Rain Water Harvesting
SAGCOT	Southern Agriculture Growth Corridor of Tanzania
SWM	Smart Water Metering
SWMS	Smart Water Metering System
TAP	Technology Action Plan
TDV	Tanzania Development Vision 2025
TNA	Technological Needs Assessment
TOSCI	Tanzania Official Seed Certification Institute
WRMD	Water Resources Management and Development
WRMDP	Water Resources Management and Development Programme,
WSDP	Water Sector Development Program
WSP	Waste Water Stabilization Pond.

CHAPTER 1: AGRICULTURE SECTOR

Agriculture is one of the two prioritized sectors for adaptation to climate change under the TNA project in Tanzania. Tanzania has total area of 94.5 Mha of land, of which 44 Mha are classified as suitable for agriculture. Out of the available arable land only 10.1 Mha or 23 percent of is currently under cultivation. Food crop production dominates the agriculture economy, with 85 percent of the annually cultivated land under food crops. Women represent the majority of the agricultural labor force.

Over many years, the agriculture sector has been by far the single most important sector in economic growth of the country. It represents about 27% of National Gross Domestic Product (GDP), 75% of exports, and provides employment for about 75% of the working population. Agriculture is linked to the non-farm sector through agro-processing, food consumption and export sectors, and provides raw materials to industry. Agricultural GDP has grew at 4.3% in 2012. Thus It is the engine of the economy as it provides employment, merchandise for exports, source of food supply and raw materials for both local and international industries (MAFC, 2013).

Farmers in Tanzania can be placed in three categories:

1. Small-scale subsistence crop producers: They comprise more than 90 percent of the farming population cultivating average farm sizes between 0.9 ha and 3.0 ha.
2. Medium-scale farmers (also known as commercial farming with farm sizes of 5 - 100 ha). (Jayne et al, 2016)
3. Large-scale farmers (also known as commercial farming with farms sizes > 100 ha).

The major staples include maize, sorghum, millet, rice, wheat, pulses (mainly beans), cassava, potatoes, bananas and plantains.

Major constraints for agriculture in Tanzania are the decreasing labor and land productivities due to application of poor production technology and dependence on unreliable and irregular weather conditions. Tanzania's level of farm mechanization still remains low as 62% of land is cultivated using basic manual tools. About 70 percent of Tanzania's crop area is cultivated by hand hoe, 20 percent by ox plough and 10 percent by tractor. The sector is highly constrained by small size of farm holdings cultivated by households with low disposable incomes generated by farmers. The farmers are faced by difficult borrowing conditions from financial institutions resulting in inability to invest in costly machinery and low investment capacity which contributes to the poor performance of the sector.

The TNA report prioritized three adaptation technologies for agriculture namely promoting use of improved seed varieties, System of Rice Intensification and Drip irrigation for the further analysis and development of the technology action plan (TAP).

Process of identifying barriers:
After identifying and prioritising technologies for the agriculture sector during the Technology Needs Assessment stage, an analysis of barriers that hinder the transfer and diffusion of such technologies was carried out through stakeholder consultations (see Annex IV) supported by literature reviews and specialist inputs. The barriers identified were prioritized and ranked according to their significance.
After compiling a long list of barriers, a stakeholder workshop was organized in order to screen and categorise them into "economic and financial barriers" and non economic barriers. The non economic barriers were further categorized into different groups to facilitate the discussions. For identification of most important barriers, a simple method was applied grouping them into key and non-key barriers.
The adaptation technologies identified and prioritized for the agriculture sector using Multi Criteria Decision Analysis are shown in Table 1.

Table 1: Prioritized technologies – Agriculture Sector

List of Prioritized Technologies	Category of the Technology
Improved Variety Seeds (ISV)	Consumer goods
System of Rice Intensification (SRI)	Other Non market goods
Drip Irrigation (DI)	Consumer goods

1.1 Preliminary Targets for Technology Transfer and Diffusion

This section provides an overview of the targets for diffusion of the prioritized technologies and the potential beneficiaries.

1. **Improved seed varieties (ISV)**

Improved Seed varieties are characterized by early maturing traits, tolerance to pests and drought meant to enhance resilience of crops to climate change hazards, particularly drought, extreme heat and shorter rain seasons. Improved seed varieties are widely used for production of food crops in Tanzania.
This technology is mainly targeted at small scale farmers across the country to address the increasing threat of food insecurity. Preliminary comparisons with the 2002/03 agricultural census show that use of key modern technologies by smallholders has remained remarkably constant just less than 20% households use any improved seeds (NBS, 2009). The Agricultural National Sample Census (NPS, 2012) provided data on the actual use of improved varieties, which was about 17% about 1,488,893 hectares indicating around 1,000,000 households. On the other hand, the total area without improved seed is 7,319,878 hectares representing 83% area of the total planted land (URT, 2012). The target is to achieve the diffusion of improved seed varieties technology to cover at least 50% of

households who are not using improved seed in a period of 10 years. The preliminary target for the transfer and diffusion of improved seed varieties is to introduce the technology to 2,500,000 farming households by the year 2030.
In order to achieve these targets, the stakeholders to be involved include policy makers in agriculture sectors, related government ministries and departments including ministry of Agriculture. Others players include manufacturers of technology components, wholesalers and retailers, technicians and researchers and experts in agriculture and irrigation sectors. The implementers including women and youth groups at local level, CBOs and NGOs dealing with agriculture issues at local and national levels and community leaders will be key players in the transfer and diffusion of the technologies in the agriculture sector.
This technology is also in line with the government policy to increase food production particularly the Agriculture and Livestock Policy (URT, 1997) with aim of improvement of the wellbeing of the people whose principal occupation and way of life is based on agriculture. The focus of this policy is to use modern production technologies and to commercialize agriculture so as to increase income levels. Thus small scale farmers are in good position to adopt the new technologies to adapt to climate change.

2. System of Rice Intensification (SRI)

SRI is an agro-ecological technology aimed at increasing the yield of the rice produced in irrigated farming by changing the management of plants, soil, water and nutrients. This technology requires 70-90% less rice seeds thus is less costly, 20-25% less nitrogen fertilizer and chemicals than conventional rice cultivation, and hence decreasing GHG emissions while increasing productivity by 10-15%.
Rice production in Tanzania is expected to reach 1.2 million tons of milled rice per year whereas the consumption needs are about 1.39 million tons, there is, therefore, a need to import about 200,000 ton of rice in 2013/2014 (Oriza 2014). Long-term projections for the East African region are for a substantial and growing deficit in food. The rice deficit is expected to rise from 1.15 million tonnes in 2009 to 2.84 million tonnes in 2020, with a rising trend forecast to continue until beyond 2025. A critical factor in terms of exports, however, is the rate of rice production growth in Tanzania. Production in the decade from 2001 to 2011 grew at 6.99 percent per annum but, because of a rapidly growing domestic demand, Tanzania will find it difficult to achieve and sustain an export surplus. If the rice sector were to achieve a 10 percent annual growth rate, there would be surplus available for export; a 5 percent annual growth rate would, conversely, result in increasing trade deficits (Wilson, R. T et al, 2015).
Rice in Tanzania is mainly grown under upland rain fed conditions (about 80-90%), and about 10-20% is grown in irrigation schemes (Aune, *et al* 2014). Given the impacts of climate change on water availability, SRI has been introduced as a technology aimed at increasing the yield of rice. SRI technology is targeted mainly at small scale rice growing farmers in

areas where there is low productivity mainly due to scarcity of water, poor agronomic practices and low soil fertility. The preliminary target for the transfer and diffusion of system of rice intensification (SRI) is to introduce the technology to 100,000 rice farming households by the year 2030.

In order to achieve these targets the stakeholders and players to be involved include policy makers in water and agriculture sectors, related government ministries and departments including ministries of Water and Irrigation and Agriculture. Others players include wholesalers and retailers, technicians and researchers and experts in agriculture and irrigation sectors. The implementers including women and youth groups at local level, CBOs and NGOs dealing with agriculture issues at local and national levels and community leaders will be key players in the transfer and diffusion of the technologies in the agriculture sector. This technology is also in line with government policy of participating in climate change mitigation activities that contribute to its sustainable national development (NCCS, 2012) as it reduces GHG emissions in rice production by reducing flooding irrigation, as is the case in traditional paddies.

3. Drip irrigation (DI)

DI is one means used by farmers to efficiently use water for agriculture as a means of adaptation to droughts. Tanzania's National Irrigation Master Plan (URT, 2002) identifies a total irrigation development potential in Tanzania of 29.4 million ha. The current irrigated area is about 450,392 ha (URT, 2013). Less than 5% equivalent to 276,958 farming households use irrigation (URT, 2013; NBS, 2009).

The Tanzania Agriculture and Food Security Investment Plan for 2011-12 to 2020-21 (TAFSIP), includes irrigation among its six investment priority areas. The main goals in the sector are to expand the area under irrigation (although no specific target is mentioned) and to improve existing traditional irrigation schemes and promoting water use efficiency.

Many small holder farms have a size range between 0.2 to 1.5 ha of land which accounts for 66% of households, there is therefore a high potential of these farmers to transform their agriculture to commercially viable farmers (URT, 2012).

The target is to achieve the adoption of drip irrigation technology for 1,000,000 households of small scale farmers to eventually cover 1,800,000 ha of various horticulture crops, over a period of 10 years by 2030. Looking at the technology diffusion cost, the technology is widely variable; however the cost of a drip irrigation system ranges from US$ 800 to US$ 2,500 per hectare depending on the specific type of technology, automatic devices, used materials as well as the amount of labor required.

This technology is targeted mainly at small scale farmers to address the availability of proper nutrition through availability of horticultural products and areas where there is potential for high-value agriculture (particularly horticulture).

Small scale farmers produce a range of horticultural crops across the country. Fruits and vegetables are grown in all regions, with greater potential in highland areas, including Tanga in the Usambara highlands, Kilimanjaro, Arusha in the northeastern highlands, Iringa, Mbeya, and Morogoro in the Uluguru Mountains. The Dodoma region in central Tanzania has potential to grow grapes and watermelon.

While fruits such as mangoes and oranges are mostly rain-fed, vegetables and flowers are commonly produced under irrigation.

This technology is also in line with government initiative of Agricultural Growth Corridor (SAGCOT) –in partnership with the private sector and civil society to stimulate public private partnership investments in high-value agriculture across the main corridor running from Zanzibar through the Southern Highlands to the borders with Malawi, Zambia, and the Democratic Republic of Congo. This initiative illustrates the interest and commitment from the government to facilitate new investments from agribusinesses across key smallholder growing areas.

1.2. Barrier Analysis and Possible Enabling Measures for Technology 1: Improved seed varieties (ISV)

1.2.1. General description of the technology

Improved seeds[1] varieties technology reduces the risk of total crop failure and provides the producers with chances of dealing with the uncertainty created by climate change because they require relatively less rainfall compared to conventional seeds. ISV are characterized by early maturing, pests and drought tolerant traits meant to enhance resilience of crops to climate change hazards, particularly drought, extreme heat and shorter rain seasons.

ISV is a consumer good involving public and private sectors as well as different actors within the market chain, mainly seed and seedling importers, which are usually agriculture companies. ISV imports are mostly on demand, where farmers make their special orders. Imported plant material is in many cases patented by plant breeders with Intellectual Property Rights (IPR), which add to the price and make the ISV more costly.

Increasing agricultural productivity, and hence total cereal production using improved agricultural technologies, has been identified as a precondition for achieving food security (Langyintuo *et al*., 2000). Small-scale farmers depending especially on subsistence agriculture have the potential to increase their welfare and food security situation if they adopt improved seed technologies.

Tanzania has a Seeds Act (2003) which emphasizes private sector participation in seed production and distribution in the country and has introduced measures to ensure that the seed produced and imported meet a set of required standards. Under the Act, a National

[1] Seeds that aim at increasing quality and production of crops by having characteristics such as drought tolerance, high yielding and early maturity (FAO, 2009).

Seed Committee functions as an advisory body to the Government. An official Seed Certification Institute (TOSCI) was also formed, with major functions relating to variety release and registration, seed certification, and training. Regulations associated with the Act were introduced in 2006. To address public varieties under the Act, Tanzania established a public Agriculture Seed Agency (ASA) to produce and distribute foundation and certified seeds. ASA operations have thus far had little effect on the market, particularly with regards to seed multiplication, and a number of private companies question the rationale for the Government to establish such a public agency after having opened the market. The Act allows for a mechanism to promote on-farm seed production and multiplication of seeds. Smallholders are now able to produce "Quality Declared Seed (QDS)" by following the formal certification process.

In 2008, the total arable land available in Tanzania was 14,642,284 hectares, 99.1 per cent (14,516,893 ha) of which is on the Mainland and 0.9 per cent (125,391 ha) in Zanzibar (NBS, 2012). Most of the land (66 %) is planted with annual crops, while permanent or perennial crops occupy 15% and about 8% is a mixture of annual and permanent crops; the remaining area (11%) is kept under fallow (ASARECA/KIT, 2014). This means most of the land has to be replanted every year and requires large amounts of seed and planting material. Some 20% of the cropped area is planted in the short rainy season and 80% in the long rainy season. However, reports from De Groote et al, (2014), ASARECA, (2012), and Mafuru, *et al*, (1999) show very low adoption of improved seed varieties.

Most commercially-sold seeds in Tanzania are imported. In 2010, 89% of the seed available in Tanzania was imported from four major countries: Malawi, Kenya, Zambia and South Africa (World Bank, 2012). To import seeds for varieties that are already approved to be sold in Tanzania, companies need an import permit from the Seed Unit of the Ministry of Agriculture and Cooperatives. A phytosanitary certificate is also required. The overall process can take up to 10 days. Tanzania is a member of the International Union for the Protection of New Varieties of Plants (UPOV) since 2015. Thus ISV can be multiplied in the country.

The majority of farmers grow improved varieties for 2-4 years, before replacing their crops with a new variety. At the same time, certified seed is bought once every 2-4 years, which appears to suggest that farmers purchase improved seed only when they change varieties and not as a routine practice to keep the yield potential of their crops high. For rice, it was noted that producers can avoid buying seed for more than 10 years (AGRA, 2010).

Generally, the proportion of farmers who are aware of improved seed varieties such as sorghum varieties ranges from about 16% in Lindi (Southern Tanzania), to as high as 80 % in Dodoma (Central Tanzania). Those with experience in growing these varieties also ranged from as low as 6% (Lindi) to as high as 62 % in Dodoma (Mgonja *et al*, 2002).

Only 27 % of cropped area for maize is estimated to use improved seed. With respect to rice cultivation, this proportion is much lower, with only 1 % of cropped area estimated to be planted with improved seed. The 2010/11 National Panel Survey (NPS) found that just 16.8 percent of rural households used improved seeds (WB, 2012). With such low levels of awareness, there is a need to promote use of this technology to enhance food security.

1.2.2. Identification of barriers for the technology

For initializing the barrier analysis process and identification of enabling measures, the consultant did a desk study of policy papers and other pertinent documents in order to identify the primary reasons why the technology is not widely adopted, and why neither the private nor public sectors have invested significantly in it. This was followed by a consultation process with stakeholders through direct interviews. Parallel to that, a technology working group representing relevant stakeholders was formed.

Barriers identified related to improved seed varieties technology are discussed below:

1.2.2.1. Economic & financial barriers

The following three economic & financial barriers were identified:

i. Improved seeds are more expensive compared to traditional available seeds as improved seed varieties take a long process to be released for adoption

Income has a direct correlation with adoption of technologies (Roger, 2003). Farmers who are well off can afford expensive new improved technologies in contradiction to low income farmers. Rahmeto (2006) adds that for rural farmers, farm income is the main source of capital to purchase farm inputs and other household consumable goods. Given the low farm incomes levels, this leads to low adoption of improved seed varieties. Many small scale farmers in the rural areas practice subsistence farming. Thus the purchasing power of these farmers depends very much on their income. Improved seed varieties are expensive compared to local seeds. Certified seed is relatively expensive in Tanzania, at 7 times the grain price for open pollinated variety (OPV) seed and 10 times the grain price for hybrid seed which is considered high. In terms of seed sector business development, purchasing power is a constraint. While seed costs are typically estimated to be modest, a hectare would require between 20-25 kg of seed, which can cost about US$25/ha for open pollinated varieties and US$50/ha for most common hybrids. In an environment of US$700 annual per capita income, seed expenses for one hectare would easily constitute the equivalent of one month worth of income for farming household.
As a result, many farmers cannot afford to buy these seeds. Even if sold at half-price, certified seed remains relatively expensive in comparison to informal seed (ASARECA/KIT, 2014). Furthermore, charges by Tanzania Official Seed Certification Institute (TOSCI) for certification, regulation and variety registration are costly for breeders and hence increase the costs of seeds to smallholder farmers (Mkindi, 2013). The seed-to-grain price ratio for maize crop using hybrid seed is 10:1.

ii. Difficulty to access finance

Most farmers do not have access to affordable finance in order to purchase high quality seeds and implement all the necessary accompanying agro-technical measures. Access to financial services, is critical to provide funds for farm investments in improved production methods, improve post harvest practices, augment household cash flow, enable better access to markets and promote better management of risks. Access to a comprehensive range of financial services is a significant challenge for smallholders. In 2011, only 8% of the rural population had access to formal financial institutions (banks and insurance companies) (WEF, 2013). Credit from commercial banks has increased significantly but only 12% of this credit went to agriculture by 2013. Only 8% of the domestic lending to agriculture went to agricultural production, with the rest channeled to agricultural trading. Bank interest rates on loans to agriculture are high, averaging 30% and the commonly offered short term loans are not attractive for farmers or agribusinesses. Further, in the absence of titles to land, smallholders have little if any collateral to offer. The Tanzania Investment Bank has an agricultural window offering concessional loans and an Agricultural Input Trust Fund (AGITF) has been issuing short term soft loans since 1994, in particular to farmers and farmers' groups for farm machineries and to stockists for inputs. The Tanzania Agricultural Development Bank (TADB) is also being established. However, these schemes mainly target medium-scale farmers who have collateral, and do not reach most smallholders (OECD, 2013).

iii. Economic viability is not guaranteed

Smallholder farmers' decision to adopt new technology is usually based on the potential profitability and perceived risks associated with adopting the new technology. Much as improved seed varieties are associated with increased yield and thus food security, farmers are uncertain about what they will do with the increased harvest. This is due to a limited access to markets to absorb the increased production from improved seed technologies. For example, the seed-to-grain price ratio for maize crop using hybrid seed is 10:1, which is considered high. As a result, many farmers cannot afford to buy seeds. Further, periodic export bans by the government on cereal crops have adversely affected the sector from time to time as producers have less or no incentive to invest in the production of crops they are unable to sell later. Produce cess does not consider whether buyers have made profit or loss and, in practice, this tax is often absorbed by the producers which represent a significant fiscal burden (OECD, 2013). Due to this fact, the majority of smallholder farmers tend to ignore the adoption of new technologies

1.2.2.2. Non Financial barriers

a. Awareness and information

Farmers get information from different sources such as radio, extension officers, seed producers, relatives, project organizations and school children. However, the majority of farmers get information from extension officers. Given that many farmers are in remote areas with limited access to extension services, accessing information on subsidies and prices of improved seeds is very challenging. Awareness is an important aspect for technology adoption. Studies shows that the major constraints facing farmers in accessing information were limited availability, poor reliability, lack of awareness of information sources available among farmers and untimely provision of information (RLDC 2009; Ozowa, 1995; Matovelo, 2008). Further, farmers still lack awareness about improved seeds and their higher yields. There is a general lack of awareness of, and demand for, certified seed of improved varieties.

b. Human Skill

i. **Inadequate human capacity**

Use of improved seed varieties have to be supported by proper practice of agronomic principles. This includes preparation of farms, proper utilization of the right fertilizers, pest control, etc. Farmers lack that knowledge, and there are also inadequate extension services to support them. Thus when the yield is below expectations, this can lead to disillusionment about the technology.

ii. **Inability to distinguish genuine and fake seeds**

Due to the poor knowledge of improved seed varieties, farmers usually face a challenge of buying fake[2] seeds due to ineffective quality control of seeds they receive. A country with a reported 20-30% of fake seed needs to take urgent steps to protect farmers. A fake seed average of 25% and a national production of 28,000 tons of seed signify that over a quarter of a million farmers are not only being cheated but their livelihoods put at risk each year (Chambers, *et al* 2013). Agro dealers have limited technical know-how of agro-inputs and thus through ignorance of dealers and hence farmers, suppliers of counterfeit seeds find it easy to penetrate up to farm levels. Due to poor knowledge to identify fake seeds, in turn farmers' trust in agro-dealers and the use of agro-inputs is undermined.

[2] Fake seed include seed varieties that are; 1) of poor quality with low germination; 2) of poor quality with moisture and other varieties; 3) have been altered with grain; 4) repackaged in fake containers; 5) sold with expired labels; and/or 6) not registered in the national variety catalogue.

c. Technical

i. Complexity of the technology

Adoption of improved seed technology requires enough knowledge of technology vs the surrounding environment. Farmers are concerned about the capacity they have to cope with the wealth of detailed and complex information available to them, highlighting the need for transparency in research and information. The country is increasingly contrained by inadequate and often decreases funding for research(MAFS, 2001). Farmers do not have adequate technical support to adopt these improved seed varieties, as there is weak research-extension-farmer linkage. A study on fertilizer use in Tanzania (AGRA & IFPRI 2011) observed that low usage of improved seeds is due to limited scientific information among stakeholders on the proper agronomic uses of fertilizer. Farmers use fertilizer of the same type and quantity that they used in the past and very little consideration is given to soil health as most of them do not have training in farming practices. This is a result of poor extension where the dwindling funding to research and development limits the national extension service to recommend the most correct advice given a particular situation for soil type differences or nutrient deficiencies, factors which require soil testing.

d. Institutional and Organizational capacity

i. Delayed release of improved seed varieties

Limited availability of good quality seed is a key constraint repeatedly identified by farmers in rural areas in many countries. Release of improved seed varieties in Tanzania is perceived to be slow as a result of lengthy procedures. The public release of the seeds is through an authorized government institution mandated to produce and distribute basic seed and certified seed called Agricultural Seed Agency (ASA). However, the ASA is constrained by limited promotion of new varieties, inadequacy in supplying sufficient basic seed in the amounts and at the time required by the seed companies. The release of the varieties is also constrained by the certification and release of new seeds process by the government authorities which takes a minimum of three years through a quality control agency Tanzania Official Seed Certification Institute (TOSCI). For farmers, improved seeds will most likely be assimilated and implemented when: the benefits of use of such seed will be quickly realized (within one to two years), the seeds are readily available and accessible in the local marketplace, the risk of the use of seeds are small and the use of such seeds can be comfortably integrated into other basic on-going aspects of daily life.

e. Policy, legal and regulatory

i. Non recognition of role of farmer managed seed system.

Farmer managed seed systems that supplies almost 90% of seeds to farmers is not recognized or supported by the seed policy and regulatory frameworks unlike the formal seed sector which supplies improved seed varieties catering for only 10% of seeds, but in contrast attracts the lion share of public support, funding, and regulatory mechanisms. The policy, however, allow for the participation of smallholder farmers in seed production through the Quality Declared Seed (QDS) system only. QDS is legally recognized, but the regulation restricts its marketing within the ward where it is produced. In addition, it also has to be multiplied from formally registered varieties. These requirements hinder seed multipliers who aim to respond to an increasing local demand for quality seed and develop viable local seed businesses. This discourages farmers and indicates non involvement of farmers in policy formulation and consequent difficulties in adoption of improved seed varieties.

ii. Limited incentive to produce for market

Incentives to produce food crops for the market are inadequate. While improved seeds are advocated to result into increased harvest, The Agricultural Sector Review 2006 (MAFC, 2006) indicates that there are existing taxations (e.g. high corporate tax, import duties on agro-processing equipment) which discourages the production of food crops in general and for the market in particular.

f. Social/cultural behavior

i. Convenience to and acceptability by small scale farmers not evaluated

There is poor information among small scale farmers on the potential benefit of the different seed varieties. This hinders the fast adoption of seeds. Before farmers decide to invest in improved seed varieties they usually prefer to observe and learn challenges and the performance of other farmers' crops (i.e. they want demonstration of proof of concept). This behavior hinders the adoption of improved seed varieties as farmers learn by doing and there are limited areas that they can learn from. This behavior impacts on the depth of marketing, and promotional activities required to encourage farmers to adopt new varieties.

1.2.3. Identified measures for the technology

The enabling measures to overcome barriers were identified through stakeholder consultations. The measures identified to overcome the barriers are given below:

1.2.3.1. Economic and financial measures

Measures:

iv. **Reduce cost of release of seeds by regulating processes at TOSCI:** Tanzania Official Certification Institute (TOSCI) is a semi-autonomous institute, responsible for seed certification and seed quality control. This institution, charges certification, regulation and variety registration for breeders. These charges usually at the end of the day are borne by the final consumer. Thus simplifying the variety release procedures and the involvement of the demand side actors may lower the price. Also it is necessary to strengthen the capacity of TOSCI to increase its efficiency and effective delivery of its services by addressing the financial, human and infrastructural constraints it faces, also to reduce the time it takes to release a new variety, as this has implications for the seed cost (currently it takes three years to release a new variety).

v. **Increase knowledge of available financial services to farmers:** There is a need for deliberate efforts of microfinance institutions to provide technical assistance, and information on credit acquisition. Also it is important to promote initiatives that will support rural and agricultural populations to create alliances with other actors (NGOs, governmental entities, producer organizations, etc.) to set up complementary services like training and technical assistance (TA). Training possibilities could be ranging from management or financial advisory services to farmers, to capacity building on entrepreneurial skills and how to use agricultural produce to repay back the loans. This will strengthen farmer's capacity to acquire and service loans.

vi. **Increase farmers' Market access- processing and distribution channels:** Government can strengthen farmer's chances to access finance by supporting and building long-term relationships for the different actors in the agriculture value chain. Strengthening of relationships between actors in marketing will provide farmers with information of available markets for their produce to enable them to decide on investment decision and use of technology. Such relationships can also play virtual guarantor role. In the long run, increasing the supply and competition in seed markets to make more seed available to many farmers at prices they can afford represents one of the most sustainable solutions. There are examples of value chain actors playing the limited role of "virtual guarantor", in which case a producer's mere association with a large buyer or processor, for instance, serves as a sign of creditworthiness in the eyes of financial institutions.

vii. **Encourage formation of groups or associations of small scale farmers:** The government can support the formation of lending groups or associations which will reduce MFI cost of reaching rural clients and operating in remote areas. The successful development of these institutions is fundamental to accelerated agricultural development. If small scale farmers, who represent the vast majority of Tanzanian farmers, can be helped to become better organized and better represented, they will be able to establish a foundation for improved credit systems, input and technical service delivery and marketing, and a platform for the articulation of farmers' needs. They will be better placed to organize demand–driven research and extension services. Farmer groups and associations can reduce client analysis and selection costs for lenders, as well as enhance the access of farmer clients to agricultural inputs and markets. Bringing small farmers together in well-organized farmer associations or locally run village banks can make them more attractive and cost-effective borrowers, leading to the greater availability of rural credit from financial institutions and agribusinesses.

1.2.3.2. Non Economic/ financial measures

a. Awareness and information

Measures:

iii. Strengthen information sharing of farmers through improving extension services. Promote use of farmer field's schools to promote use of improved seeds.

iv. Reorient ASA funding to promote the development of new seed companies in under-served regions of Tanzania through private sector services in marketing, business planning, and internal quality control mechanisms, as well as increasing farmers' understanding of the importance of certified seed.

b. Human Skill

Measures:

i. **Improve human capacity:** Engage with the private sector in public private partnerships (PPP) so as to strengthen capacity of famers and extension agents to utilize improved seeds. PPPs can be used as a means to access critical resources and achieve sustainability and scale in rural poverty reduction. This would include training on how to use seeds properly through proper agronomic practices at village level and funds to build capacity of extension agents.

ii. **Develop programmes to educate stakeholders to distinguish fake and genuine seeds:** Educate farmers to identify genuine seeds through selection of seeds in the value chain. Certification seal by Tanzania Bureau of Standards (TBS) should be mandatory for all seeds. All wholesalers and retailers would check for the seal before buying and selling. Regulation of seed quality by standardization and monitoring should be a regulation issue where, wholesalers and retailers would therefore be required to watch out for the TBS seed seal. The programme should be implemented while strengthening the link of farmers, research and extension on seed issues; connecting local market to breeders; and developing a seed quality control (certification) system.

c. Technical

Measure:

i. **Complexity of technology:** The government to strengthen the research and development to provide necessary support to farmers to be able to address technical issues of the adopted technology. Such support may include, simplifying the technology to suit the present situation, ensure accessibility of spare parts and technical maintenance of the technology.

d. Institutional and Organizational capacity

Measure:

i. **Delayed release of improved seed varieties**

Reduce time for release of improved seed varieties: This involves reducing the time required for seed variety registration and release, and revising the committee process for variety release. Variety release decisions undergo four levels of review before a final decision is made. Streamlining this process through combining the NPT-TC and National Variety Registration Committee (NVRC) and eliminating review by the NSC would avoid lengthy delays in variety release and bring Tanzania's procedures in line with those of its East African neighbors. This reform will require an amendment of the Seed Act and is indeed already contemplated as part of the proposed amendments to the Seed Act.

e. Policy, legal and regulatory

Measure:

i. Seed quality control programme: Tanzanian government should develop strategies that explicitly recognize farmers' rights and support flexible and adaptive seed quality control processes appropriate to local conditions. This can be done by developing a national program for the control of seed quality in the marketplace. A good seed market quality control program over a 2-year period with randomized site visits, clarification and expansion of powers to inspectors, district inspectors, and police, and a stiffer system for penalizing offenders would make a significant impact on would-be cheaters. Specifically this program should recognize and provide for exemptions in the seed law for all uses of farm-saved seeds so as not to criminalize farmers' activities concerning seed, and remove propriety ownership on all seed once it enters the farmers' seed system.

ii. Funding support for the development of an inclusive seed R&D programme. Public resources through programmes and budgets should be channeled towards experimentation and development in farmers' existing seed systems through the improvement and development of farmers' varieties. Farmers should not only be seen as the end user but as part of the system/value chain as breeders and seed producers in meeting the demand of seed in the seed sector.

iii. The Tanzanian government should consider promotion schemes for agriculture similar to those existing in tourism and mining (e.g. tax reductions, special loan facilities).

f. Social/ Cultural Behavior

Measure:

iii. **Demonstration of improved seeds**: The release of new varieties needs to be accompanied by establishment of demonstration fields which can be used for the learning purpose where all technical issues can be resolved. Through observation and learning, farmers will have information that will enable them to make informed decisions. These fields will promote the released varieties and fast track adoption.

iv. **Establish networks**: Government to address the value chain actor coordination challenge through consultation with all key stakeholders in seed management. Relevant government institutions should develop communication strategy, awareness materials and promotional strategies to ensure public acceptance of ISV.

1.2.4 Cost benefit analysis

Since improved seed varieties are diverse and different from one crop to another, in this particular exercise sorghum is selected for the cost benefit analysis exercise as shown in Table 2. This crop is not only vulnerable to climate change, but is also of national importance. In Tanzania, it is the second most widely grown cereal grain crop, cultivated on an area of approximately 700,000 ha with an annual production of about 500,000 mt. Sorghum is almost entirely grown by smallholder farmers on a subsistence level. Less than 2% of the harvest enters the formal market. Thus, the main contribution of sorghum is to farm household food security (Rohrbach and Kiriwaggulu, 2007). In recent years, a number of high yielding sorghum varieties, which are also tolerant to other field problems such as pests, diseases and weeds have been developed by the Department of Research and Development, Tanzania in collaboration with international research organizations, e.g. ICRISAT. Despite research efforts, adoption of new sorghum varieties by farmers and spread of improved sorghum production and storage practices (i.e., fertilizers and insecticides for storage) have been low. Thus local varieties are still widely grown (Mafuru *et al.,* 2007).

It is assumed that the small scale farmers specialize in the growing of sorghum on 1 ha piece of land. Key assumptions for the CBA for sorghum production are as follows:

- The average sorghum yield for Tanzania is estimated to be approximately 451 kg ha^{-1}.
- a field price of 450 Tanzanian Shilling (Tsh) per kg was used. The field price is the average price at crop harvest. Prices, however, cannot directly be linked to the variety. This estimation is based on the price of crops during harvesting period. It is not fixed and varies from season to season (CIMMYT, 1988).
- The deployment of improved sorghum cultivars in Tanzania could raise the nationwide average sorghum yield substantially above the current average nationwide cereal yield of approximately 1000 kg per hectare (FAOSTAT, 2008).
- variable cost (seed, fertilizer, labor) will be the same for all cultivars
- Quantity of labour used for each operation for sorghum and millet. Total labour use averaged 234 man-days/ha for sorghum

- Family labour accounted for 87 % of total labour use for sorghum

Table 2: Elements of Costs and Benefits of the Existing Scenario and of adopting Improved Seed varieties Technology

	Existing scenario	Adaptation Technology
Description	Cultivation of local variety of sorghum using hand hoe on 1 ha plot of land	Cultivation of Improved variety of sorghum using hand hoe on 1 ha plot of land
Adaptation objective		The technology reduces the risk of total crop failure and provides the producers with chances of dealing with the uncertainty created by climate change because they require relatively little rainfall
Key assumptions	1 ha piece of land by 1 small scale farming household Cultivation of local sorghum variety (2009-2010 farming season) - Land rent is valued at zero in rural areas. - $1=Tsh 2130 - Farming household spends 5 hrs per day in the field. - Unit price of labour is $ 2.4 per day/person. - Total of 234 man-days. - Yield for local sorghum is 451 kg/ha - Unit price of sorghum per kg is $ 0.11	Assumptions are the same as for conventional technology except for the following: - Cultivation of improved sorghum variety (2009-2010 farming season) - Total of 234 man-days are being used. - Yield for improved sorghum is 1000Kg/Ha
Benefits	- Crop yield x price=451 Kg x $0.11=$49.61	- Crop yield x price=1000 Kg x $0.11=$110
Breakdown of costs	- Ploughing & ridging:$ 28 - Weeding (x2): $24 - Planting: $10 - Harvesting: $10	- Ploughing & ridging: $28 - Plant protection: $5 - Weeding (x2): $20 - Planting: $18 - Harvesting: $13
	Total cost: $72	Total investment cost: $
Key assumptions	the cost of improved seeds compared to current ordinary seeds	

It is clear from the above analysis over 10 years that the value of the Improved Seeds Variety technology has positive cost benefits and it is therefore viable, either for marketing or as a way strategy for avoiding food purchases.

1.3 Barrier Analysis and Possible Enabling Measures for Technology 2: System of Rice Intensification

1.3.1. General description of the Technology

Rice is the second most cultivated food and commercial crop in Tanzania after maize, with a cultivated area of about 681,000 ha, which represents 18% of the cultivated land. Yields are generally very low (1-1.5 tons/ha.) as most rice is grown with traditional methods. In addition, 71% of the rice is grown under rainfed conditions. About half of the country's rice is grown by 230,000 smallholder farmers in the Tabora, Shinyanga and Morogoro regions of the Central Corridor. With large amounts of suitable, unfarmed, arable land, a high rate of self-sufficiency and potential for increasing yields, the Government of Tanzania hopes to increase rice production and become a large net-exporter of rice.

A new method of paddy cultivation was introduced to Tanzania in 2009 by Kilombero Plantations Limited in an effort to increase the country's food security. It was further adopted through a project aiming at introducing climate smart agriculture in Kiroka village in Morogoro Region that was initiated by FAO and Sokoine University in 2011 and this has resulted in tripling some farmers' yields with system of rice intensification (SRI). As of 2013, SRI was being practiced in Mkindo and Dakawa in Morogoro region, and in the Mwanza and Kilimanjaro Regions. The method has successfully increased the yield of paddy significantly with less water, less seed as well as with less chemical inputs than the conventional method of paddy cultivation. A note from World Bank (2007) argues that six key elements distinguish SRI farming practices from traditional rice growing methods. They are (a) transplanting seedlings much earlier than in conventional methods, (b) planting only one seedling per hole, rather than a handful, (c) spacing plants wider apart than in conventional methods and arranging them in a square pattern, (d) applying water intermittently instead of continuous flood irrigation, (e) using rotary weeding to control weeds and promote soil aeration, and (f) applying organic fertilizers to enhance soil fertility and yield.

1.3.2. Identification of barriers for the Technology

1.3.2.1. Economic and financial barriers

i. Inadequate financial resources

Practicing SRI requires a close monitoring of proper agronomic practices. These include systematic preparation of farms, timely sowing of the seeds and weeding. These practices need to be supported by availability of improved variety rice seeds and other agro inputs such as fertilizers and hand-pushed rotary weeders. Because SRI is a labor-intensive cultivation method, it typically requires a reallocation of paid farm labor into family unpaid farm labor to perform time-consuming tasks such as weeding and compost preparation. For some poor farmers who have very few opportunities to earn cash, the cost is simply too high. SRI also requires good quality of seeds and fertilizers of which many rural farmers cannot afford. The availability of these agro inputs requires a farmer to have done a proper investment plan with enough financial resources to buy the agro inputs. Due to remoteness of many farms, farmers have to travel a long distance to buy these inputs. A number of initiatives done under SRI have been supported by the private sector. The private sector has been supporting farmers with the required inputs and ensuring farmers adhere to proper agronomic practices. Thus farmers have been faced with limited access to finance to practice SRI.

ii. Lack of agricultural credit and loans

Practicing SRI requires a prepared investment plan. Since SRI constitutes a set of new, unconventional and un-familiar agronomic practices, success relies heavily on sustained training and extension services. About ninety-five percent of farm operations in paddy production are done manually. These operations are coupled with intensive labour requirements. Planting is mainly done by hand, likewise harvesting, threshing and cleaning of paddy. Transportation of paddy from the field to storage (home/market) is by direct head loading and sometimes ox-carts or vehicles are used depending on availability. The labour input in rice cultivation is high, requiring between 300 and 350 man hours/ha, similarly manual transplanting and weeding are labour intensive, and each operation requires between 200 and 300 man hours /ha (URT, 2009). Introduction of SRI requires higher labor inputs than traditional methods for land preparation, crop maintenance, and water management, and thus adoption of SRI typically leads to reallocation of resources from other economic activities. The resulting decrease in household income from other activities may offset the income increase from higher SRI yields (Moser and Barrett, 2003; Barrett et al., 2004). Thus adoption of SRI requires farmers to have access to credit and loans to raise sufficient funds to invest in the technology (because of lack of capital, limited access to credit, or temporary cash flow problems). This also concerns funds to pay extra labour when the technology requires activities during peak-periods of normal fieldwork.

1.3.2.2. Non Financial Barriers

a. Information and awareness

An awareness of recommended practices or the optimum that is achievable in terms of efficiency determines adoption. A lack of understanding or knowledge about the recommended practices is often cited as a strong barrier to the adoption of recommended practices or innovations (Duvel, 1991).

i. Access to Information and Extension Services

Farmers typically have inadequate information regarding the technology. This may be due to poor extension services or poor research-extension linkages. When information passed is inappropriate and extension approaches are poor, it is difficult for the technology to be adopted. When farmers don’t have access to information on potential of SRI to deliver higher mean yields and mean income, they can easily abandon the practice. Currently, farmers learn by observing the performance on other farms, thus, in a situation where there is limited experience of SRI adoption is very low.

ii. Perception of climate change among the farmers

The negative impacts of climate change are arguably most felt by hugely agrarian and rainfed economies of many semi-arid areas. Perception is the process by which a person receives information or stimuli from the environment and transforms it into psychological awareness. Changing climatic patterns (as perceived by farmers) influences the decision to adopt SRI. Farmers perceive climatic changes through reduced rainfall and increased temperature. Those who have observed decreasing rainfall patterns are more inclined to adopt SRI than those who have not perceived these changes. This suggests that adoption of SRI could be regarded as an adaptation mechanism to climate change since one of its key objectives is to reduce water usage in rice farming while increasing the yield.

b. Human Skill

SRI is a knowledge-intensive cultivation technique that requires significant local adaptation and managerial skills but requires time and aptitude. Farmers are constrained by information and skills to manage challenges such as of increased harvest which are necessary for local adaptation of the technology.

c. Policy, legal and regulatory

i. Inadequate regulations and bylaws

Inadequate regulations to address irrigation issues on irrigation schemes are constraining SRI adoption. Examples of challenges of implementing SRI include the issue of when to irrigate and how to control seepage from neighboring non-SRI practicing farms. Discussions with farmers revealed a large number of farmers could not adopt SRI or abandon conventional rice farming practices because of irrigation issues. The irrigation system requires collaboration among farmers of nearby plots of land to pump water at the same time. Farmers in neighboring plots need to agree on timing of irrigation. Such decisions require proper information guided by agreed regulations to enable adoption.

ii. Frequent ban of crops export

While among the incentives to use of adaptation technologies is to increase yield, reduce vulnerability and ensure food security some policies hinders the efforts. The Tanzanian government has been implementing a policy of banning the exportation of food crops on several occasions since the 1980s. The government argues these bans ensure an adequate domestic food supply and help stabilize consumer prices. The export bans are implemented through a direct government gazette notice prohibiting exportation of food crop for a given period of time by eliminating the issuance of new export permits and also withdrawing export permits already given to traders. While low domestic prices benefit urban consumers, the bans negatively affect farmers' and traders' incomes by hindering their access to lucrative prices in international markets. Because the bans are often ad hoc and spontaneous, the policy causes market uncertainty which may have long-run implications for future food security and technology adoption opportunities.

Food crop export bans lower the prices farmers receive, and thus hurt farmers' profitability. As a result, farmers' welfare declines. Households that are highly dependent on food crops as a source of income are affected more by lower prices. Moreover, export bans discourage farmers from producing for income generation. Farmers are affected by the policy and are not satisfied with the income generated from sales, however do not stop producing; instead, they reduce their production to level of their households' level of consumption.

e. Institutional and Organizational capacity

i. Poor institutional coordination

The shared canal system presents challenges for effective adoption of SRI. Due to the need for intermittent flooding and draining, SRI requires more regular cleaning and maintenance of shared drainage canals than necessary under traditional methods to enable more precise water management. Because irrigation and drainage canals are shared, it is a challenge for a single farmer to adopt SRI while not assured of availability of water for irrigation. Thus it is important that at least the whole irrigation scheme adapt to the technology as coordinated adoption and canal maintenance may yield greater benefits than adoption in isolation.

f. Social, Cultural and Behavioral

Networks and social settings affect decisions of adopting a given technology. In the absence of inter-household coordination of uptake there may be social stigma effects associated with adopting visibly different rice production and water management methods within ostensibly homogenous production communities (Moser and Barrett 2006). Because SRI farms differ visibly from traditional rice farms, social norms and conformity pressures may discourage the ultimate adoption decision.

1.3.3. Identified measures for the technology

The identification of required measures to overcome key barriers has been carried out through stakeholder consultation and by using Logical Problem Analysis (LPA) methodology as described in the TNA Guidebook 'Overcoming Barriers to the Transfer and Diffusion of Climate Technologies'(see Annex I). The enabling measures thus identified are given below.

1.3.3.1. Economic and financial measures

In order to overcome the existing economic and financial barriers to the adoption of System of Rice Intensification (SRI) technology, the following measures are proposed:

i. Establish small holder credit facilities: National policies, which support smallholder credit, can be an important adoption driver to overcome wealth constraints to investment in new technologies. Initiatives from banks such as TIB and TAIB should focus on majority farmers who are small scale farmers. Through research such initiatives can come up with packages that make it possible for farmers to access credit.
ii. Conduct economic and financial feasibility studies: Relevant state institutions such MAFL, research institutions, academia etc should conduct economic and financial feasibility studies and make the study findings available to the public and to the decision makers. The task of conducting these studies may be entrusted to competent national officials. Such studies may be used to convince financial institutions to provide finance to small scale farmers
iii. Support to establishment of informal savings and credit groups at community level: Social networks in village economies could potentially play an important role for agricultural technology adoption and social acceptability needed for SRI to diffuse quickly. A number of studies argue that existing social networks may play a prominent role in mediating the learning, informal credit and act as insurance for farmers (Islam *et al*, 2016). Such initiatives strengthen discussion platforms and have long proved to be worthy and effective. They may even enhance opportunities for collective action in natural resource management.
iv. support to research institutions and extension services: A special support (through necessary funding) to research institutions and extension services to strengthen their capacity to perform their technical mandates
v. Encourage private public partnership to initiatives such as SACGOT at the small scale level
vi. Enhancing producer price support mechanism, facilitate market access and avail information on markets to small scale farmers and supply of marketing of improved seeds to increase yields.

1.3.3.2 Non Financial/ Economic measures

a. Information and awareness

Measure:

i. Establish SRI demonstration plots and on farm trials as these spread information without much effort through informal communication networks. Knowledge sharing about the technology could then be facilitated through communication infrastructure, media access and a functional network of continuously updated extension agents such as NGOs and local agro dealers.
ii. Exchange visits of rice scientists, extension officers, processors and farmers to share experience and encourage network of technology adopters.

iii. Increase campaigns of climate change awareness and how to reduce risk exposure where adoption of SRI should be emphasized. Understanding of the contribution of technologies to yield variability is important.

b. Human Skill

Measure: Strengthening of farmer field schools and use of existing agricultural research and training institutions to train farmers and to learn on what works in practice. Other channels include training of early adopter farmers, processors, extension officers and other stakeholders in rice technologies at the Ministry of Agriculture Training Institutes/centers

Furthermore to increase management skills of increased production, deliberate efforts have to be done to introduce/ adopt supporting technologies to complement the realized gain from SRI. For instance, the development and availability of improved post-harvest processing technologies and value addition processes is important while promoting SRI.

c. Policy, legal and regulatory

Measure: Relevant authorities should work together to advocate the harmonization of principals of SRI and existing policy regulations. Policy around issues of access to genuine seeds, availability of needed farm inputs such as weeding instruments, control of irrigation and promoting zero grazing for better availability of compost are also required.

d. Institutional and Organization capacity

Measure: Strengthen water user associations (WUAs) on use of water for irrigation. Good management, operation and maintenance of irrigation schemes by farmers themselves is essential to get the farmer participation in water-sharing and intermittent irrigation.

Ministry of Agriculture, Fisheries and Livestock and Ministry of Water and Irrigation should coordinate farmers sharing a canal to manage the canal collectively increases their likelihood of adoption of SRI.

e. Social, Cultural and Behavioral

Measure: Enhance use of farmer field schools and deliberate identification of champions within the community who can influence the community on decisions.

1.3.4 Cost Benefit Analysis

The cost-benefit analysis as referred in table 3 was done by first identifying both direct and indirect costs and benefits associated with existing paddy cultivation and the implementation of System of Rice Intensification technology. The cost benefit analysis was based on costs for improved seeds, land preparation, equipments. The costs and benefits for current scenario and adaptation scenario are per year.

The cost-benefit analysis was based on costs and benefits to introduce the technology to 100,000 ha of farms by the year 2020. Elements and costs were obtained from expert judgment, consultation and discussion with stakeholders and desk search

Table 3: Elements of Costs and Benefits of the Existing Scenario and of adopting System of Rice Intensification (SRI) Technology (1USD=2130 tsh)

SN	**Item**	Amount USD
1.0	**Existing Scenario**	
1.1	Traditional Seed cost 77kg/ ha @ 2500tsh	91
1.2	Fertilizers (manure)	9
1.3	Land preparation	5
1.4	Insecticides	2
1.5	Herbicides	4
1.6	O & M costs	4
1.7	Other costs	7
	Total Cost	**122**
2.0	**Cost of Adaptation Technology**	
2.1	Improved Seed cost 10kg/ha @5000Tshs	23
2.2	Land preparation	6
2.3	Insecticides	2
2.4	Fertilizers	7
2.5	Herbicides	2
2.6	O & M costs	4
2.7	Other costs	7
	Total cost	**51**
	Benefits	
1.0	**Existing scenario**	
1.1	Crop harvest (20 bags@150,00Tshs)	1408
	Total Benefits	**1408**
2.0	**Adaptation Technology Scenario**	
2.1	Increased yield per acre (60 bags @150,000Tshs)	4225
2.2	Water saving	
2.3	Reduced emission	
	Total Benefits	**4225**

It is clear from the above analysis that over 10 years, the System of Rice intensification technology has positive cost benefits and it is therefore viable since the main identified barrier is initial cost associated with high cost of seeds and labour.

1.4. Barrier Analysis and Possible Enabling Measures for Technology 3: Drip Irrigation

1.4.1. General description of the Technology

Drip Irrigation is an irrigation delivery system that deliver drips of water directly to plants through pipes. Small holes or emitters control the amount of water that is released to the plant. Drip irrigation does not contaminate above ground plant surfaces e.g.: leaves (WHO, 2006). Drip irrigation can also be described as a direct irrigation method that allows water to leak slowly from pipes to the root zone of the plants (also known as trickle or micro irrigation) (World Plumbing Council Working Group 2008).

Drip irrigation is a good option for farmers to optimally use limited amount of water and also help in environmental conservation. Drip irrigation has been found to increase farmer yields by up to 300 percent compared to non-irrigated traditional production practices, save 30 to 70 percent on water usage, and reduce the cost of labor by up to 80 percent (Fintrac, 2016). Therefore using drip irrigation technology provides a room for the prospects of boosting optimal use of limited amount of water, improved productivity and increase incomes for small-scale farmers.

Irrigation is important in Tanzania to deal with the erratic rainfall, especially in the context of climate change (MoWI, 2016). Therefore, drip irrigation is one type of technology that can be used by farmers for effective use of water and for optimal crop production. The positive impact of drip irrigation is acknowledged in Tanzania. For example, as explained by a joint FAO/IAEA programme (2009-2014) for tea production, the use of drip irrigation provided a tea yield that was 17 times higher than rain-fed, non-irrigated tea.

Stakeholders in Tanzania indicate that the commercially viable farmers most likely to adopt drip irrigation in Tanzania are those operating a minimum of 0.5 ha dedicated to higher value agriculture such as vegetables (FINTRAC, 2016). Those farmers primarily growing staple crops of maize and rice are considered less likely to adopt drip irrigation given the allocation of output to household consumption and low economic returns on surplus production. Most smallholders are engaged in mixed farming systems where food crops dominate, but there are estimated to be 1.7 million ha of small-scale holdings dedicated to horticulture production.

Adoption also varies according to initial investment costs and is sometimes related to the gender of the farmer. Tumbo *et al*. (2014) observed that men usually have more power to make adoption decisions that involve general changes in farm technology; women may not have this power because they lack access to and/or ownership of land. In any case, smallholder farmer support is vital in order to boost adoption of new irrigation technologies.

1.4.2. Identification of barriers for the Technology

Under the TNA, drip irrigation is categorized as a consumer good with a considerable market chain. Identification of barriers involved literature review of published and grey literature and web-based resources on the subject, consultations with key stakeholders, particularly the Irrigation Department under the Ministry of Water Resources and Irrigation, inputs from water resources and irrigation experts in academic institutions, NGOs promoting the technology, actors in the marketing of irrigation equipment, as well as consultant's own knowledge. The following 2 broad categories namely: economic and financial barriers and non-financial barriers were identified as hindering the uptake of drip-irrigation technology.

1.4.2.1. Economic and financial barriers

The following economic and financial barriers were identified:

i. **High capital cost**

Use of drip irrigation requires capital investments in the relevant technical components normally costing around 1400 USD per ha. The cost is increased further by the need for training the practitioners of drip irrigation for proper utilization of the technology. Materials including pumps, pipes, tubes, emitters for assembling the system are imported and are subjected to high tax.

ii. **Difficulty to access finance**

Available credit and loan facilities and conditions are not suitable for most farmers, e.g. microfinance institutions offer loans of one year or less, whilst drip irrigation loans need to be for at least 18 to 24 months. A period of more than one year enables farmers to at least harvest some of the products and repay loans. Farmers are discouraged to take loans because of conditions put forward by financial institutions once the payment is defaulted. The drip tape and filter depreciate rapidly and therefore it can't be used as collateral for loans. Farmers are required to put up 40-50% of the cost of the drip system up-front which is not possible for most small-scale farmers. The banks are reluctant to finance such projects related to drip irrigation because the rate of return from such investment is much lower than for other projects. Currently the majority of drip irrigation projects are based on isolated household cases, mainly funded by NGOs and Development institutions.

1.4.2.2. Non financial barriers

a. **Information and Awareness**

i. **Farmers have limited awareness of the technology**

Due to limited extension support services, especially in rural areas, farmers do not get enough information about the technology. Those who happen to be knowledgeable have other challenges and lack networking that could support them in adopting the technology. Smallholder farmers have little or no experience with drip irrigation, and when they do, it is primarily low investment furrow practices. On the whole, they have no understanding of drip system operation and maintenance, so introducing the technology requires thorough training and practical demonstration to illustrate the potential and educate them on how to use drip irrigation. Additionally, drip irrigation needs to be presented as a tool within a broad package of good agricultural practices and improved inputs if it is to meet its productivity potential.

Smallholder farmers who practice market-oriented horticulture production have yet to recognize the market opportunity for bringing horticulture crops to market in the dry season. Farmers have little information and no technical knowledge of using irrigation methods such as drip irrigation to capture the market.

ii. Farmer mindset

The typical smallholder farmer does not operate his or her farm like a business. About 90% of smallholder farmers rely on seasonal rainfall, and staple crops for subsistence dominate land use decisions. It is indicated that shifting smallholders to farming as a business mindset will require time, entrepreneurial skills training, a break from dependence on input handouts, and access to readily available market opportunities for higher value horticulture.

Furthermore, farmers are not perceiving water as a limited resource due to climate variability, thus water saving is not a farmer priority due to its low price.

b. Technical

i. Insufficient understanding of the use of the kits and functionality.

Complexities in the designing of drip irrigation system are a challenge to small-scale farmers who have limited technical knowledge. Furthermore, farmers highlighted that drip irrigation is a tool, not a solution. Without the application of good agricultural practices, including proper land preparation, and the utilization of hybrid seeds, water soluble fertilizer, and crop protection products, the returns from drip irrigation will hardly meet their expectations.

Extension services across the country are weak, with government extension services under-resourced with poorly trained extension technicians and limited skilled labour for design of irrigation system / network, layout and dripper line placement for uniform water and nutrient application placement and maintenance.

Additionally, without practical knowledge on drip operation and maintenance, farmers who invest in drip often abandon the system if it becomes clogged and inoperable because of poor management.

Furthermore, drip irrigation is not suitable for all crops due to different crop spacing and height, soil types /topography and slopes.

ii. Inadequate pest and disease control

Being the only green spot, especially during the prolonged dry spells the system can attract pests and diseases such as insects, rodents, squirrels, aphids etc. who are either looking for water or find refuge in the drip gardens. As such, farmers may lack the technical capacity to deal with the pests and this affects their crop production.

c. Policy, legal and regulatory

i. Government policy and incentives

Policies instituted by the government have not supported the profitable investment in drip irrigation systems for potential investors and thus there is low private sector interest. The public sector can't afford to fund irrigation alone.

In Tanzania, national policy has not been supportive of drip irrigation adoption. Drip irrigation equipment is included in the agricultural implements that are not exempted from VAT. While the government provides duty free import of drip equipment if it enters the country as a complete scheme, individual drip components are subject to import duties. This is a bottleneck for repair and maintenance of the systems which later are abandoned as it becomes expensive to repair them.

Furthermore, the complex and inefficient importing procedures give a competitive advantage to the largest drip distributors who are able to hold large stocks of equipment inventory to fill orders. Other smaller distributors do not have the capital or warehouse capacity to stock significant inventory, and are therefore often unable to fill customer orders in a timely manner. This prevents wider adoption of technology as only large scale distributors who are in big towns are suppliers of the technology (FINTRAC, 2016).

Furthermore, there are no quality controls or standards of irrigation equipment available locally to check if equipment on sale is of required standards.

d. Institutional and Organization Capacity

i. Weak link between research, extension and farmers

Farmers have limited opportunities to receive technical assistance from extension officers. Extension services are important for providing assistance on information about the soil conditions, and landscape of the farm for successful adoption of the technology. The extension services are hampered by limited budget, resources and limited personnel.

Extension services are important to link farmers and research, thus when extension is weak even research and development is weak. Thus this creates a weak link between research, extension and farmers.

ii. Limited institutional capacity for research and development

Research and development is constrained by budget, human resources and infrastructure to enable easy adoption of the technology. Currently, Tanzania has limited number of laboratories where farmers can check the quality of their soils to make a proper decision of adoption. There are limited extension specialists in irrigation to address needs of farmers country wide. Also, there are limited resources to set up demonstration sites around the country to facilitate learning by farmers.

Furthermore, there are weak linkages between suppliers and R&D, which limits the interest of private sectors in the technology.

e. Socio-Cultural

i. Resistance to adopt the technology

This technology is mainly suitable for areas which have scarcity of water. Communities in these areas usually are pastoralists with women working on horticulture gardening. Given the fact that women are the ones that bear the burden of fetching water for irrigation, men who own means of production may not see the need to adopt the technology. It should also be noted that irrigated agriculture using water lifting agriculture techniques (WLATs) is mainly a commercial activity and there is a tendency in Tanzania, as in many African countries, for men to be engaged more in commercial activities even if it is vegetable farming (IWMI, 2013).

ii. Community conflicts

Many areas that have scarce land and water have continuous conflicts of community claims to land and water rights. This leads to misunderstanding or even confrontations among community members. Conflicts of land tenure hinder investment in new technology and hinder farmer's engagement in productive activities using the land and water at their disposal.

iii. Fear of unknown

Often introduction of new technology is supported by many other new management systems of farms. For drip irrigation farmers may be required to shift to high value cash crops for economic viability meaning a farmer is required to adopt new agronomic practices, engage in several processes to manage uneven field conditions. New technology also leads to increased farmer management efforts such as preventing theft and vandalism which sometimes are perceived as increased labour.

1.4.3. Identified measures for the technology

The following are the measures to address barriers of low adoption of drip irrigation technology by small scale farmers. The measures are categorized through two main categories, economic and financial measures and non financial measures.

1.4.3.1 Economic and financial measures

v. Government to engineer provision of credit facilities, grants, and subsidies as instruments to support farmers to invest in drip irrigation (DI) equipment. These financial measures can support the purchase of irrigation systems. Such provision should focus on dry areas such as small scale farmers in central Tanzania to ensure food availability and areas with potential for high value crops (e.g.: horticulture), and should particularly focus on women who seldom have ownership of collateral but form part of the backbone of small scale farming system and technologies application level, where DI adoption would results in real water and energy saving and maximize socio-economic impacts (IWMI, 2012).

vi. Establish an appropriate land tenure system to enable farmers to own the land legally. Land ownership with title deed is expected to strengthen security of tenure, contributing to growth in agricultural production. This will enable farmers to have collateral for accessing loans.

vii. Reduce or eliminate government taxes on importation of drip irrigation equipment. This will decrease the investment and operational costs of the technology and also attract more private sector involvement in the market chain of the same. Such an initiative would improve the financial viability of the deploying technology and increase uptake.

viii. Local governments Authorities (LGAs) should consider establishing a fund to provide low interest credits/loans for drip irrigation projects. The fund source can be through imposing a levy on establishment of commercial farms.

ix. Development institutions with a mandate to promote these technologies could consider providing required funds on agreed terms. They may need to consider providing funds on concessionary terms to local private sector to access these technologies and widen the market to rural areas. Such funding, if necessary, may be channeled through the government treasury and through commercial banks.

1.4.3.2. Non financial measures

a. Information and Awareness

Measure:

i. Promote awareness programmes using public meetings; strengthen extension support services, especially in rural areas to provide information about the technology. Devise cost-effective communication channels e.g. farmer field schools, community schools, radio listening groups *etc* to encourage one another and share information. Provide funds to translate materials on drip irrigation into easy-to-read and user-friendly format.

ii. Promote programmes that bring awareness to farmers on opportunities that their farming activities have in changing their livelihood. With the aim of transforming their farming practices, provide knowledge to farmers through demonstration farms on off season harvest, train them on diversification of crops, marketing and record keeping.

Furthermore, promote programmes that would facilitate farmers to trust and use information from relevant authorities on increased variability and importance of sustainable use of water.

b. Technical

Measure:

i. Drip irrigation systems should be viewed as a tool toward increased productivity, not as a stand-alone solution. Effective utilization of drip irrigation needs to be tied to technical assistance to ensure farmers are maximizing the benefits of the system and applying other required and complementary good agricultural practices. Technical assistance on how to install and use the system is crucial for farmers to maximize their productivity gains.

ii. Promote technical assistance in partnership with development institutions, NGOs, or government agencies to provide irrigation management, crop production, agronomic training and advice, and market access support.

c. Policy, legal and regulatory

Measure:

Reduce or remove VAT and duties for drip irrigation equipment to enable local private sector to supply irrigation equipment to small scale farmers at affordable cost.

Enable local private sector to import the technology through regulating inefficient importing procedures. This can be through promoting public–private partnerships; and it is important to make explicit the roles for the state, firms and donors, particularly in regard to provision of extension services, credit and inputs, provision and maintenance of infrastructure, and farmer representation.

Furthermore, local standards for drip irrigation equipment and vetting systems need to be developed for quality control to check if equipment on sale is of required standards.

d. Institutional and Organization Capacity

Measure:

i. Strengthen the collaboration among the stakeholders through training, regular 'sharing' meetings and developing system of communication that enable quick transfer of information using organized platforms of farmers to facilitate technology transfer and diffusion.

ii. **Limited institutional capacity for research and development:** Development partners and the government in their joint programmes, should aim to increase budget for R&D institutions, increasing numbers of skilled/ technical people, strengthen south south collaboration to enable sharing of new knowledge

e. Socio-Cultural

Measure:

Provide extensive awareness programme through media to ensure a large section of the population become familiar with the technology. Furthermore, deliberate efforts to solve land conflicts by strengthening coordination of village and LGAs are important.

1.4.4 Cost Benefit Analysis

The cost-benefit analysis (Table 4) was done by first identifying both direct and indirect costs and benefits associated with current water sources for irrigation and the implementation of the Drip Irrigation technology.

The cost benefit analysis was based on costs for installing the irrigation kit for irrigating one acre of land. The costs and benefits for current scenario and adaptation scenario are per year.

The cost-benefit analysis was done based on costs and benefits of constructing drip irrigation kits units for 150,000 small scale farmers. Elements and costs were obtained from expert judgment, consultation and discussion with stakeholders and web search.

Table 4: Elements of Costs and Benefits of the Existing Scenario and of adopting Drip Irrigation Technology

SN	Item	Amount USD
1.0	**Existing Scenario**	
1.1	Labour (Land preparations, weeding, planting and harvesting) (4 people@3USD/day for 230 days)	2,760
1.2	Crop failure (120USD/hh)	18,000,000
1.3	Health treatment costs associated with poor nutrition (children and aged) (USD 350 per capita per year)	52,500,000
	Total Cost	**70,502,760**
2.0	**Cost of Adaptation Technology**	
2.1	Installation of complete drip irrigation system (@ USD530/household)	79,500,000
2.2	Ensured Water availability (30 boreholes@ 6000 USD)	180,000
2.3	Labour (2people@3 USD/day for 200 days)	1,200
2.4	Training and capacity building (25 USD/ hh *150,000)	3,750,000
2.5	O & M (including tech support) 5% of investment in drip irrigation	3,975,000
	Total cost	**87,586,200**
	Benefits	
1.0	**Existing scenario**	
1.1	Crop harvest (8 bags@50USD*150,000hh)	60,000,000
1.2	Indigenous knowledge	750
	Total Benefits	**60,000,750**
2.0	**Adaptation Technology Scenario**	
2.1	Increased yield per acre (16@50USD*150,000hh)	120,000,000
2.2	Improved health	3000
2.3	Economic opportunities due to employment (markets)	800
	Total Benefits	**120,003,800**

It is clear that from the 10 years value (USD 263,722,423) that the Drip irrigation technology has large benefits and it is therefore viable despite the high initial cost.

1.5 Linkages of the Barriers Identified

As it was indicated in previous sections, barriers related to the implementation of technologies for agricultural sector have been identified in two main categories: i) economic/financial barriers, and non financial barriers which had i) policy/regulatory barriers, ii) technical barriers, iii) information/capacity barriers and iv) social barriers.

Some of the identified barriers are common among the technologies. For instance, difficulties in accessing funds, inadequate information and awareness and lack of technical knowledge and advantages of the technology are some of the main barriers to deployment of all prioritized technologies under the agricultural sector. Small scale farmers are accustomed to traditional irrigation and cultivation practices.

Difficulties in accessing funds and high investment costs of the technologies

These are the major barriers in adopting the technologies in agriculture. Owing to the sector being highly dominated by smallholder farmers, lack of finance remains the leading obstacle and yet banks – the major supplier of finance are quoted to be the least suppliers of finance to farmers despite capital adequacy and ability to lend to smallholder farmers at lower interest rates compared to other suppliers.

Rural areas are characterized by higher transaction costs for both the financial institutions and their clients, higher systemic risks, more volatile cash flows; as well as lower risk-bearing ability and higher vulnerability due to higher incidences as well wide spread and depth of poverty. Therefore, while a large majority of the poorest households are directly linked to agriculture in many ways, agricultural lending remains mostly an uncharted territory for development finance.

‶ Access to bank credit and; lack of collaterals, vital bank information, proximity to banks and high interest rates were some among the major obstacles hindering smallholder farmers‶ accessibility to bank credit. Further still, access to bank credit was found to have a significant influence on the performance of smallholder farmers as it influenced both output and increase in annual returns.

Inadequacy in technical Capacity

One of the biggest barriers to the adoption of adaptation technology among small scale farmers is inadequate financial support of the government and private sector to invest in research and development capacity (human and infrastructure). Research and Development at the Ministry of Agriculture has been constrained with several factors including:

- Fragmentation of research among several institutions;
- A too large research agenda for available resources given the emerging threats of climate change;

- Rundown physical infrastructure; and
- Inadequate and often decreasing funding for research.

Effective application of technology requires knowhow and capacity of technological adaptation and dissemination. Furthermore, technologies that are focusing to enable adaptation need to be area specific given the wide range of climatic zones and agro ecological zones of the country. Such conditions necessitate 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 nature of small scale famers who makes investment in adaptation technologies non-profitable. 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.

1.6 Enabling framework for overcoming the barriers in the agriculture Sector

Among prioritized technologies for wider development of energy sector, some of them are already included in different national plans e.g. improved seed varieties. According to this plan Tanzania is expected to increase use of Improved Seed Varieties through various programs such as SAGCOT.

To overcome, difficult in accessing funds, Credit guarantee initiatives have been introduced to encourage greater lending by the formal sector. The Private Agricultural Sector Support Limited (PASS) has been exceptionally successful because it works closely with beneficiaries and financiers thus reducing risk for the financing sector (InfoDev, 2012).

Table 5 is the summary of common barriers for the three technologies together with the addressed enabling framework.

Table 5: Cross cutting barriers with the relevant enabling framework

Type	Broad/common barriers	Enabling framework	Responsible
Financial	Difficulties in accessing funds	Facilitate development of land ownership through government or traditional title deeds to strengthen farmers' capacity to access credits.	Ministry of Finance and Planning(MOF), Ministry of Lands, Housing and Human Settlements Developments(MLHSD), Ministry of Industries and Trade (MIT)
		Mobilize farmers to form groups which can be used as collateral for accessing loans	Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDEC), Presidents' Office Regional Administration & Local Government (PORALG), MOF.

Type	Broad/common barriers	Enabling framework	Responsible
		Public private engagement in the form of public private partnerships (PPP) is another suggested approach mainly on the part of investing on SRI and Drip Irrigation technology.	Tanzania Private Sector Foundation (TPSF), MOF, MIT.
Policy, laws and regulations		Government to develop and implement policy implementation tools i.e. targeted economic incentives, such as tax exemptions or subsidies to the private operators who have interest in investing in these technologies.	VPO- DoE, MOF, Ministry of Agriculture, Fisheries and Livestock (MAFL).
		Government to develop standards for these technologies to control counterfeit equipment and seeds.	Tanzania Bureau of Standards (TBS), MIT, MAFL
		Government to support farmers on post harvest care and markets regulations.	MAFL, Agriculture Research Institutes (ARIs), NGOs
		Government need to identify ways that will incentivize extension officers to visit farmers who are in remote areas.	MAFL, PORALG, MOF
Inadequate technical skills		Strengthen training for the farmers through Farmer's Field School (FFS), to enable farmers to receive training on technologies and appropriate farming practices, share ideas, and learn from each other through observation and experimentation.	MAFL, ARIs,
Institutional and organizational capacity		Government to strengthen and support the extension services technically and financially by providing regular training on new technologies and enable extension officers to reach farmers in the rural areas. Government to realise that, these technologies are not stand alone solutions, but efforts to provide good environment institutionally and financially are key to success.	VPO-DoE, MAFL, MoWI, NGOs.

CHAPTER 2: WATER SECTOR

Tanzania is endowed with relatively abundant freshwater sources, but these are unevenly distributed. According to the Food and Agriculture Organization (FAO), in 2008 Tanzania had 96.27 km^3 of renewable water resources per year. This corresponds to 2,266 m^3 per person a year. On average, Tanzania's annual renewable water resource is 89 km^3 and the annual average available water per capita was 2000 m^3 in 2012 compared to 2700 m^3 in the year 2001. This amount is projected to lessen by 30% corresponding to 1400m^3 per capita per year in 2025 as a result of diminution of water resources and increase of population (WSSR, 2014). Water resources are however distributed unevenly – both in time and space.

Despite of all these resources, Tanzania is faced with severe and widespread water shortages in many areas because of climate variability, poor distribution of the resource in time and space, and inadequate management of the water resources.

The semi-arid central and northern parts of the country, including areas immediately south of Lake Victoria receive less than 700 mm of rainfall per annum and are dry for an average of seven consecutive months a year. River flows in these areas are intermittent. In the southern, western and northern highlands, which receive more than 1,000mm/year of rainfall, rivers are perennial, and some of these experience frequent floods.

Global water demand is expected to increase 22% by 2030. Climate change is affecting weather patterns and especially the water cycle. Some regions are seeing amplifications in floods, droughts and hurricanes. According to the United Nations, almost 3 billion people in 48 countries will face water scarcity by 2025 (DCU,2013). With 80 million more people on earth each year, water demand will keep going up unless we change how we use it. The United Nations has set the level of availability of renewable freshwater resources, at 1700m^3/capita/year denoting water stress, and 1,000m^3/capita/year denoting water scarcities. However, due to projected population growth alone, Tanzania's annual renewal rate is projected to drop to 1,500m^3/capital/year by 2025, thus categorizing the country as water stressed (World Bank, 2006).

Tanzania Water Sector Management

The water sector has undergone significant reforms since 1960's in terms of policy, institutional and legal frameworks, which have to larger extent necessitated efficient and effective implementation of various programme interventions. Table 6 gives a summary of the reforms that have taken place in the sector.

This transformational set up strengthens sector institutions for improving the integrated water resources management and development, and ensuring that the number of people with access to clean and safe water supply and sanitation services in urban and rural areas reaches the targets aspired by our macroeconomic policies such as the National Development Vision by 2025.

The Tanzanian water sector is divided into two sub sectors: Water Resources Management (WRM) sub sector and Water Supply and Sanitation (WSS) sub sector. These are managed by the Water Resources Management Act No.11 of 2009 and the Water Supply and Sanitation Act No.12 of 2009 respectively.

The provision of water supply and sanitation services is carried out by the Water Supply and Sanitation Authorities (WSSAs) which are responsible for management of water supply and sanitation services mostly in urban areas and Community Owned Water Supply Organization (COWSOs) in rural areas.

There are nine major drainage basins in Tanzania, divided according to the recipient water body. In 1989, through the Water Utilization (Control and Regulation) Act No. 42 of 1974, Amendment No. 10 of 1981) the Minister for Water gazetted nine (9) water basins[3] for the purposes of water resources administration and management. The basins are illustrated in Figure 1.

Basin Water Offices (BWOs) are responsible for regulating and planning the use of water resources, based on the *Water Resources Management Act Nr. 11* of 2009. There are 9 water basins as shown in figure 1. The water resource management section of the Water Sector Development Programme requires that their activities be carried out in line with the principles of Integrated Water Resources Management (IWRM).

Stakeholders

Key stakeholders in the water sector include: national government; local government authorities; development partners; the private sector; non government and community organisations. To ensure effective institutionalised linkages between stakeholders, the NAWAPO and NWSDS prescribe roles for different players in the water resources management and water supply and sanitation services. Enactment of the Water Resources Management Act No.11 of 2009 and the Water Supply and Sanitation Act No. 12 of 2009 has empowered different institutions to implement their mandated roles, according to the NAWAPO and the NWSDS. This allows harmonization and synchronisation of other sector laws and regulations to reduce contradictions and duplications.

Table 6: Key dates in the reform of the sector in Tanzania

Year	Event
1970s	High profile Mtu ni Afya campaign on sanitation
1970s–80s	Top-down, free water approach to water supply
1991	First National Water Policy, introducing user charges
2001	Legislation for an independent utility regulator passed
2002	National Water Policy (NAWAPO) adopted
2002	Rural Water Supply and Sanitation Program launched

[3] **Water Basin:** An extent of land which contains water resources in the form of surface or groundwater within defined hydrological boundaries

2003	Leasing of Dar es Salaam water supply to private sector company
2005	Renationalization of Dar es Salaam water supply
2005	National Water Sector Development Strategy (NWSDS) developed
2007	Launch of the Water Sector Development Program ($951 million over five years)
2008	Approval of NWSDS
2009	New water legislation passed by Parliament

Source: Water Sector development plan (2006)

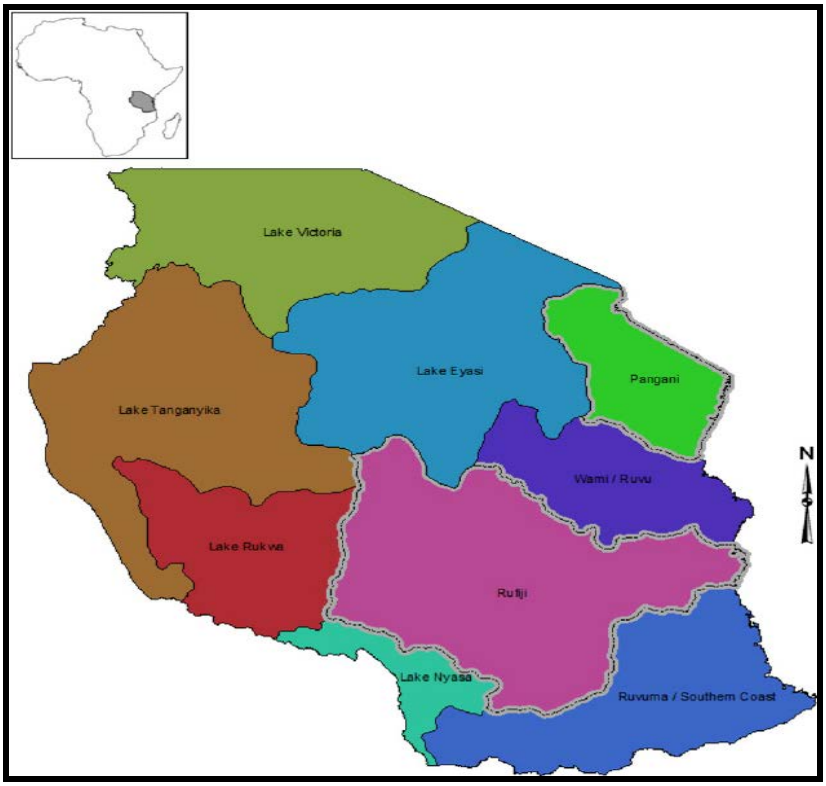

Figure 1: Map showing the nine water basins in Tanzania
Source: Water Resources Management and Development Programme (URT, 2009)

Process of identifying barriers:

Although potential technologies for the water sector have been identified and prioritized during the Technology Needs Assessment stage, there are barriers that hinder the transfer and diffusion of such technologies. Therefore, a barrier analysis was carried out through stakeholder consultations (see Annex IV) supported by literature reviews and specialist inputs. The barriers thus identified have been prioritized and ranked according to their significance.

The adaptation technologies identified and prioritized for the water sector using Multi Criteria Decision Analysis are shown in Table 7:

Table 7: Prioritized technologies – Water Sector

SN	List of Prioritized Technologies	Category of the Technology
1	Rain water Harvesting from roof tops	Consumer goods
2	Water Leakage reduction programme	Other Non market goods
3	Water re cycling and re use	Consumer goods

2.1 Preliminary Targets for Technology Transfer and Diffusion

Tanzania faces a water stress situation in some parts of the country, as water demands exceed available resources. Climate variability, resource degradation and pollution have become a threat to the sustainability of critical water using sectors- hydropower, irrigation, mining, tourism, livestock, urban and rural water supply. Population pressure, deforestation and unsustainable land and water management in fragile catchment areas have led to degradation of the resource base and the livelihoods of the people that depend on it.

Since Tanzania has a variety of landscapes, water resource management has always been very crucial. The country is challenged by a high degree of water resource variability, particularly from rainfall, both spatially and temporally. With increasing demands of water and the unequal distribution of water, the country has to carefully manage its water resources.

The major water uses in Tanzania are irrigation and domestic. Hydroelectric power generation can be considered as non-consumptive use except for the considerable evaporation losses that occur from reservoirs. Flow requirements for hydropower generation depend on the installed capacities at power plants, which are mostly located in areas within a basin that restrict other upstream uses.

1. Rain water harvest technology

A large volume of water is lost to the sea annually in the form of surface runoff as can be observed from the water drainage system. In recent years, the country has been recording high intensity short duration rainfall events, and these types of rainfall events give rise to high surface runoff, a large part being lost to the sea. Regardless of its many advantages, rainwater harvesting (RWH) is one of the least sought after sources of water. By April 2015, 1862 RWH tanks had been built in 931 villages under the water sector development programme, (which is about 9.2% of villages in Tanzania based on the 2009 statistic) (NBS, 2011). The rainwater harvesting technology proposed will serve two purposes. The water collected will be used for gardening and cleaning and also for increasing groundwater recharge. The RWH technology is being targeted at residential sector. The technology targets constructing Roof Rainwater Harvesting units for 150,000 families comprising 4 people.

2. Water Leakage Reduction Programme through Smart water meters

Among the challenges that the water supply and sanitation authorities have been facing is the loss of water before reaching the consumer. In general, Non-Revenue Water (NRW) is a big challenge to the water industry in general and it openly affects service sustainability in water sector. High levels of NRW reflect huge volumes of water being lost through leaks, not being invoiced to customers, or both. Developing countries including Tanzania have an average of 35.2% of NRW for regional UWSSAs while in big cities, it is estimated to be about 50% (NOA, 2012). The level of NRW in Dar es Salaam is an issue of concern due to its increasing trend. The current level is over 50 %(WSDP, 2014). Dar es Salaam Water Supply and Sanitation Project (2002-2011) had financed a baseline study and preparation of technical specifications for a performance based contract for non-revenue water reduction in Dar es Salaam. The study was completed in October 2011. DAWASCO has established an independent NRW unit, which has become operational and signed an agreement with a consultant, to carry out a mini study on two pilot DMAs (Kawe and Boko) and develop a strategy for NRW.

Smart Water Metering System is proposed to manage the challenge, using smart metering technologies makes it possible to achieve a lot more than just collecting statistics for cash collection but to "significantly improve the quality of service, increase the cost efficiency associated with water provision and conserve the national resource". Conservation is a primary driver of smart metering systems. It collects more intelligent data at the metering point.

The technology target to reduce NRW to 50% and the targeted institution is the Dar es Salaam Water Supply Company (DAWASCO) Authority and the key institutions which are directly concerned with water utility regulation, such as the EWURA. The project is expected to last over 10 years. In the first year (stage 1) of the project, a dedicated unit will have to be created and provided with the facilities (computers, printers, software, etc). 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. In the last two years, the focus will be more on providing technical support to the dedicated team and ensuring knowledge transfer as well data collection.

3. Water reuse and recycling through Waste Water Stabilization Ponds

During the barrier analysis workshop, stakeholders agreed to have Waste Water Stabilization Pond as a specific technology to address Water Re use and Recycling. This was based on the fact that in urban centers there is big volume of waste water generated and discharged either haphazardly or into water bodies. Commonly, this wasted water ends up posing negative public health consequences to the urban community as it tends to be breeding sites for vermin as well as polluting pristine water environment. Therefore, workshop participants recommended waste recycling and reuse as one approach to minimize water shortage, and at the same time prevent negative health impacts.

According to an article by a group of researchers from the Waste Stabilization Ponds and Constructed Wetlands (WSP & CW) Research Group at the University of Dar es Salaam, stabilization ponds have been the most common technology for wastewater treatment in Tanzania. Waste stabilization ponds have been introduced since the late 1960s, due to the favourable tropical climate and the availability of natural wetlands. At that time, twenty wastewater pond systems were recorded as existing; five of them were used to treat textile, paper mill, tannery and other industrial wastewater. However, many waste stabilization ponds systems are ineffective because of poor operation and maintenance, design and configuration mistakes and the mixing of municipal and industrial wastes.

The technology targets key institutions which are directly concerned with water and sewerage authority, such as the Dar es Salaam Water and Sewerage Authority (DAWASA). The project is expected to last over 5 years. The project is to build 6 waste stabilization ponds in three different regions of Tanzania. 3 in Dar es Salaam, 2 in Dodoma and 1 in Mwanza. The ponds are to have a capacity to receive 100,000 m^3 of water.
The following section describes the barriers to the diffusion of the prioritized technologies.

2.2 Barrier Analysis and Possible Enabling Measures for Technology 1: Rain Water Harvesting

2.2.1. General Description of Rain Water Harvesting

Tanzania being geographically privileged with respect to the rainwater resource receives abundant annual renewable water of approximately 89 km^3 while spatial distribution of the annual rainfall ranges between 400mm to 2000mm (URT, 2014). Rain water harvesting[4] (RWH) technology involves the collection of water from roof surfaces, ground surfaces as well as intermittent or ephemeral streams on which rain falls and stored in tanks, deep ponds or soil for future use. The most basic systems of rainwater harvesting require a catchment area (typically a rooftop), a conveyance system (e.g., gutters, downspouts, plumbing) and a holding tank (e.g., rain barrel, cistern). These systems grow in complexity in order to address the quality of water captured (i.e., treatment) and the ease of its use (e.g. pumping for indoor toilet use) (LaBranche, 2007).

[4] Pacey and Cullis (1986) and Dutt *et al* (1981) defines rainwater harvesting as a process of concentrating, collecting and storing water for different uses at a later time in the same area where rain falls or in another area during the same or later time.

Captured rainwater can supply or augment both potable and non-potable uses such as range rehabilitation, tree and agroforestry, domestic stock, gardening and crop production. While captured rainwater is naturally “soft” (NVRC, 2007) it often does not meet drinking water standards (Meera, 2006). In order to serve as a potable water source some level of treatment (e.g., filtering, chlorination) must be incorporated, thus increasing the system’s complexity. Instead of treating rainwater to potable water standards, the use of untreated rainwater for non-potable uses that would otherwise be supplied by potable water ultimately conserves supplied potable water (Persyn, 2004). RWH is regarded as a simple and effective method of storing water for countries with seasonal rainfall patterns like Tanzania. Adopting the RWH technology implies that excess rainfall can be reserved into tanks during wet seasons then later consumed during dry seasons.

2.2.2 Identification of barriers for the technology

2.2.2.1 Economic and financial barriers

i. Cost of Material and equipment

RWH related equipment and material costs are often high. The cost depends on the type of catchment, conveyance and storage tank materials used. The provision of the storage tank is the most costly element, and usually represents about 90% of the total cost (Water Aid, no date). Low storage capacity will limit rainwater harvesting potential, whereas increasing storage capacity will add to construction and operating costs. The effectiveness of storage can be limited by the evaporation that occurs between rains. The design is expensive since the country does not have a standard approach for rainwater harvesting designs. Due to the initial costs, RWH systems are typically prohibitive for most individual households.

ii. High initial cost for individuals investments

Individual investments which are encouraged in urban settings is high in terms of individual cost. Usually, installation of such system requires several months of income and would be difficult for most households to afford without assistance. The situation is exacerbated by lack of credit. In addition, in areas with a highly variable rainfall or an arid climate, larger storage systems may be needed to ensure reliable supply, leading to even higher investment costs.

2.2.2.2 Non financial barriers

a. Information and Awareness

i. Limited Information and Awareness towards climate change and adaptive solutions

Awareness on the link between climate change impacts and water resources, preparedness and adoption of adaptive technologies i.e. RWH knowledge is limited especially within communities. Therefore, lack of awareness about issues linked to climate change and technological options is one of the barriers.

b. **Technical**

i. **Quantity and quality aspects**

Technically, most RWH storage tanks have problems related to water quantity and quality. In terms of quantity, the main challenge is the annual temporal and spatial rainfall variability, most specifically due to rainfall shortages during the dry season. Additionally, water quality is affected by sediment accumulation, turbidity due to suspended particles, and even tiny visible insects.

ii. **Limited accessibility of data on Rainfall, weather**

RWH requires a reliable and accessible data for implementation. In most cases information required includes sub daily rainfall, temperature, relative humidity and wind speed which requires an automatic weather station. Automatic and manual gauges are needed to monitor daily rainfall as well as daily evaporation data which can be obtained using a screened Class A Pan. These data are essential inputs for establishing efficient designs. In many situations these data are quite expensive and not easily accessible.

c. **Human Skill**

Absence of Guidelines, technical Standards, targeted research and poor workmanship

Technical capacities to develop RWH systems are limited due to limited business opportunities. Facilitating institutions and communities have inadequate knowledge and skills necessary to implement RWH. This is connected to the absence of approved technical standards and guidelines. This leads to poor design in the process of harvesting rainwater for consumption, and leads to leakage, cracks, and infiltration by contaminants. Additionally, low quality workmanship partly contributes to negative perception for the technology.

d. **Policy, legal and regulatory**

Absence of Policy tools for RWH

Even though the demonstrations of constructed pilots are available within communities, still there are no supporting policies, incentives or regulations promoting adoption. There is very limited land use planning that could provide readily areas for the investment, and there are no building designs technologies that encourage RWH. There is also limited awareness of RWH for best management practices. Besides, local water committees have limited access to financial and technical support due to limited interest within government bodies.

e. Institutional and Organization Capacity

Local water management skills of consumers affects how the collected water is stored leading to mis use of water. Furthermore, low investment capacities do not stimulate the communities to be motivated to invest on RWH. There is also limited awareness of RWH best management practices as there are very few demo projects thus leading to poor perceptions.

2.2.3 Identified measures for the technology

The identification of required measures to overcome key barriers was carried out through stakeholder consultation and by using Logical Problem Analysis (annex 3) methodology. The enabling measures identified are given below:

2.1.2.1 Economic and financial measures

Measure

i. **Cost of material and equipment:** The government has to introduce incentives such as subsidies and tax breaks. We recommend a 50% subsidy on rainwater harvesting equipment to attract business dealers in the market to realize the potential of RWH as business opportunity. This will increase the availability of these materials even at very local level, thus reduce the cost of purchase. These financial measures can support the purchase of materials and equipment for the system

ii. **High initial cost for investments**

There should be deliberate initiatives to promote provision of credit facilities, grants for demonstration sites, as instruments to support investment in RWH. Individuals, at the community level can establish the microfinance schemes leading to self-funding initiatives such as the saving and credit systems (VICOBA). Tanzania's government should offer incentives and subsidies to support individual efforts to address their water supply challenges with RWH. Local governments Authorities (LGAs) should consider establishing a fund to provide low interest credits/loans for RWH projects. The fund source can be through imposing a levy on establishment of commercial farms.

Development institutions with a mandate to promote technologies could consider providing required funds on agreed terms. They may need to consider providing funds on concessionary terms to local private sector to access these technologies and widen the market to rural areas. Such funding, if necessary, may be channeled through the government treasury and through commercial banks.

Community RWH can also be established with co-financing, cash/in-kind contributions, as well as labour contributions and this can attract support outside the community from the government, private sector as well as well as international organizations. Such approach of co-financing reduces a total reliance from government support or external donors and promotes ownership. Equally, investments financed under self-funding initiatives have the potential to be sustainable.

The government can also encourage CSR in the private sector to promote RWH. Such initiatives can enhance the RWH diffusion.

2.1.2.2. Non financial measures

a. Information and Awareness

Measure:

Improved Information and Awareness towards climate change and adaptive solutions like RWH:

- There is need for education, involving media in promoting knowledge regarding climate change and the connected environmental and socio-economic impacts. Awareness on RWH technology can equally be facilitated by media involvement, training, and inclusion of technology basics in the education system to improve technology awareness as well as empowerment.
- Also it is essential to establish demonstration or pilots projects on RWH. Pilot projects facilitate easier technological diffusion or community adoption. This approach may facilitate technological acceptability and enable individual mindset change. A demonstration project will serve as a model for promotional plans, guide, and direct training, build capacity, and ensure consistency in design and application of the technology. The demonstration approach is also an opportunity to run training and capacity building to local engineers, technicians as well as beneficiaries. Similarly, pilots or demonstration projects assist to promote awareness and adoption of targeted construction and maintenance skills to the community. It should be noted that water problems are site specific, thus, it is recommended that location for pilot projects should be representative of areas with specific unique rainfall characteristics, topographical and geological conditions when harvesting is through dams.

b. Technical

Measure

i. **Water Quantity aspects:** Introduction of dual water usage system during very dry seasons where rooftop rainwater can be used for drinking only while surface and groundwater can be used for other purposes. This approach will eliminate the mindset that rainwater can be the only resource to address the water shortage problems.

ii. **Improved accessibility of Data:** Strengthening of the Programme on Monitoring and modeling of water quantity and quality. In addition, it is important to develop and implement a programme on measuring local weather data.

c. Human Skill

Measure

i. Develop and improve skills on workmanship:

- There is a need for developing skills of qualified human resource regarding rainwater harvesting technology. In this respect, it is proposed that establishing a research institute can help to explore, study, and sustain the RWH technology. Similarly, in order to sustain, develop, and address prevailing water supply challenges in the country, it is very important to strengthen the established water institutions with a water research centers. Such a centre would develop and run targeted research to address the challenges of water. The proposed center can be affiliated with other institutions like universities and colleges, industrial and private sectors, for increased efficiency and influence.

d. Political, legal and regulatory

Measure:

Develop supporting Policy and regulatory instruments for RWH technology: Targeted regulations are essential in order to guide, encourage, and enforce the adoption and diffusion of the RWH technology. Moreover, national RWH technology guidelines and standards are crucial as highlighted earlier. Similarly, establishment of enabling policies including cost-sharing strategies, provision of subsides along with technical know-how and capacity building for promotion of RWH is recommended. To promote urban water harvesting, policies should include a mix of incentives and penalties, and that such policy initiatives should be strengthened further through legislation.

e. Institutional and Organization Capacity

Programmes should be introduced to enhance local water management skills such water purification, proper collection and use suitability, and organization capacities which can address RWH.

2.2.4 Cost Benefit Analysis for Roof Rainwater Harvesting

A cost benefit analysis was done in order to access the economic benefits associated with adoption and diffusion of Roof Rainwater harvesting technology compared to the existing scenario. The Existing scenario involves fetching water from centralized water kiosk which could take up to 45 minutes per day a situation that negatively affect women and children welfare through reduced productivity and missing out in education respectively. The other challenge associated with the current scenario is that due to water scarcity at times households may be forced buy water from unknown sources with compromised quality leading to water borne diseases.

The cost-benefit analysis (table 8) was done by first identifying both direct and indirect costs and benefits associated with current water sources and the implementation of the Roof Rainwater Harvesting technology. The cost-benefit analysis was based on constructing Roof Rainwater Harvesting units for 150,000 families comprising 4 people. Elements and costs were obtained from expert judgment, consultation and discussion with stakeholders and web search.

Table 8: Elements of Costs and Benefits of the Existing Scenario and of adopting Roof Rain Water Harvesting Technology

SN	**Item**	Amount USD
1.0	Existing Scenario	
1.1	Opportunity cost for fetching water per HH (@ 0.68 USD household/day for one year*	37,000,000
1.2	Health treatment costs associated with poor water quality and nutrition (USD 5 per capita per year)**[5]	3,000,000
	Total Cost	40,000,000
2.0	Cost of Technology	
2.1	Tanks (10 m^3) and installation (@ USD700/household)	105,000,000
	Total Cost	105,000,000
	Benefits	
1.0	Existing scenario	
1.1	Social benefits associated with social interaction for women and youth (have time to attend other things)	1,500,000
	Total Benefits	1,500,000
2.0	Technology	
2.1	Reduction of costs for water	37,000,000
2.2	Improved health	3,000,000
2.4	Economic opportunities (resulting from time served from searching for water)***[6]	9,332,386
	Total Benefits	46,332,386

*Assuming that unconnected HH spent about TZS 30 per 20 liters bucket and 1,000 litres per day 1USD = 2200 TZS[7]

**Assuming 4 people per household

***Assuming that household use 45minutes per day to get water, minimum wage of TZS 40,000 per month[8]

It is clear from the analysis that over 10 years, a value of USD 109,561,227 indicates that the roof rainwater harvesting technology has large benefits and it is therefore viable.

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[5] sanitationandwaterforall.org/.../Tanzania%20-%20WASH%20Economic%20Briefing_.

[6] Household with no water connection spend about 45mimute per day to get water

[7] http://www.waternetonline.ihe.nl/symposium/9/full%20papers/wfp/simon.pdf

[8] http://www.africapay.org/tanzania/home/salary/minimum-wages

2.3 Barrier Analysis and Possible Enabling Measures for Technology 2: Water Leakage Management– Smart Water Metering System (SWM)

2.3.1 General description of Water Leakage Management -Smart Water Metering System (SWM)

The history of the Water Sector in Tanzania dates back to the 1930s when water supply was confined to urban areas and farming settlements owned by settlers. The water development authorities face a number of challenges such as water supplies which do not meet demand and old infrastructure resulting in water losses that reduce financial viability of water utilities resulting in poor services.

There are no reliable and standardized methods for accounting for water losses. Leakage management performance was measured in terms of "unaccounted-for water." The water losses are due to water leakages in the distribution system referred to as non revenue water (NRW)[9]. Non-Revenue Water (NRW) is water that has been pumped, treated, distributed but does not get billed. The amount of NRW is typically represented as a percentage, and is made up of both real and apparent losses, as well as unbilled authorized consumption. Real losses refer to water lost from leaks and water main failures, while apparent losses come from theft and metering inaccuracies. Unbilled authorized consumption comes from water that is provided for public services that is not billed, such as fire hydrants.

NRW is caused by p**hysical (or real) losses - Leakage from all parts of the system** due to poor operations and maintenance, lack of active leakage control and poor quality of underground assets; **Commercial (or apparent) losses** due to **c**ustomer meter under registration, data handling errors and theft of water in various forms (e.g. Illegal Connections); **Unbilled authorized consumption** such as **w**ater used by the utility for operational purposes, water used for fighting fires and water provided for free to certain consumer groups.

NRW is a serious challenge in urban areas and is estimated at 37% while in a big city like Dar es Salaam it is estimated to be about 50% (NAO, 2012). UWSSAs carry out water metering. The maintenance of water meters and the associated costs have been identified by MoWI as one of the pressing problems for urban water suppliers (MoWI, 2009).

Smart water metering (SWM)[10] technology is one of the key solutions to NRW as well as improvement of revenue collection.

[9] Non Revenue Water(NRW) can be defined as water that is produced for consumption and lost before it reaches the customer.

[10] Smart Water Metering (SWM) technology is a "system that measures water consumption or abstraction and then communicates that information in an automated fashion for monitoring and billing purposes".

Smart meters are different from conventional meters as they are able to measure water consumption in greater detail and then transmit that information back to the service provider without the need for manual readings. Additionally, SWM can be configured in various ways and can be broadly defined as Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) systems. Gambe (2015) clarifies further that AMR system allows automated collection of meter readings without the need for physical inspection while AMI involves two-way communication, one being transmission of water consumption information to the utilities and the second one is that utilities can issue commands to water meters to undertake specific functions.

Leakage control is feasible when the entire supply network is monitored and pressure controlled. It is indeed an expensive undertaking, requiring effective tools and equipment besides skilled personnel. Usually an estimated amount of NRW should be known in order to detect and finally locate leaks. Usually, consumers' premise is the last point of the water network where a lot of small leakages that waste water permanently can be identified. Smart metering can help reducing and detecting leakages through its capacity of giving accurate, timely and more frequent meter readings such as the date and time when the leak started and the amount of water through this leak thus detecting abnormal consumption. Smart Water metering by itself does not control NRW, but rather helps in identifying whether NRW problems exist before deciding to invest on control measures.

Furthermore, SWM can reduce energy consumption and CO_2 emissions. Water utilities are typically one of the highest consumers of energy. Electricity is one of the key challenges for governments, and many countries are implementing innovative grid solutions to minimize the cost increase impact to consumers. Frost and Sullivan (2015) estimate 65% of water utility expenditure is on electricity and with smart metering this could be reduced by up to as much as 30%. Therefore, the recommended measure here is to implement SWM technology in Tanzania urban water systems to reduce water losses. In this regard, the analysis is focusing on the anticipated adoption barriers when the SWM, as new technology is deployed in Tanzania. Elimination of the identified barriers could facilitate SWM diffusion.

2.3.2 Identification of barriers for the technology

2.3.2.1 Economic and financial barriers

i. High Cost of Capital Investment and system maintenance

A large capital outlay is necessary to implement Smart Water Metering systems. Thus, there is a high cost connected to the purchase, installation and maintenance of the Smart water meter system. This includes purchase of necessary equipments such as the meters, sensors radio modules together with other ICT data analytics in order to manage the AMI data. The general observation from the national auditing office report was that, the majority of the water utilities in Tanzania are struggling to operate and maintain the current conventional meters with at least 50% of meters being non functional due to financial challenges (NAO, 2012). In this regard, it is easily perceived that the SWM require financially stable institutions to operate and maintain it. As such, Tanzania water Utilities is likely to face economic challenges connected to the initial capital for the SWM investment as well as maintenance.

ii. Mobile payment tariffs

It can be presumed that the implementation of SWM technology in Tanzania may take the advantage of the available telecoms companies like Vodacom, Airtel, Tigo etc. This is likely since the water service providers or utilities in Tanzania already introduced mobile bill payment mechanism like M-pesa, Airtel Money, Tigo-pesa as well as Max Malipo. However, there is a risk of elevated bills due to additional mobile phone payment tarrifs likely to be covered by the consumer (water user). As such, these tariffs can create an inhibiting condition for the SWM technology adoption.

2.3.2.2 Non financial barriers

a. Information & awareness barriers

i. Limited awareness among water users (consumers)

The use of smart water meters is a new technology in Tanzania and will require significant awareness to consumers both commercial and domestic. Usually, customers take for granted the water supplier undertakings and feels that water is a gift of nature requiring simple process to provide. While authorities are installing these meter systems to manage leakages consumers who have poor perception of water meters may find ways to tampering with the meter or diverting water flow from passing through the meter. Most of the domestic consumers prefer charges based on flat rate because the system has less complication between them and the water utility. Consumer feels to lose money when payments are based on water meter reading, especially when comparing with a paying less neighbor whom they believe to have similar use. Thus installation of the new meter system can face resistance due to low awareness of the performance of the SWM.

Meters that have been in use are those that meet the Water Act specifications, where the authorities are supposed to install water meters for the purpose of measuring the amount of water produced and supplied to the customers (Water Act, 2009). Embarking into a Smart water metering programme is a huge challenge involving planning, requires skilled personnel, customer information system and management.

ii. Insufficient information and data

Data availability and management are the main components of a smart water management system. In Tanzania, majority of water Utilities are faced with challenges on aspects of data management. The water authorities are still not able to follow or keep regular water distribution system monitoring. In addition, many other areas receive water but are not connected in a formal district metered areas (not yet mapped) to be in the water distribution zone due to illegal connections. Such situation makes it difficult for the water authorities to know exactly where, how and why water is lost thus making computation and management of NRW difficult (NAOT, 2012).

b. Technical

i. Poor Infrastructure

Majority of utilities have obsolete meters or haven't installed bulk meters at the production and distribution points. In these cases, the quantity of water produced is estimated based on the installed pump capacity. Due to the overlap of the networks, the absence of bulk meters, and defective or non-operational bulk meters, the authorities can neither correctly measure the amount of water that flows into the operational areas nor accurately account for water losses for each of the areas. Furthermore, the distribution system for the majority of utilities suffers from the following problems:

- Old infrastructure leading to leakages
- Illegal connections and meter by pass
- Meter under registration resulting in loss of water. Ageing or damaged meters are not detectable as this translates into reduced consumption that is not readily attributable to the meter. This is not true anymore with advanced smart metering that is capable of detecting meter abnormal behavior.
- An incredibly large number of distribution pipes are in shallow depth a situation that makes them vulnerable to damage during road grading or movement of heavy trucks
- High percentage of non metered customers
- Less accurate and non updated consumers database

ii. Lack of relevant experience and expertise

Considering that this is a new technology in the water supply industry in Tanzania, it is most likely that the available human resource lacks the relevant technical expertise. This implies that there are additional costs of training the relevant team in order to manage the technology. These include the SWM implementation skills as it may require new forms of partnerships as well as financing and business model. Connected to this, is the need for new skills in design and other cross cutting disciplinary specializations. It should be noted that absence of experienced human resource can significantly extend the project duration impacting on the project cost, quality and success. Additionally, other associated costs will emerge on implementing the data and information system for the SWM technology. It is important to note that, lacking the ability to interpret and understand the collected data can cause a serious risk of communicating less reliable information to the customer, a situation that can eventually lead to SWM adoption failure.

iii. Lack of Reliable Electricity

Since the quality of electricity supply in Tanzania is unreliable, technological effectiveness can be compromised during outages. According to the NAOT (2012) this relates mainly to poor quality electricity supply especially to pumping stations and water intakes. This has caused a lot of damage to the equipment due to water hammers. Due to this, there is a risk of losing important data or information from the system.

c. Regulatory and Institutional

i. Standards and Guidelines

Since this is a new technology for the water distribution industry in Tanzania, the technical guidelines and standards for this technology are yet to be established. Absence of these regulatory instruments could be a barrier to deliver quality services. In addition, this technology can be a trigger for higher water supply tariffs. Generally, the analytical costs and benefits of the SWM technology will require new regulatory framework as currently the water Act (2009) allows for water meters with a purpose of measuring the amount of water produced and supplied to the customers while SWM goes beyond that purpose.

d. Social cultural

i. Social Acceptance

The secure collection and use of personal electronic data and information could be a concern to consumers for the acceptance of SWM technology. In Tanzania, already there have been cases of cyber crime relating to illegal money transfer through the banking system. Because of this, customers' data and privacy are still regarded as less secure and this inhibits use of the electronic banking system. Thus, SWM technology could be received with a similar mentality and this can hinder its diffusion.

2.3.3. Identified measures for the technology

a. Financial and economic measures

Measure:

i. Affordable Investment Capital Cost and system maintenance: Private sector involvement through the public private partnership (PPP) can be one of the mechanisms to overcome the high initial investment cost as well as system maintenance costs. This implies that through the PPP approach, utilities will get the opportunity to share the investment costs as well as expertise. It will be the opportunity as well for the private sector or technology providers to understand exactly the utility needs and operational approach.

Eventually, such partnership may allow technology providers to help the utilities develop marketable smart water network product solutions as well as adopting SWM standards

ii. Mobile payment tariffs: The government can introduce subsidized tariffs to the telecommunication firms for the service. But on the other hand, the telecommunication firms can regard this as giving back service or as corporate social responsibility (CSR).

Non Economic Measures

a. Awareness and information

i. Improved awareness to water users and authorities

Measure: Consumers must be educated and involved in safeguarding water meters and other facilities. Franceys (1990) commented that unless consumers are involved, systems will not be maintained correctly and will fail. Development of a comprehensive awareness programme through audio and visual media as well as printing media to enable adoption of the meters. The programme should benefit authorities through capacity building, workshops, exchange programmes and gear towards making consumers feel in control of their water consumption by publicizing that smart metering gives back the control to the consumer, through:

- Providing in timely fashion notification when they experience unusual consumption avoiding unexpected high bills.
- Developing appropriate payment terms to reduce bill pain.
- Providing evidence of consumption so customer can focus on fixing the issue.
- Providing means and data to truly act positively on protection of the environment and witness the results.
- Empowering water utilities to offer targeted solutions that truly benefit the consumer.

ii. Data availability

Measure: Availability of data is linked to effective monitoring of the distribution system and database establishment. Therefore, utilities could do the following:

- Undertake customer mapping in the network
- All customers to be metered
- Undertake regular monitoring of the water distribution system
- Establish and update the customer database

b. Technical

i. Improved Water Distribution Infrastructure

Measure: The SWM system is effective when the water distribution system infrastructure is sound and in good operational condition. As such, good condition of the water distribution system (Fig 1) including the trunk mains and their connections, service reservoirs, distribution system mains, service pipes, booster stations, service tanks, air valves and others will allow effective operation of the SWM system.

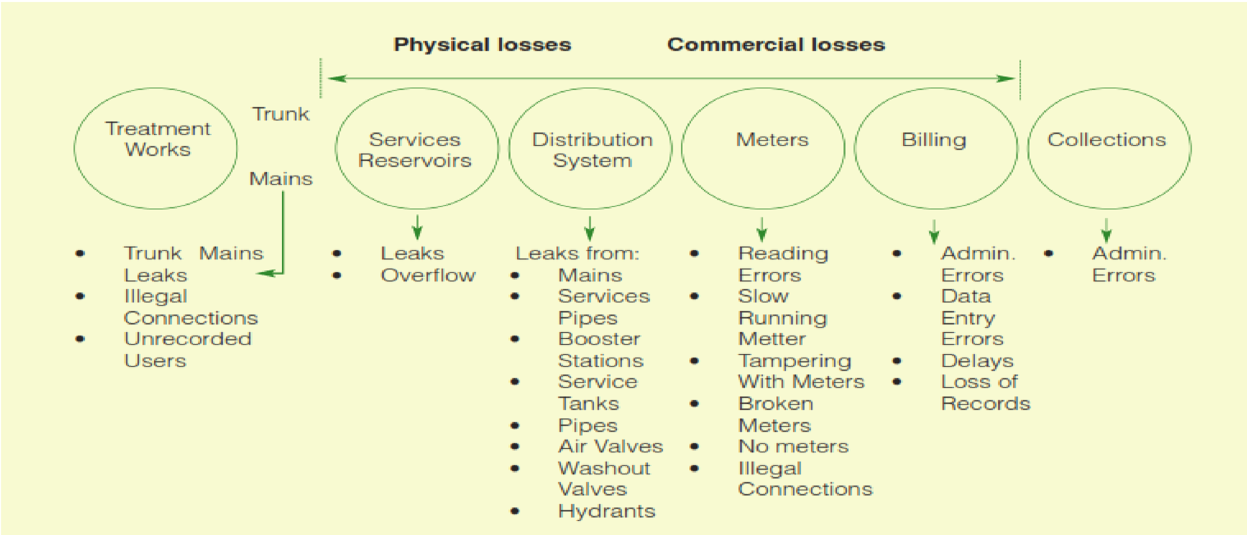

Figure 2: Water Distribution System, possible leakage points (Adopted from NAOT, 2012)

Under the Urban Water Supply and Sanitation investments (original allocation: US$ 480 million), there were Capital development grants to support rehabilitation and expansion of water supply and sanitation works in Dar es Salaam, 19 UWSAs, 109 gazetted small towns and district headquarters, and 7 National Projects. This shows that infrastructure rehabilitation/ development is being done under the Water Sector Development Programme (2005-2025). However, to run effective smart water metering, the water distribution system has to be repaired or retrofitted. Therefore, utilities have to do the following for immediate steps to improve infrastructure:

- Undertake diagnostic studies to determine the underlying causes of physical water losses,
- Utilities management should prepare plans and budgets for the water distribution repair and maintenance.

In reality, utilities may not be able to immediately cover the associated costs of such measures. Therefore, it is recommended that Private sector involvement through the public private partnership (PPP) can be adopted as a mechanism to overcome the associated cost as well as system maintenance.

ii. Develop relevant skills and capacity building

Measure: Since the SWM technology would be new to the utilities, it is likely that there may be resistance within utilities to adopt it. This could be due to lack of relevant experience and expertise. To instil confidence and mindset change, utilities have to engage with technology providers. This will help in developing relevant skills and build the capacity of the authorities. Partnership with technology providers can be one of the opportunities for utility staff to create awareness (which could be through remedial courses, demonstration projects or both) or get educated about smart water networks, the impacts on the utilities performance as well as cost benefit analysis of the SWM investment.

c. Regulatory and Institutional Barrier

i. Standards and Guidelines

Measure: SWM technology is new and is likely to result in modified tariffs and administration. Therefore, there is a need of the governing regulatory framework that will address the relevant technical standards and guidelines. Therefore, the government has to come up with relevant standards that will address tariff structuring, ownership structure in project planning and delivery, product technical aspects, system operations, operations and maintenance, security (privacy issues) as well as human development aspects.

d. Social Cultural

i. Social acceptance

Measure: It is suggested that the government has to develop a regulatory mechanism aiming at cyber security focusing on public privacy aspects for personal consumer information. On the other hand, the technology providers together with utilities have to undertake communication campaigns regarding customer data protection. The campaign should address system operation aspects, assurance about technical as well as managerial measures in place to protect the customer data or privacy.

2.3.4 Cost Benefit Analysis for Smart Meter Installation in Kinondoni District

A cost benefit analysis as shown in Table 9, was done in order to assess the economic benefits associated with adoption and diffusion of Smart Meter Technology in Kinondoni District compared to the existing scenario. The Existing scenario involves using conventional meters which are responsible for huge Non Revenue Water Losses since they can easily be by-passed, they can be tempered with but more critically users of water do not pay their bills in time.

The cost-benefit analysis was done by first identifying both direct and indirect costs and benefits associated with current conventional technologies and the implementation of Smart Meter Technology. The cost-benefit analysis was based on installing Smart Meters in

Kinondoni District where there about 1,410 water connections[11] and costs were obtained from expert judgment, consultation and discussion with stakeholders and web search.

Table 9: Elements of Costs and Benefits of the Existing Scenario and of adopting Smart Meter Technology

SN	**Item**	Amount USD
1.0	Existing Scenario	
1.1	Opportunity cost as a result of Non Revenue water losses (assuming that 50% of NRW is resulting from non-commercial losses	3,800,645
1.2	Cost of reading meters (@Tsh/hh)	2,727
1.2	Cost of printing water bills or sending sms to customers (TZS 250 per sms per month)	1,923
	Total Cost	**3,805,295**
2.0	Cost of Technology	
2.1	Cost of smart meter (@USD 500[12] per meter)	705,000
2.2	Cost of Installing Smart Meter System	1,000,000
2.3	O&M per year	100,000
	Total Cost	**1,805,000**
	Benefits	
1.0	Existing scenario	
1.1	Reduction in costs of following wrong bills estimated at 100 hours per month	1,000
	Total Benefits	1,000
2.0	Adaptation Technology Scenario	
2.1	Reduction of costs for water loss	3,800,645
2.2	Reduction of meter reading costs	2,727
	Total Benefits	**3,803,372**

It is clear from the value of USD **14,817,430.87** that the Smart Meter technology is viable compared to the current baseline technology.

[11] Assuming that 50% of HH are connected (Kinondoni has about 2,820 Households - http://www.cluva.eu/meetings/Leipzig_Workshop/Day2-Tuesday_6.12/Regina_Dar_es_Salaam_Case_studies.pdf)

[12] https://www.baltimorebrew.com/2013/10/18/totaling-up-the-costs-of-smart-water-meters/

2.4 Barrier Analysis and Possible Enabling Measures for Technology 3: Water Reuse and Recycling - Waste Water Stabilization Pond

Waste water reuse can produce obvious benefits as it reduces the need for extraction of water from surface and groundwater resources. Especially given the current pressure and water shortage due to climate change impacts, reused waste water can provide an alternative water resource. In Tanzania, only a very small percentage of waste water is reused. Though recently there is a growing interest, the common application has been for small farming practices. To a lesser extent, effluents are being used for industrial purposes or for the augmentation of domestic supplies.

One of the common technologies for waste water treatment in developing countries is the waste stabilization ponds. Waste stabilization ponds (WSPs) are usually the most appropriate method of domestic and municipal wastewater treatment where the climate is most favorable for their operation. In addition, wastewater treatment plants are reported to operate in the municipalities of Morogoro, Dodoma, Iringa, Arusha and Songea and in the cities of Dar es Salaam and Mwanza. Wastewater samples are collected from these wastewater treatment plants. The result of the analysis of 250 samples showed that national standards for effluent prior to discharge were met in 88% of cases.

2.4.1 General description of Water Reuse and Recycling - Waste Water Stabilization Pond

Waste stabilization ponds (WSPs)[13] are earth structures capable of containing wastewater and facilitate the occurrence of biological processes (e.g., aeration or digestion), with or without the presence of oxygen. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. WSPs are low-cost for O&M and BOD and pathogen removal is high. However, large surface areas and expert design are required. The effluent still contains nutrients (e.g. N and P) and is therefore appropriate for the reuse in agriculture , but not for direct recharge in surface waters.

The basic design of the system includes a series of ponds, consisting of: (i) inlet, (ii) anaerobic pond (for organic matter removal), (iii) facultative pond (pathogen destruction and organic matter treatment), (iv) maturation pond (pathogen and suspended solids removal), and (v) outlet. The waste water treatment process that occurs in ponds is biological and is entirely natural due to the bacteria and microalgae processes. The

[13] Waste or Wastewater Stabilization Ponds (WSPs) are large, man-made water bodies in which blackwater, greywater or faecal sludge are treated by natural occurring processes and the influence of sunlight, wind, microorganisms and algae.

anaerobic pond operates anaerobically as it receives the raw waste water. The second pond operates by both anaerobic and aerobic waste decomposition. The final basin, the maturation pond, operates aerobically and its main function is to eliminate pathogens. The well treated effluent from the maturation pond can later be reused for irrigation, fishing or vegetable watering.

2.4.2 Identification of barriers for the technology

The identification of barriers was carried out through a stakeholder consultation and by using the logical problem analysis methodology as described in the TNA Guidebook 'Overcoming Barriers to the Transfer and Diffusion of Climate Technologies'. The identified barriers are given below:

2.4.2.1 Economic and financial barriers

i. Poor access to affordable financing for WSPs construction

There are limited opportunities for accessing financial resources for investing in WSPs. Financial institutions are not motivated to provide loans and credits to non-commercial investments. Therefore water authorities have limited economic means to invest in WSPs and end up not investing in WSPs at all as they are more focused on water supply. As a result WSPs receives very little funds as a share from water authorities.

ii. High investment costs

WSPs involve high up-front costs emanating from the procurement of and the availability of land as ponds needs large pieces of land. Construction costs represent about 80 % of the total estimated cost of sewage treatment facilities. As it is widely acknowledged, very few households are connected to the central waste water system which is indicative of the high cost of the technology. The most commonly used sanitary facility in Tanzania is the traditional pit latrine (99%), followed by central sewer (12%), and septic tank (10%). The data for the regional analysis also shows that 10% of the population in the region has no facilities and practice open defecation (UNEP, 2009). Other cost items include: (a) facilities such as interceptors and outfall sewers; (b) pumping stations not contiguous to the treatment plant; and (c) administrative, engineering, and legal services.

2.4.2.2 Non financial barriers

a. Technical

i. Limited research on wastewater treatment technologies, WSPs

Absence of targeted policies leads to the limited support for wastewater reuse related research. Currently, few donor supported research initiatives are executed in state universities and are just for academic purposes only. Absence of targeted research is one of the contributing reasons for the lack of local WSPs related data. As a cascading effect, there is no scientific baseline information to support the formulation of local WSPs standards and specifications.

b. Policy and Regulatory framework

i. Absence of Policy instruments targeted on wastewater recycling and reuse.

Wastewater recycling and reuse is not yet a priority for the government. For example, the effluent from a waste stabilization pond may not be of adequate chemical quality to meet the requirements, or there might be some aesthetic reason for not using ponds. Such decisions involving projected water uses and comparisons of alternatives must remain the responsibility of the engineer. He must design treatment facilities within the framework of local, regional, and national regulations and needs, taking both health considerations and water resources into account. In this respect, if there is no targeted policy instruments, education and awareness programme to support the relevant authorities, technologies such as the WSPs are not given priority.

ii. Weak implementation of the land policy

Tanzania land policy stresses the importance of urban planning. However, this policy is challenged by the rural – urban migration. The urbanization rate is estimated to be 30% (Kidata, 2013) of the total population. The statistical trend indicates that proportion of the population living in urban areas is escalating at the rate of 30% per annum (URT, 2012). However, the rate of urban immigration is not at the same pace with urban planning. This situation forces the urban immigrants to live in squatter settlements. This situation imposes a big challenge to the urban infrastructure including the WSPs. Thus, in some urban centers the WSPs sites are already being encroached by the rapid expansion of squatter residences. As the consequence, the WSPs tend to be solid waste dumping sites. Additional to this, WSPs tend to become hostile facilities to the residents as they become sources of waterborne diseases as well as breeding sites for mosquitoes.

2.4.3. Identified measures for the technology

2.4.3.1 Economic and Financial Measure

Financial measures depend mainly on the need for government action to attract external support for the effective implementation of the technology; this can be by subsidizing cost of construction to at least 50 %. Also enabling municipalities to access loans and grants to meet costs of construction.

2.4.3.2 Non financial measures

a. **Technical**

Measure:

i. Develop specific standards and design specification for WSPs: Government should develop relevant standards and specifications that can reflect the local situation. In depth studies that can address area specific conditions for the ponds construction should be conducted.

ii. **Support research (R&D) on wastewater treatment technologies**: Support by the government to research institutions is important. This includes regular monitoring of the operational WSPs in order to determine the trends on operational efficiency with the objective of wastewater reuse and recycling. As an incentive, the government can prepare the annual award for the private operators i.e. industries who may come up with further innovations to facilitate wastewater reuse and recycling.

b. **Policy and Regulatory**

Measure:

i. **Develop supportive Policy and regulatory instruments to promote WSPs:** The government should formulate targeted policy instruments. This may be targeted economic incentives, for instance tax exemptions or subsidies to the private operators interested in investing in this sector. On the other hand, the government can impose strict and elevated tax for those operators discharging or disposing waste water. Importantly, the government could develop awareness on waste water reuse/recycle programmes to the public, processing industries inclusive.

ii. **Improve implementation of the land policy:** The government has to strengthen and enforce urban planning laws and regulations. Urban residents who happen to reside close to the WSPs have to be resettled and compensated appropriately for their reallocation. For the new WSPs sites, government should develop and enforce strict sustainable land settlement regulations.

2.4.4 Cost Benefit Analysis for Waste Water Recycling using Waste Stabilisation Ponds

A cost benefit analysis was done in order to assess the economic benefits associated with adoption and diffusion of Waste Stabilization Ponds Technology in Dar es Salaam, Dodoma, and Mwanza compared to the existing scenario. In the existing scenario, less than 10% of population in these Cities use central sewer. Majority of City dwellers use septic tank tanks and soak away pits and when the ponds are full they are emptied using trucks and discharged into the few existing stabilization ponds. Because the trucks are so few, they are unable to meet demand (Mkaboko *et al* 2014[14]). As a result waste water is discharged in the environment without meeting the required standards.

The cost-benefit analysis as shown in Table 10, was done by first identifying both direct and indirect costs and benefits associated with current on site waste water treatment systems and the construction of additional stabilization ponds (3 ponds in Dar es Salaam, 2 Ponds in Dodoma and 1 Pond in Mwanza). The costs were obtained from expert judgment, consultation and discussion with stakeholders and web search. The number of people that will be connected to new central sewer is a follows: Dar es Salaam 10% of population which is not connected to the sewer for each Kinondoni, Ilala and Temeke municipalities amounting to 79446 households, in Mwanza, Nyamagana district 10% amounting to 36345 households will be targeted, while in Dodoma Urban District 82,191 households which is 20% will be targeted. Thus in total the technology targets to 200,000 husehold by 2030.

[14] A.S. Mwakaboko, E. H. J. Lugwisha and C.W. Kayogolo (2014). http://www.ijset.net/journal/443.pdf

Table 10: Elements of Costs and Benefits of the Existing Scenario and of adopting Waste Stabilization Ponds Technology

SN	Item	Amount USD
1.0	Existing Scenario	
1.1	Opportunity cost for emptying septic tanks per HH (@ 7 USD per household for one year (assuming the septic tanks are emptied every three years at USD22 per trip))	1,385,874
1.2	Health treatment costs associated with coming into contact with contaminated water (USD 5 per capita per year)**[15]	578,955
	Total Cost	**1,964,829**
2.0	Cost of Technology	
2.1	Construction of stabilization pond (@ USD427,730/stabilization pond[16])	2,138,653
2.2	Annual operating costs of stabilization ponds @ 16,504/stabilization pond[17]	82,521
2.3	Cost of construction a sewerage system (assuming 80km of pipeline (per city) at 650m TZS per 20 km)[18]	3,388,908
	Total Cost	**5,610,082**
	Benefits	
1.0	Existing scenario	
1.1	Benefits of not using septic tanks	1,385,874
1.2	Health avoided costs	58,955
	Total Benefits	**1,500,000**
2.0	Adaptation Technology Scenario	
2.1	Revenue from using sewerage system (assuming 7m^3 per month of water at 20% of water costs)	2,115,975
2.2	Improved health	578,955
2.4	Revenue from septic emptier (assuming 50 tanks per day per pond at TZS30,000)	1,244,318
	Total Benefits	**3,939,248**

It is clear from the value of USD 21,590,770 that the wastewater recycling through construction of stabilization ponds is viable compared to current waste water treating technologies.

[15] sanitationandwaterforall.org/.../Tanzania%20-%20WASH%20Economic%20Briefing_.
[16] https://journal.gnest.org/sites/default/files/Submissions/gnest_01279/gnest_01279_published.pdf
[17] https://journal.gnest.org/sites/default/files/Submissions/gnest_01279/gnest_01279_published.pdf
[18] http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1169585750379/UDS14_UrbanExpansionTanzania.pdf

2.5 Linkages of the Barriers Identified

It is important to note that the Smart Water Metering is a technology that is expected to be implemented into Tanzania in the short term. As such, the barriers identified were already known. On the other hand, the SWM barriers are already being confronted.

Through this barrier analysis process, it was noted that some of barriers are common to all the three technologies while others were just common to only two technologies i.e. rainwater harvesting (RWH), Smart Water Metering (SWM) as well as the Wastewater Stabilization Ponds (WSPs). The common barriers cutting cross the three technologies are high investment cost, access and data availability, technological guidelines and standards, policy frameworks and finally are the aspect of capacity of the targeted institutions. Below is further discussion regarding the crosscutting barriers.

Barrier on Data access and availability

Aspect of data access and availability mainly due to the absence of research as well as regular monitoring. Lack of targeted research is linked with lack of government support. Regular monitoring on the other hand is caused mostly by understaffing as well as poor technology. On the other hand, there is an institutional coordination gap thus creating difficulties to access and share available data.

Barrier on Standards, Policy and regulatory

Absence of targeted policy and regulatory instruments is noted as common barrier for the three technologies. Absence of targeted economic incentives like subsidies to enhance technological diffusion is obvious. On the other hand, technical standards and guidelines are another common challenge. Notably, aspects of guidelines and standards are closely linked with availability of sustained research (and development) as well as data access. As highlighted earlier, data access and mobilization is still a big challenge.

2.6 Enabling framework for overcoming the barriers in the Water Sector

Table 11 gives a summary of common barriers for the three technologies together with the addressed enabling framework.

Table 11: Cross cutting barriers with the relevant enabling framework

Type	Broad/common barriers	Enabling framework	Responsible
Economic and Financial	Limited financial capacity	Strategy to access funds from within the country and outside the country through bilateral and multilateral arrangement Partner with financial institutions providing project start-up capital. Public private engagement in the form of public private partnerships (PPP) is another suggested approach mainly on the part of investing on SWM and WSP technology.	MoWI, MOF, MIT
	High capital costs	Provide tax incentives to private developers Government can introduce economic incentives e.g. subsidies on equipment and accessories for RWH ,SWM and WSP technologies	MoWI, MOF.
Non Economic non financial	Data Access and availability	Regular monitoring of the operational systems in order to determine the trends on operational efficiency. Develop and regular update of the customer database	MoWI, EWURA, Water Authorities
	Guidelines and Technical Standards	Government to design respective technical standards for equipment or accessories for rainwater harvesting as well as Smart Water Metering technologies. For WSPs, government can develop and establish design and implementation standards In additional, government can develop relevant guidelines addressing the implementation mechanism for the three technologies	TBS, MoWI, Universities
	Poor infrastructure	Undertaking of diagnostic study in order to determine the underlying causes of physical deterioration as well as operational deficiencies. Utilities management shall prepare plans and budgets for the system repair and maintenance as well as construction of new sewers.	MoWI, Research institutes
	Policy and regulatory framework	Government to develop and implement policy and regulatory instruments Put in place a policy to assist innovators and	MoWI, MAFL, Research Institutes

Type	Broad/common barriers	Enabling framework	Responsible
		technology champions Strengthen inter-agency coordination	
	Limited research	Government to support research and development programmes crosscutting to the three technologies Establishment of research/ demonstration centers for the three technologies	MoWI, Research institutes, EWURA

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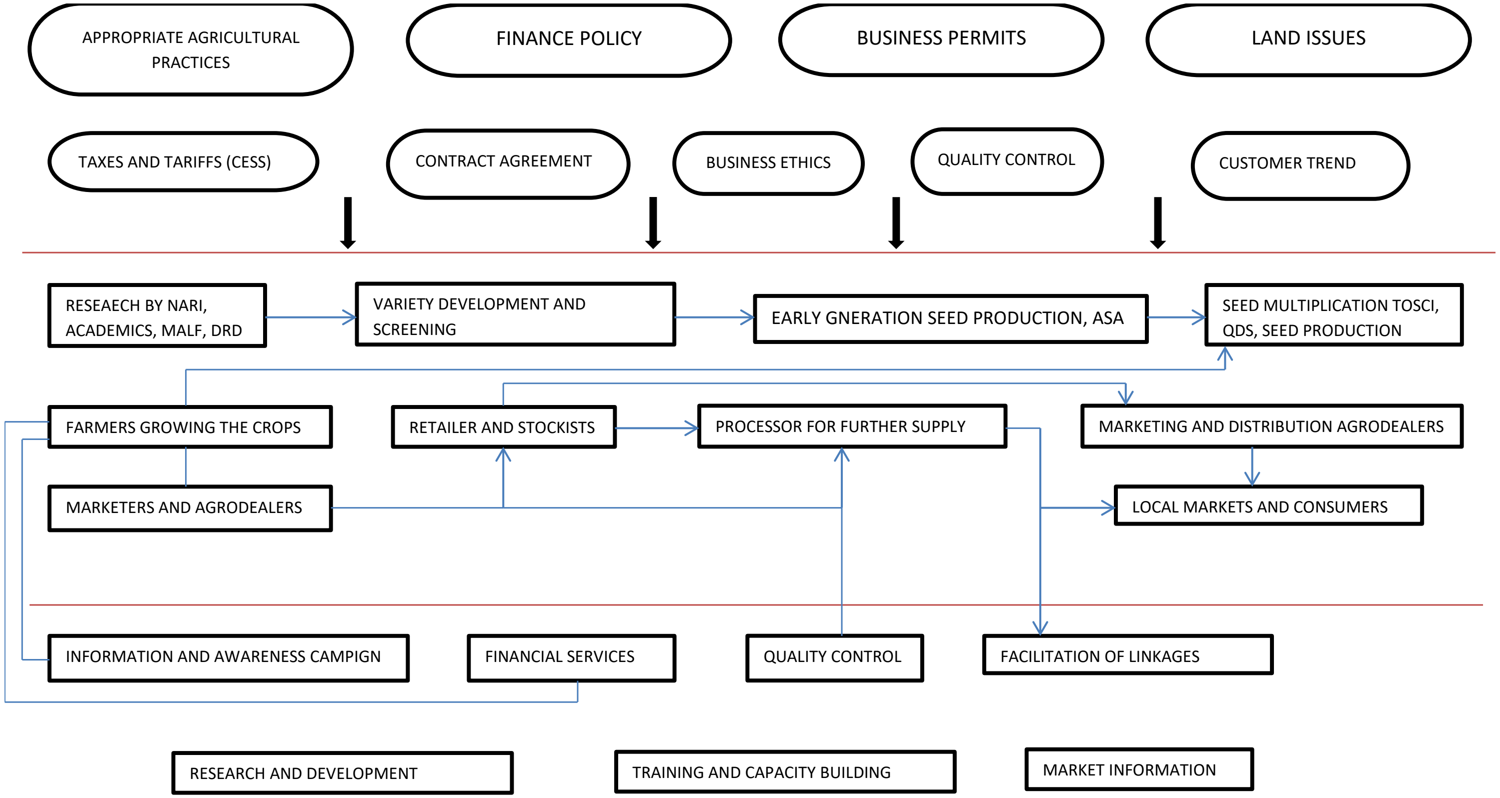
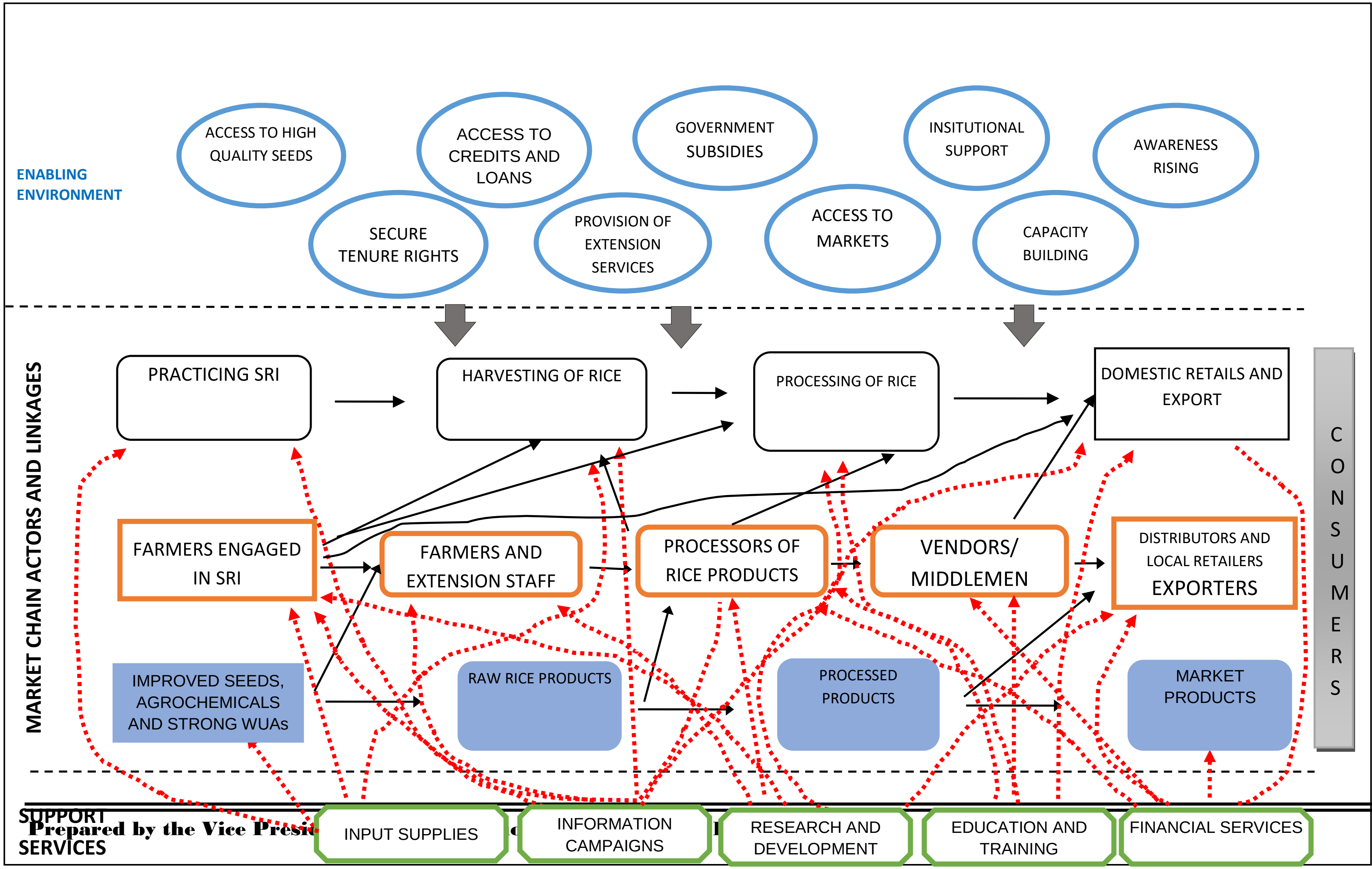
ANNEX I: MARKET MAPS

Agriculture Sector

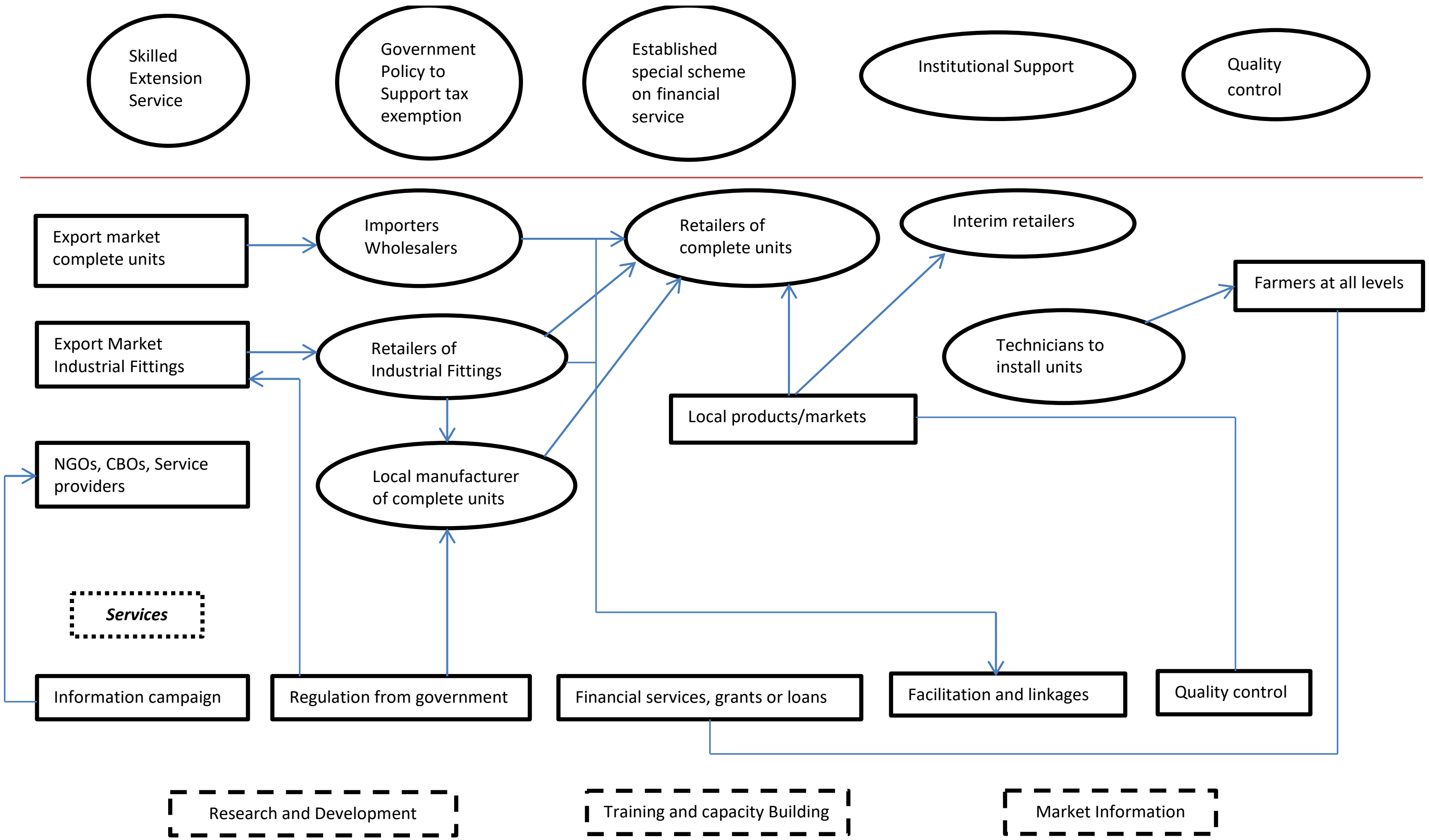
i. IMPROVED SEED VARIETIES



ii. SYSTEM OF RICE INTENSIFICATION

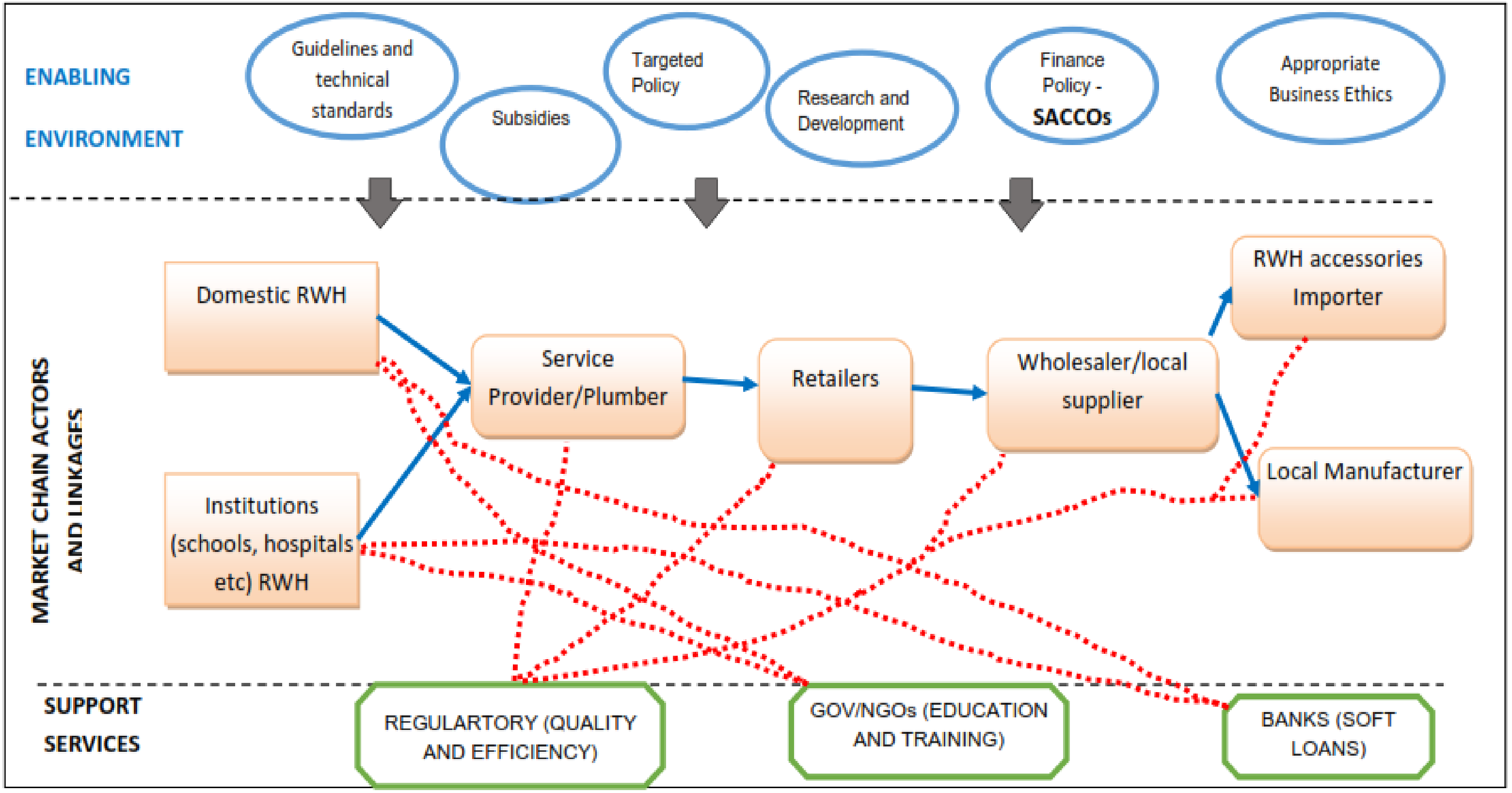


iii. DRIP IRRIGATION

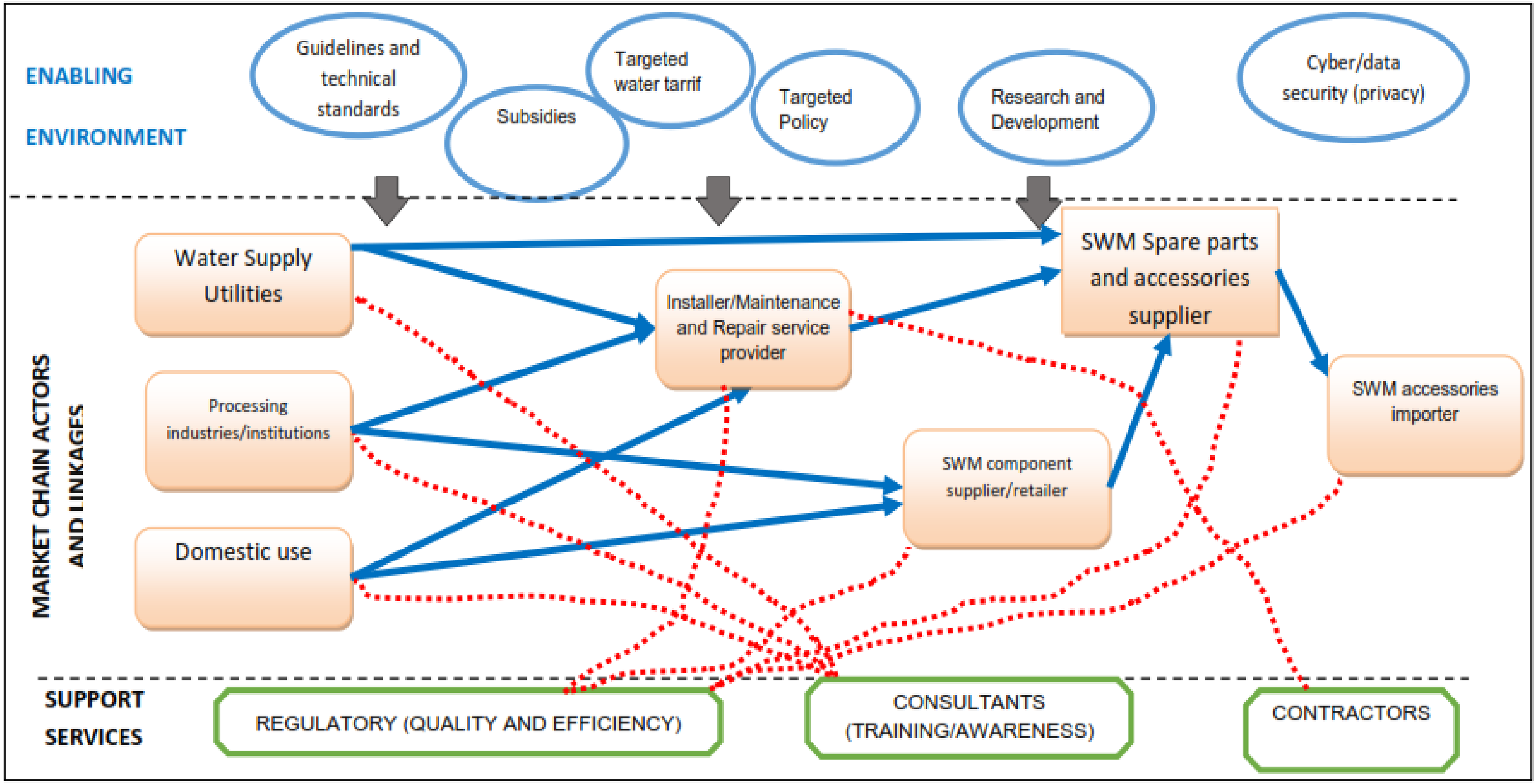


Water Sector

i. RAIN WATER HARVESTING



ii. SMART WATER METERING (SWM)



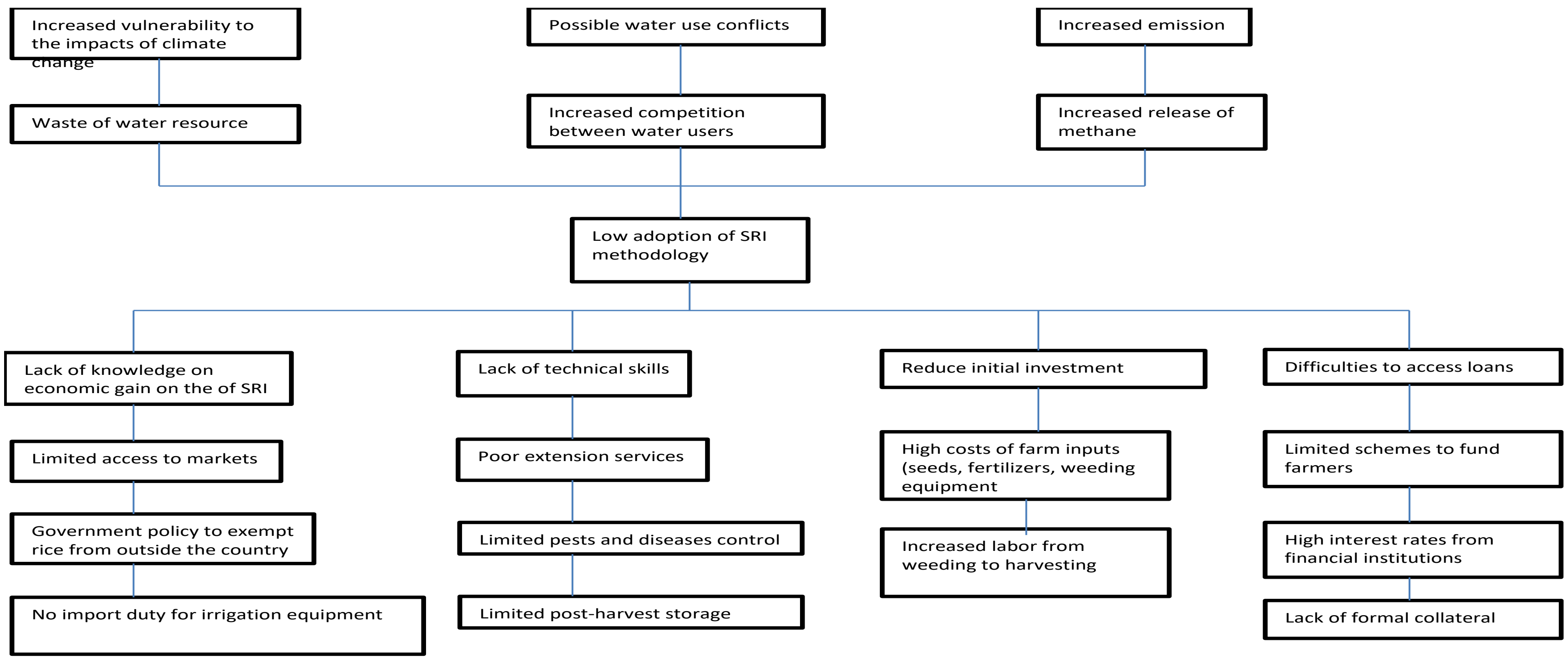
iii. WASTE STABILIZATION POND

ANNEX II: LOGICAL PROBLEM ANALYSIS

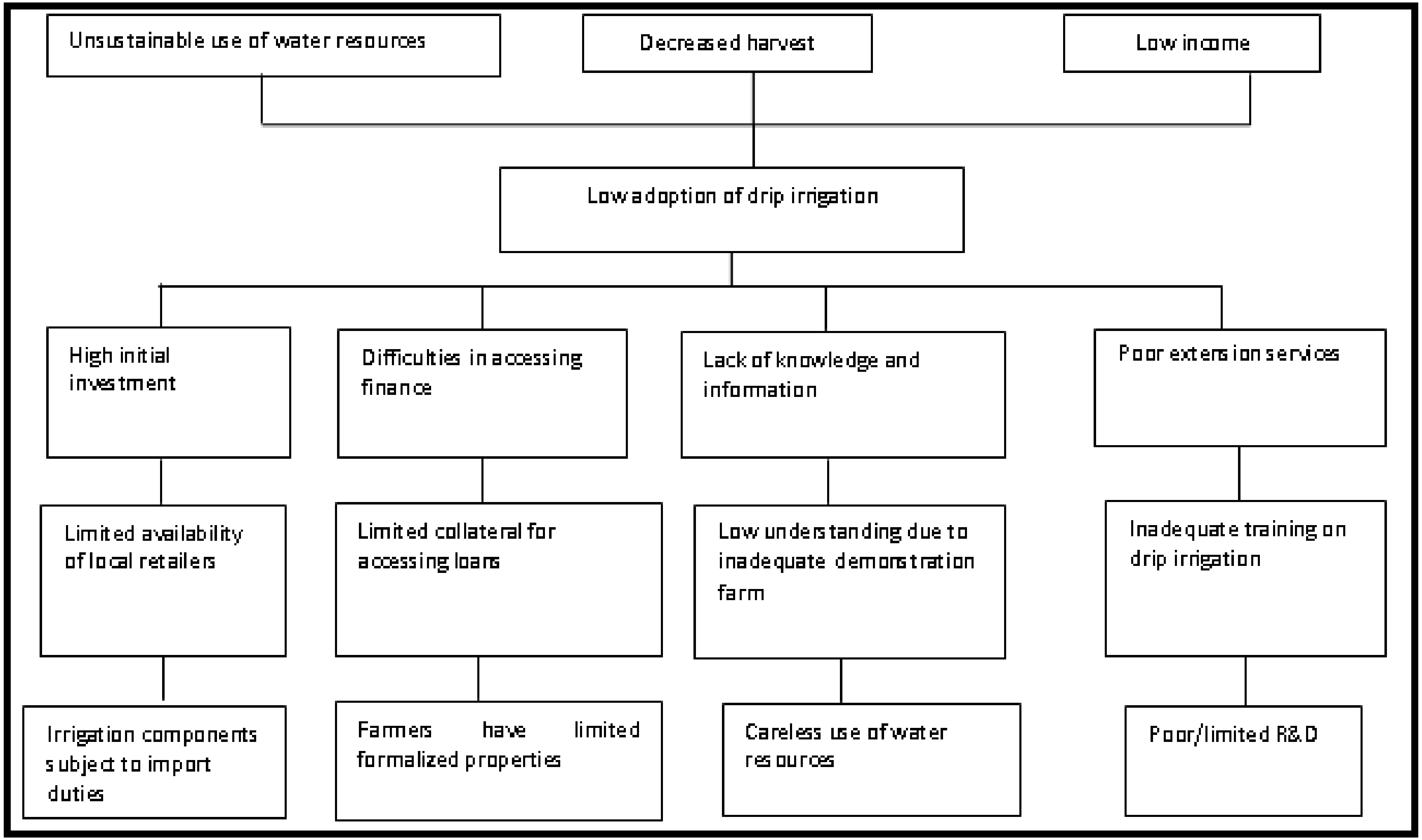
Agriculture Sector

i. IMPROVED SEED VARIETIES

ii. SYSTEM OF RICE INTESIFICATION

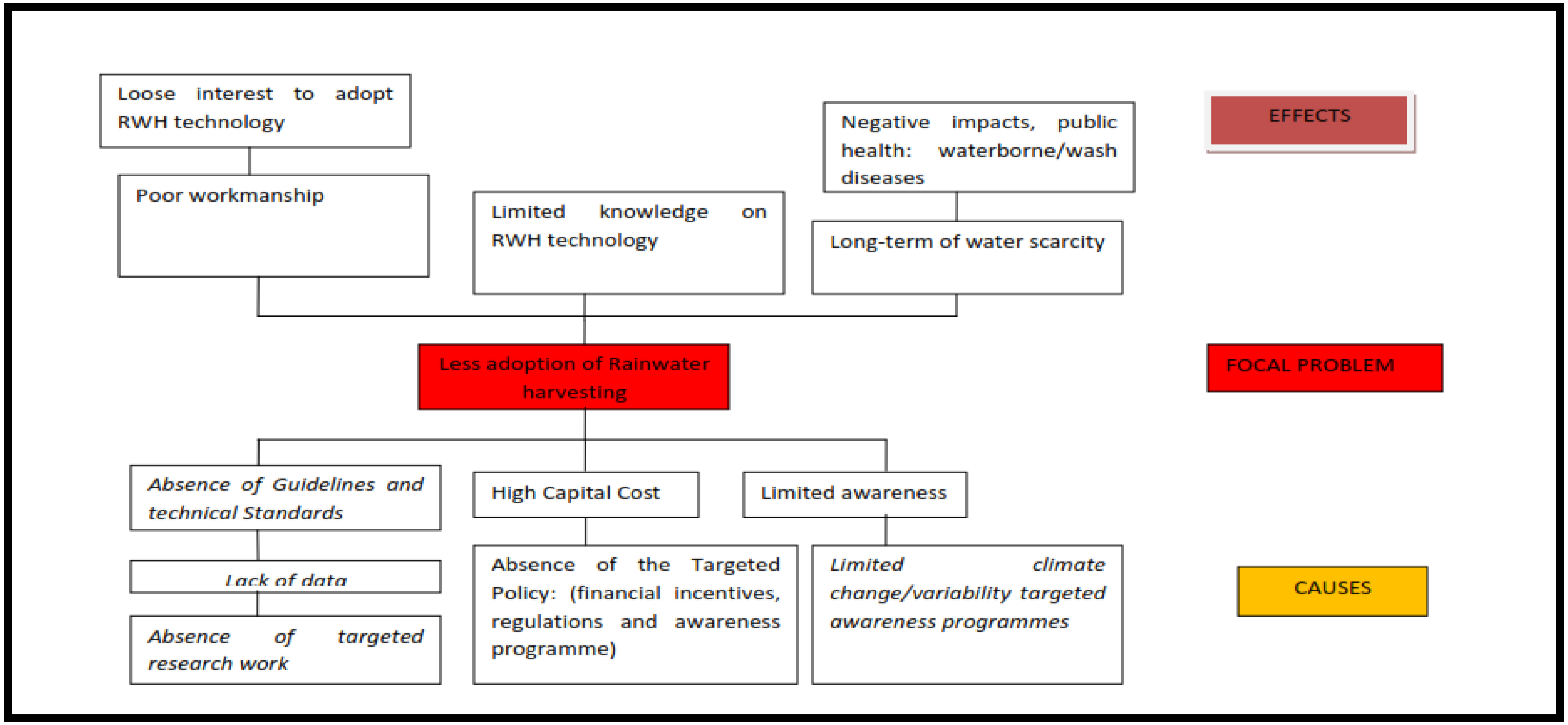


iii. DRIP IRRIGATION


Unsustainable use of water resources
Decreased harvest
Low income
Low adoption of drip irrigation
High initial investment
Difficulties in accessing finance
Lack of knowledge and information
Poor extension services
Limited availability of local retailers
Limited collateral for accessing loans
Low understanding due to inadequate demonstration farm
Inadequate training on drip irrigation
Irrigation components subject to import duties
Farmers have limited formalized properties
Careless use of water resources
Poor/limited R&D

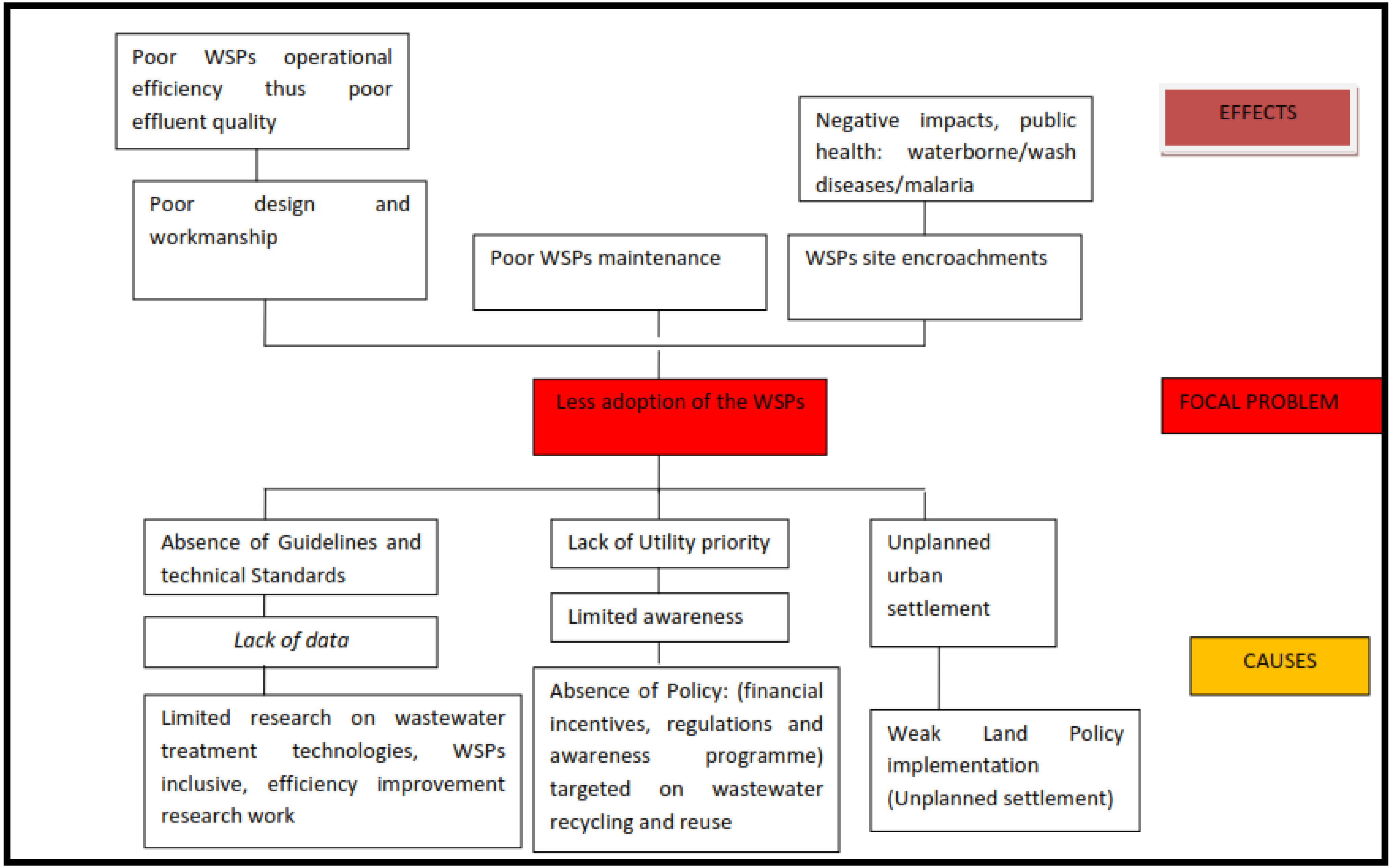
Water Sector

i. RAIN WATER HARVESTING



ii. **SMART WATER METER**

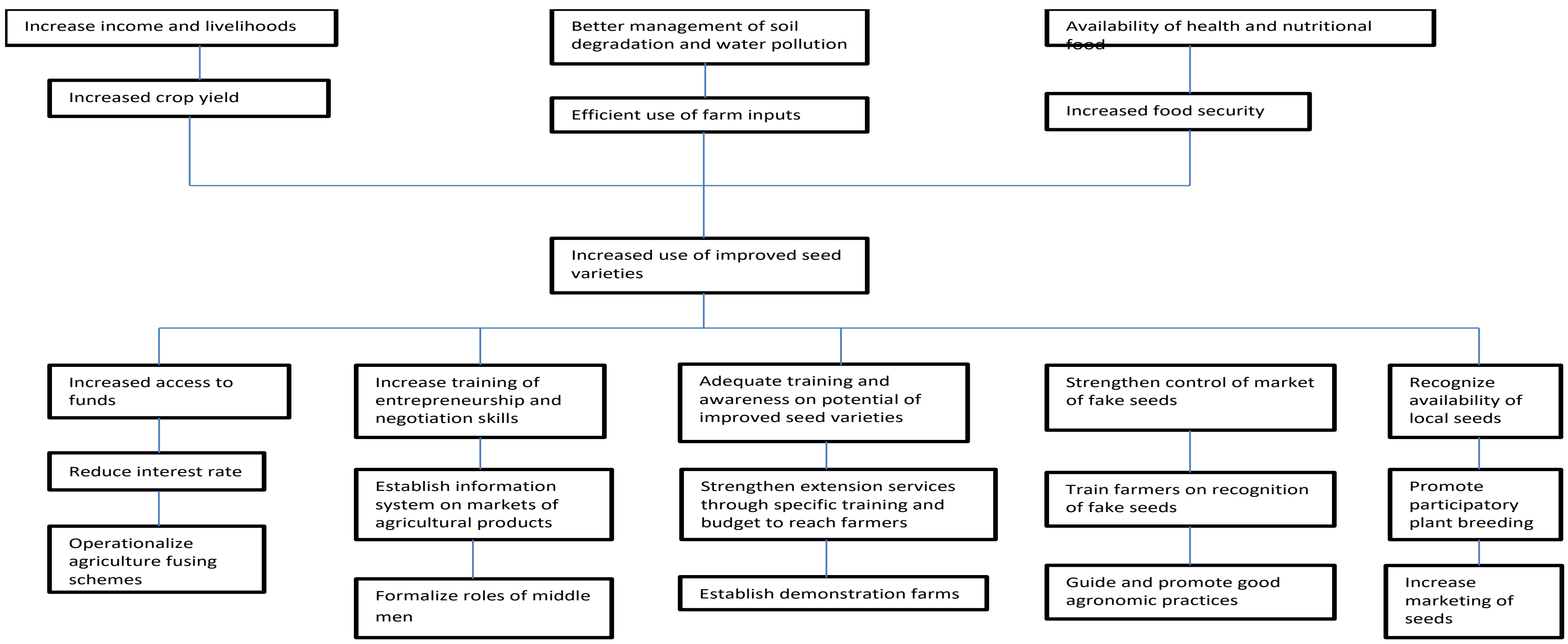
iii. **WASTE STABILIZATION PONDS**


Poor WSPs operational efficiency thus poor effluent quality
Negative impacts, public health: waterborne/wash diseases/malaria
EFFECTS
Poor design and workmanship
Poor WSPs maintenance
WSPs site encroachments
Less adoption of the WSPs
FOCAL PROBLEM
Absence of Guidelines and technical Standards
Lack of Utility priority
Unplanned urban settlement
Lack of data
Limited awareness
CAUSES
Limited research on wastewater treatment technologies, WSPs inclusive, efficiency improvement research work
Absence of Policy: (financial incentives, regulations and awareness programme) targeted on wastewater recycling and reuse
Weak Land Policy implementation (Unplanned settlement)

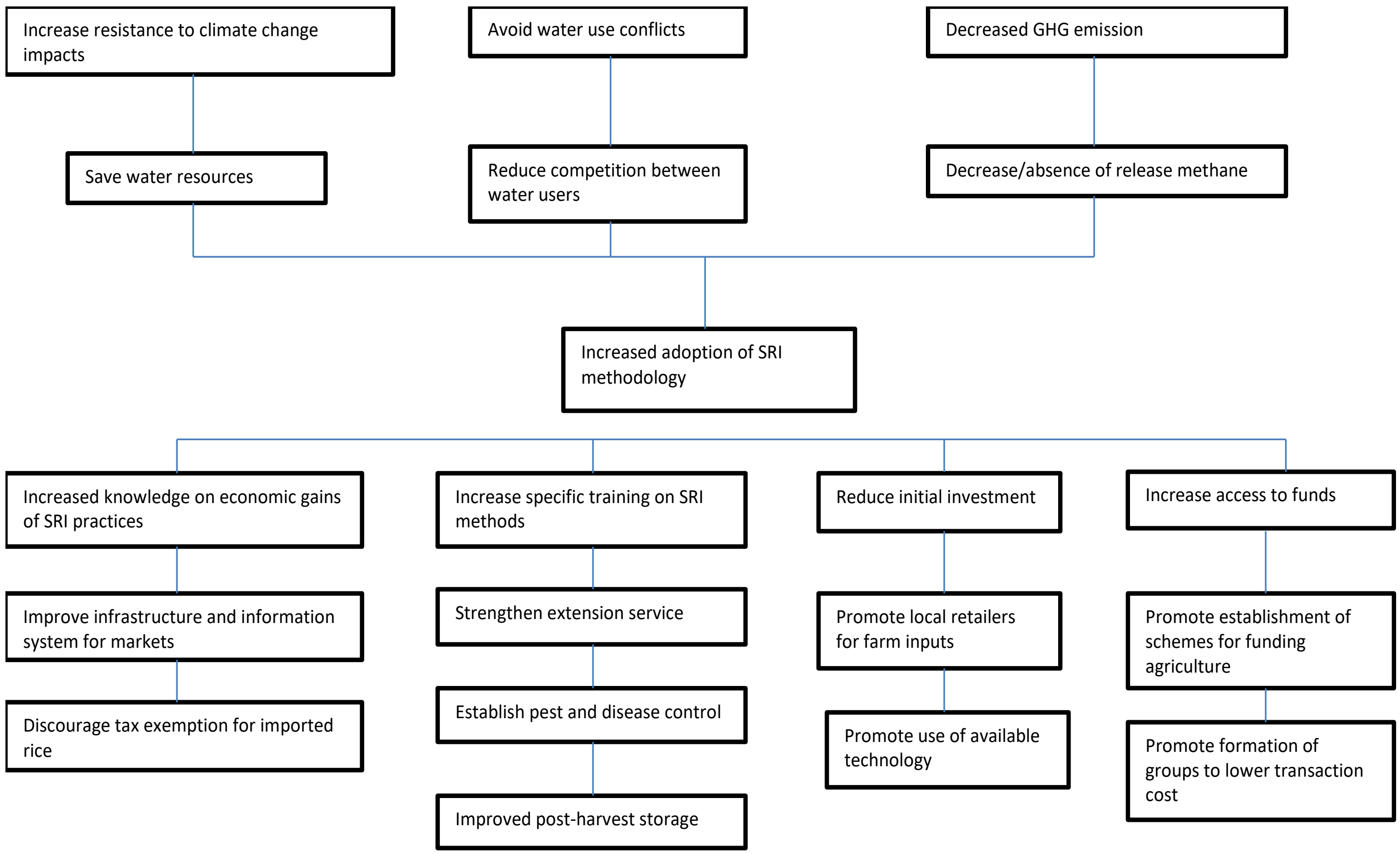
ANNEX III: OBJECTIVE TREE ANALYSIS

Agriculture Sector

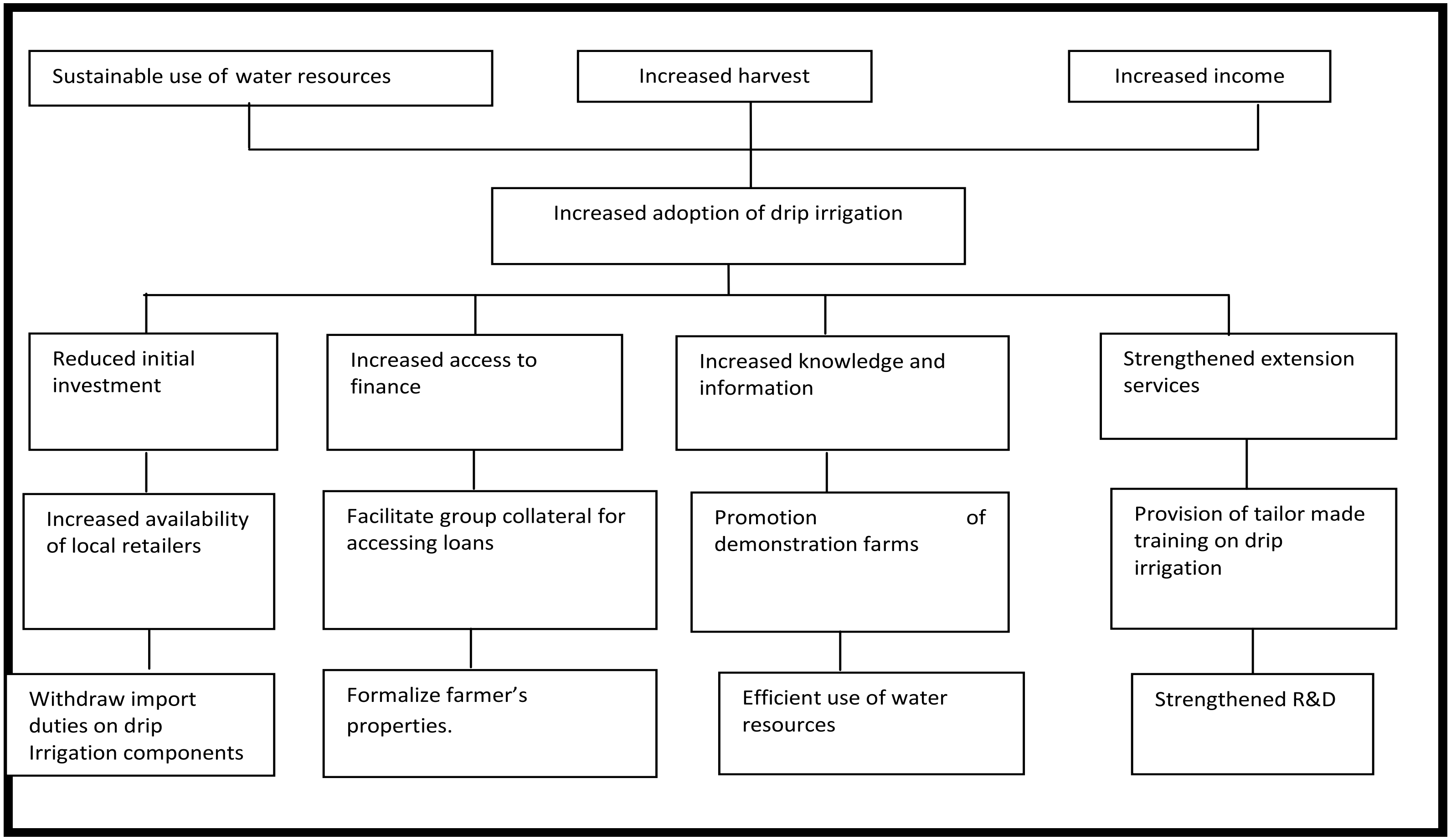
i. IMPROVED SEED VARIETIES



ii. SYSTEM OF RICE INTESIFICATION



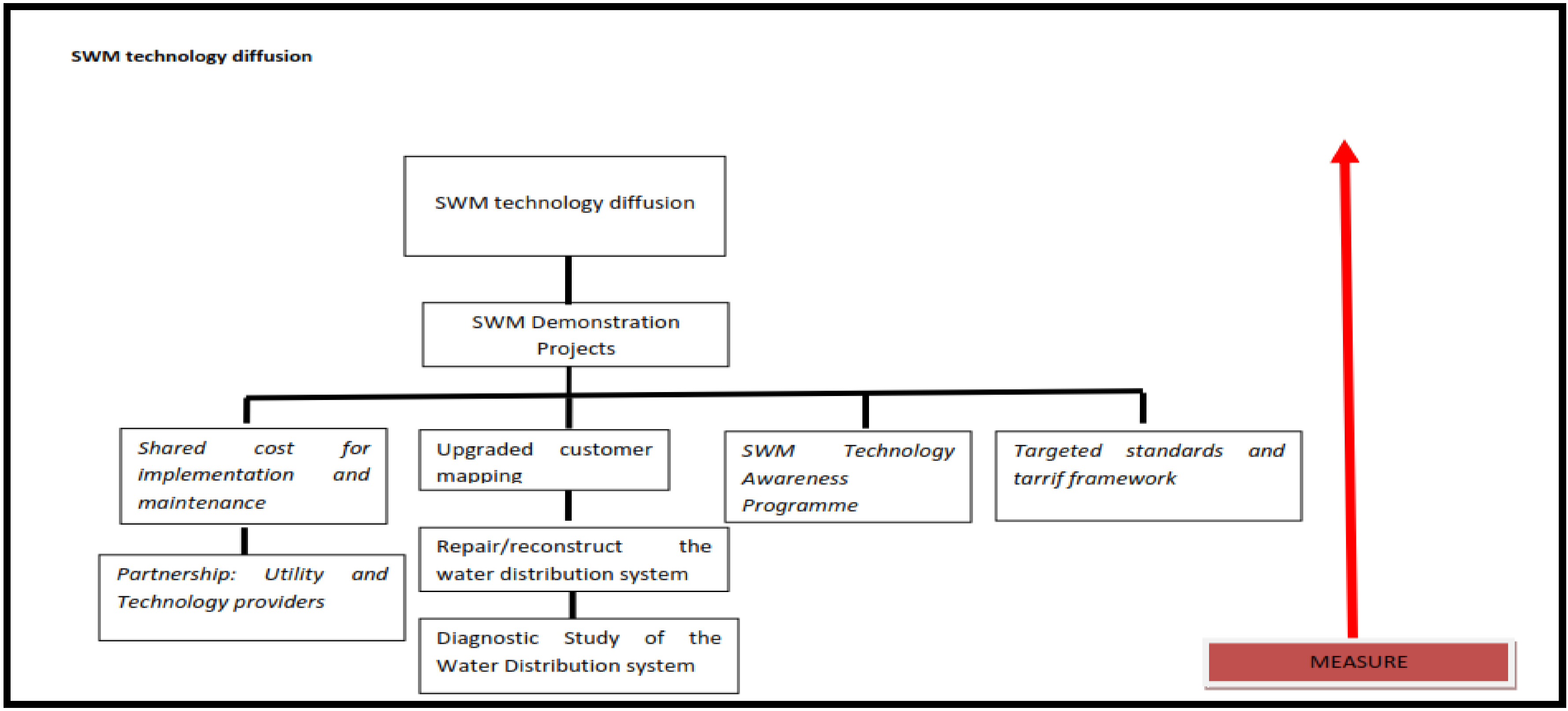
iii. DRIP IRRIGATION



Water Sector

i. **ROOF RAINWATER HARVESTING**

ii. **SMART WATER METERING**



iii. WASTE STABILIZATION PONDS

ANNEX IV: LIST OF STAKEHOLDERS INVOLVED AND THEIR CONTACTS

S/No.	Names	Institutions	Contact
1)	Maxmilian Mahangila	Vice President's Office	mahangila@yahoo.com
2)	Geofrey Bakanga	Vice President's Office	bakgef@yahoo.com
3)	Theresia Massoy	Ministry of Agriculture, Livestock and Food Security (MALF)	tmassoi@yahoo.com
4)	Marius Nzalawahe	Ministry of Agriculture, Livestock and Food Security (MALF)	0754654240
5)	Esther Mfugale	Ministry of Agriculture, Livestock and Food Security (MALF)	0657470722
6)	Gerard Kafuku	COSTECH	0766604977
7)	Charles Mafie	IUCN	0759967156
8)	Karim Lichela	Ministry of Water (MOW)	0658536164