REPUBLIC OF KENYA

BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR CLIMATE CHANGE TECHNOLOGIES ADAPTATION

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This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Risoe Centre (URC) in collaboration with Environmental Development Action in the Third World (ENDA Senegal) for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein is a product of the National TNA team, led by the National Environment Management Authority-Kenya (NEMA-Kenya).

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This report has assessed the technology needs for climate change adaptation in Kenya. The report has further prioritized technology needs for adaptation within the water and agriculture sectors using a multi-stakeholder process and a linear additive Multiple Criteria Analysis Framework. A Barrier Analysis and Enabling Framework for the prioritized technologies have been done and measures identified to overcome these barriers. Finally, Technology Action Plans and Project Concepts have been developed. It is my sincere hope that these 4 part report findings will prompt all stakeholders to take timely action in climate change adaptation and that the reports will form an important reference tool to spur all actors to implement the prioritized technologies in order to build the resilience of our country in a changing climate.

PROF. GEOFFREY WAHUNGU
DIRECTOR GENERAL, NEMA

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LIST OF ACRONYMS

ASALs	Arid and Semi-arid Lands
CBA	Cost Benefit Analysis
CBOs	Community Based Organisation
GoK	Government of Kenya
KARI	Kenya Agricultural Research Institute
KENGEN	Kenya Energy Generation Company
KNCPC	Kenya National Cleaner Production Centre
KShs	Kenya Shillings
MEMR/CCS	Ministry of Environment and Mineral Resources/Climate Change Strategy
mm	Millimetres
MSPND&V2030	Ministry of Planning National Development and Vision 2030
NARs	National Agricultural Research Stations
NCST	National Council Science and Technology
NEMA	National Environment Management Authority
NGOs	Non-Government Organisation
NPV	Net Present Value
OPM	Office of the Prime Minister
PPPs	Public Private Partnerships
PTC	Professional Training Consultants
RWH	Roof Rainwater Harvesting
UNDP	United Nations Development Programme
VAT	Value Added Tax

EXECUTIVE SUMMARY

The Report covers Barrier Analysis on transfer and diffusion of the prioritised technologies for Climate Change adaptation in the Water Resources and Agriculture Sectors. In addition the enabling framework and measures for overcoming the barriers are addressed. The technologies prioritized in the Water Resources sector include Surface Run-off Water Harvesting and Roof Rainwater Harvesting. In the Agriculture sector the technologies include Drought Tolerant Sorghum and Drip Irrigation.

For each of the four (4) Technologies mentioned above, a systematic approach of describing and analysing the various aspects and issues of barriers and identification of measures and enabling framework was adopted and including the following:

- Identification of preliminary Targets for the Technology
- General Description of the Technology giving the advantages and disadvantages
- Identification of the Barriers through stakeholder participation
- Categorization of barriers into broad categories
- The Screening of the barriers into the essential and non-essential ones in order to come up with the most significant ones.
- The screened barriers were then decomposed into Category, Elements and Dimension of barriers covering Economic and Financial as well as Non-Financial Barriers to make analysis easier.
- Casual Relations leading to the development of Problem Trees and Objective Trees
- Identified Measures for overcoming the barriers through stakeholder involvement
- Market Mapping that depicts the relationship between the business services and enabling factors
- Cost Benefit Analysis for the four technologies.

In undertaking this assignment the consultants reviewed relevant literature and consulted stakeholders and technical working group and experts throughout the process. The consultants also made use of TNA barrier analysis guidelines (e.g. Boldt et al., 2012), resources provided by UNEP-Risoe and ENDA during regional workshops and information and templates provided by UNEP-Risoe and ENDA specialists.

A review and analysis of data in water sector showed that the technology transfer and diffusion of Surface Run-off Water Harvesting Technology and Roof Rainwater Harvesting Technologies had key common barriers. These include economic and financial barriers associated with high initial cost of installation of the technologies. Other barriers to the diffusion of the technology include limited awareness, traditional habits and cultural preferences. Climate variability was also identified as a critical barrier to transfer and diffusion of the technologies in the water sector.

Barriers in the two technologies can be overcome by putting in place appropriate financial and economic policies on introduction of low interest rates and appropriate subsidies. This will facilitate access to finances to install the water harvesting technologies. Once the measures are put in place, the outcome will be improved water supply, improved hygiene and livelihoods which will set pace for the communities' social and economic development.

In the agriculture sector, barriers to the transfer and diffusion of Drought Tolerant Sorghum Technology and Drip Irrigation Technologies were identified as inadequate financial resources and credits, inadequate awareness of the technologies, poor communication and extension and lack of

training. The can be overcome by provision of adequate financial resources including credits, loans and reduction of interest rates on credits and loans. The identified enabling measures include rebate on taxes on tools and machineries, equipment and inputs. The outcome of instituting the measures to overcome barriers are enhanced adoption and diffusion of technologies through improved access to credit and loans to buy machineries, equipment, tools and inputs for the technologies.

Other measures to overcome barriers in this sector are provision of adequate training, creation of adequate skills and effective extension services. The training will improve skills and enhance adaptation and diffusion of the technologies. Once these measures are put in place the overall outcome are improved incomes, food security and livelihoods leading to poverty reduction and diversification of income generating activities.

The Cost Benefit Analysis (CBA) carried out on the four (4) Technologies indicated that the Net Present Value (NPV), have high positive benefits compared to the cost and therefore viable despite the major barriers identified.

CHAPTER 1
WATER RESOURCES SECTOR

1.1 Preliminary Targets for Technology Transfer and Diffusion

In this sector, the Climate Change adaptation technologies prioritised for transfer and diffusion in Kenya are surface run-off rainwater harvesting community systems and household roof rainwater harvesting systems. The preliminary targets for the transfer and diffusion of these technologies are:

i) To construct 10,000 community surface run-off rainwater harvesting system each with a capacity of about 30,000 m^3 in the ASAL areas
ii) To assist 500,000 households in the ASAL areas to install roof rainwater harvesting systems, each with a capacity of 10 m^3.

In order to achieve these targets the stakeholders and players to be involved include policy makers in water sector, related government ministries and departments including ministries of Water and Irrigation, Agriculture, Housing and Human Settlements. Other players include manufacturers of technology components, wholesalers and retailers, technicians and experts in water and irrigation sector. The implementers including women and youth groups at local level, CBOs and NGOs dealing with water issues at local and national levels and community leaders will be key players in the transfer and diffusion of the technologies in the water sector.

1.2 Barrier Analysis and Possible Enabling Measures for Surface Run-off Water Harvesting Technology

1.2.1 General Description of Surface Run-off Water Harvesting Technology

Most precipitation that falls on human settlements is lost to the atmosphere through evapotransporation, or runs into rivers away from settlements before it can be used. However, if the rain is collected using appropriate infrastructure, it can contribute greatly to the volume of freshwater available for human use. This is particularly relevant in arid and semi-arid regions, where the little rainfall received is usually very intense and often seasonal (Elliot et al. 2011).

Surface runoff water harvesting is the collection, accumulation, and storing of storm-water for its eventual reuse. It can also include other catchment areas from manmade surfaces, such as roads, or other urban environments such as parks, gardens and playing fields. Surface runoff water is an excellent alternative to using piped drinking water and if properly designed, surface runoff catchment systems can collect large quantities of rainwater.

The technology involves harnessing surface run-off from ground surfaces and directing the water into a retention earth pan (dam) for storage. Harnessing of the surface runoff involves construction of channels to direct water into the retention dam and sediment traps to reduce sediment loading into the dam. The dam is constructed by excavating the earth followed by impoundment and water proofing the surface either using impermeable clay soil or polythene sheets. The water can then be used directly for livestock, irrigation or for drinking after appropriate treatment. The technology can be applied for small household pans or large communal dams.

Surface runoff water harvesting has been practised in some arid and semi-arid areas in Kenya for years as a source of water for livestock and domestic use, but at different individual and

community levels and capacities. However, according to MW&I (2010) there are presently only 26 large dams in the country and 3,000 small dams and water pans with a total storage capacity of about 124 Mm^3, which is far below the required threshold of 4.5 Bm^3 of storage. The low water storage capacity has been attributed to among others lack of clear policy on water harvesting and storage, which has led to, among other factors, limited investments in water storage infrastructure, high maintenance of existing storage structures due to siltation and uncoordinated and unfocussed approaches to the development of water harvesting and storage (MW&I, 2010).

1.2.1.1 Technology Category and Market Characteristics

The Surface Runoff Water Harvesting Technology can be categorized as a public good when established at community level and other non-market good category when adopted by individual households. The option taken in this report is community surface water harvesting system which is a public good.

1.2.2 Identification of Barriers for Surface Run-off Water Harvesting Technology

The following barriers were randomly identified by the consultants through literature review and expert knowledge and through consultation with the stakeholders and Adaptation Technical Working Group during workshops and brain storming sessions:

- High initial cost
- Lack or inadequate access to financial resources
- Consumer preferences and social biases
- Lack of social acceptance due to water quality consideration
- Technology stigmatisation
- Traditions and habits
- Inadequate understanding of local needs
- Gender participation
- Inappropriate land tenure
- Inadequate information
- Insufficient capacity among the local community
- Environmental impacts
- Local pollution due to poor sanitation
- Animal and mixed use pollution
- Breeding grounds for disease vectors including mosquitoes

The identified barriers were then categorized into broad categories and described to enable further analysis and screening (see Table 1.1)

Table 1.1: Barrier categorisation and description

Barrier Category	Barrier	Barrier Description
Economic and Financial Barriers	• High initial cost	• Cost associated with construction of a dam and water harvesting channels
	• Lack or inadequate access to financial resources	• Lack of access to credit by rural individuals and communities. This is associated with the high interest rates and requirement for loan security like guaranty to get loans etc
Social, cultural and behavioural	• Consumer preferences and social biases	• Consumers are used to and prefer traditional water sources such as river and ground water
	• Lack of social acceptance	• Due to water quality consideration
	• Technology stigmatisation	• Considered to be only for highly water scarce poor areas
	• Traditions and habits	• Resistance to change, due to cultural reasons
	• Inadequate understanding of local needs	• Lack of stakeholder involvement
	• Gender participation	Lack of gender participation in decision making and implementation
	• Inappropriate land tenure	• Small land holdings and lack of community land for dams
Information and awareness	• Inadequate information	• Lack of knowledge of the technology and its benefits
Technical	• Insufficient capacity among the local community	• Inadequate human skills to site and construct water harvesting and storage facilities
Environmental	• Interference with local hydrology	• Harvesting and storage of surface run-off likely to negatively impact hydrology of downstream streams
	• Local pollution due to poor sanitation	• Poor sanitation in the surrounding area likely to introduce pollution (faecal) into the dam
	• Animal and mixed use pollution	• Pollution associated with directly livestock watering and washing in the dam
	• Unfavourable local geology	• Some areas do not have flowing water for harvesting due to poor nature of the soil or sand.
	• Breeding grounds for disease vectors including mosquitoes	• The dam stagnant water likely to act as breeding ground for disease vectors like mosquitoes
	• Climate variability	• Surface water harvesting will depend on rainfall reliability

The barriers were then screened, during brainstorming sessions with stakeholders, in order to identify the most important barriers to the adoption and of the technology. The following were identified as the key barriers to the adoption of surface water harvesting technology in Kenya:

- High initial cost
- Lack or inadequate access to financial resources
- Inappropriate land tenure
- Unfavourable local geology
- Insufficient capacity among the local community

1.2.2.1 Economic and Financial Barriers

The main identified economic and financial barriers to the adoption of surface water harvesting technology in Kenya are High Initial Cost and Lack or Inadequate Access to Financial Resources. The barriers was further analysed through decomposition and problem tree analysis (Boldt et al. 2012) in order to identify the root cause of the barrier.

Decomposition of the High Initial Cost barrier (Table 1.2) revealed that the high initial cost is associated with high cost of material and labour for the construction of harvesting channels, sediment traps and storage dam, estimated to cost US$75,000 for a system serving 200 households (based on expert knowledge). It is also associated with high cost of obtaining financing for individuals and communities since financial institutions charge interest of up to 30% on credits (based on spot checks on lending rates by various financial institutions in Kenya). Barrier decomposition found Lack or Inadequate Access to Financial Resources to be a sub-barrier of High Initial Cost barrier.

Analysis of the barriers using a problem tree (Annex 1.2A) showed that the high cost of materials is as a result of high VAT (16 %) and that the high labour cost is due to lack of government subsidies on mechanised excavation equipment for dam construction (provision of mechanical excavating equipment by the government will lower labor costs). The effects of the high initial cost for surface runoff water harvesting are inadequate water for domestic use and livestock which lead to malnutrition and associated poor health for the communities. The other effect is negative impacts on gender and children education since women and children are forced to spend most of the day looking for water leading to loss of opportunities.

Table 1.2: Economic and Financial Barrier Decomposition

Barrier Category	Barrier	Elements of barriers	Dimension of barrier elements
Economic and financial	• High Initial Cost	• High cost of materials for constructing run-off harvesting channels and retention dam	• A construction of run-off water retention dam for 200 families is about US$ 75,000
		• High cost of Labour	• Labour cost @ 10% of the project cost is about US$ 7,500
		• High cost of obtaining financing	• Up to 30 % interest rate from local financial institutions High electricity tariffs

1.2.2.2 Non-Financial Barriers

The main identified non-financial barrier to the adoption and diffusion of surface water harvesting technology in Kenya are Inappropriate Land Tenure, Unfavourable Local Geology and Insufficient Capacity among the Local Community. The barriers were further analysed through decomposition and problem tree analysis in order to identify the root cause of the barrier. However, since unfavourable local geology barrier is a killer (non-starter) barrier, it was not analysed further.

Decomposition of the Inappropriate Land Tenure barrier (Table 1.3) revealed that the elements of this barrier are associated with small land holdings by many individual house holds, leading to lack of land for establishment of surface runoff water harvesting facility. The other element of the barrier is lack of community land for establishment of community surface runoff water harvesting facility due to allocation of available community land for other social or individual uses and also due to the location of land being inappropriate for surface runoff water harvesting. Decomposition of the insufficient capacity among the local community barrier showed that the lack of community capacity is easily complemented by availability of technical experts from relevant government departments. However, capacity building of local community is necessary for enhanced adoption and diffusion of the technology and for long-term sustainability of water harvesting system.

Table 1.3: Non-Financial Barrier Decomposition

Barrier Category	Barrier	Elements of barriers	Dimension of barrier elements
Policy, legal and regulatory:	• Inappropriate land tenure	• Small land holdings	• Lack of enough land for household dam construction
		• Lack of community land for dams	• Community land taken up for other social or individual uses
			• Community land location inappropriate for water harvesting

1.2.3 Identified Measures

The measures for overcoming barriers to the adoption and diffusion of surface water harvesting technology were identified through stakeholder consultation, review of relevant policy documents, expert knowledge and analysis using objective trees for each barrier according to Boldt et al. (2012). The objective trees for the economic and financial and non-financial measures are presented in Annex 1.3A. The identification of measures for both economic and financial and non-financial barriers is discussed in the following sections.

1.2.3.1 Economic and Financial Measures

The identified economic and financial measures for overcoming barriers to the adoption and diffusion of surface water harvesting technology are:

(i) VAT waiver for construction materials. This will result in lowering the cost of construction and hence make the initial cost of the technology low.

(ii) Introduction of low interest credits. Low interest credits will increase access to affordable financing for communities and individuals for development of surface runoff water harvesting system.
(iii) Providing appropriate subsidies. Subsidies include availing free government technical professional services and advice to help lower labour costs during the implementation.

The impact of implementing the identified measures is availability of adequate water for domestic use and livestock which will consequently result in improved women welfare and children education and improved nutrition and health for the communities. The overall results are lower poverty levels and child mortality and improve local economy.

1.2.3.2 Non-Financial Measures

The identified non-financial measures for overcoming barriers to the adoption and diffusion of surface water harvesting technology are:

(i) Priority for community land given to surface runoff water harvesting projects.
(ii) Community land repossessed. Through enforcement of relevant land laws community land in private hands be reverts back to the community and be availed for surface runoff water harvesting technology projects.
(iii) Change of cultural values through sensitisation on the negative economic impacts of sub-division of land into small units.
(iv) Introduction of appropriate land policy to discourage subdivision of land into small uneconomic units and protect community land from land grabbers.

The impact of implementing the identified measures is making land available for development of surface water harvesting systems and hence availability of adequate water for domestic use and livestock. This will consequently result in improved women welfare and children education and improved nutrition and health for the communities and result in lower poverty levels and child mortality and improve the local economy.

1.2.4 Cost Benefit Analysis for Surface Runoff Water Harvesting

A cost benefit analysis was done in order to asses the economic benefits associated with adoption and diffusion of surface runoff water harvesting technology compared to the existing scenario. This scenario involves fetching water and watering livestock from long distance sources, a situation that negatively affect women and children welfare through reduced productivity and missing out in education respectively. Water stress during dry seasons may also lead to loss of livestock which negatively affects food security and local economy. The other challenge associated with current scenario is use of water from sources with compromised quality leading to water borne diseases.

Cost Benefit Analysis (CBA) is a technique for assessing the monetary costs and benefits of implementing a technology over a given time period.
The following principles are relevant for CBA.

i) It can show whether it is feasible or not and acceptable to transfer and diffusion of a particular technology
ii) It includes externalities such as social/environmental impacts and 'private' economic costs and benefits so that externalities are incorporated into the decision making process
iii) Can take account of the economics of time (discounting)

The cost-benefit analysis was done by first identifying both direct and indirect costs and benefits associated with current water sources and the implementation of the surface water runoff harvesting technology (Table 1.4; elements and costs were obtained from expert knowledge during consultation and discussions with stake-holders). The costs and benefits were based on establishing a surface runoff harvesting unit for supplying water to 200 families. Water treatment was not included in the analysis (and in the technology) since under the existing scenario, communities use water without treatment, except limited disinfection (boiling) at household levels.

Table 1.4: Elements of Costs and Benefits of the Existing Scenario and of adopting Surface Runoff Water Harvesting Technology (Based on expert knowledge

	Item	**Amount (KShs)**
Costs		
1.0	Existing scenario	
1.1	Opportunity cost for women and children* (@ KShs 100/household/day, for one year)	7,300,000
1.2	Loss of Livestock (@2 animals/household/per year	1,600,000
1.3	Health treatment costs associated with poor water quality and nutrition (KShs 200/month/household)	480,000
	Total Cost	9,380,000
2.0	Cost of Technology	
2.1	Cost of excavation (labour and hiring of mechanised equipment)	4,000,000
2.2	Dam lining (water proofing)	1,000,000
2.3	Water harvesting channels and sediment traps	1,500,000
2.4	Fencing	200,000
2.5	Soil conservation	100,000
2.6	Environmental costs (mosquito nets and anti-malarial drugs @KShs 500/4 family members/200 house holds/year)	400,000
2.7	Construction of livestock watering troughs	500,000
	Total Cost	7,700,000
		Benefits
1.0	Existing scenario	
1.1	Social benefits associated social interaction for women and youth	200,000
1.2	Reduced incidences of malaria	400,000
	Total Benefits	600,000
2.0	Technology	
2.1	Increased opportunities for women and children*	7,300,000
2.2	Reduced loss of livestock	1,600,000
2.3	Improved health	480,000
2.4	Improved micro-climate and biodiversity	100,000
2.5	Economic opportunities including aquaculture and horticulture	1,000,000
	Total Benefits	10,480,000

*Opportunities and costs associated with time taken (or saved) by women and children fetching water: In ASAL areas women and children spend many hours in a day fetching water instead of participating in other socio-economic activities (women) and attending school (children).

Net benefits for existing scenario = KShs (600,000-9,380,000) = -8,780,000 (1)
Net benefits for technology = KShs (10,480,000-7,700,000) = 2,780,000 (2)
Net Benefits for the technology = (2)-(1)
= 2,780,000 - (-8,780,000) = KShs 11,560,000

Net present values for the technology (NPV) = $\sum \frac{\text{Net Benefit}_t}{(1+i)^t}$

Where t is the year and *i* is the discount rate (10%)

NPV for year 1 = $\frac{11{,}560{,}000}{(1+0.1)^1}$
= KShs 10,509,091

NPV for year 2 = $\frac{11{,}560{,}000}{(1+0.1)^2}$
= Kshs 9,553,719

Similarly, calculations were done for the next 8 years (total 10 years) and the NPV values are presented in Table 1.5.

Table 1.5: 10 years NPV values for Surface Runoff Water Harvesting Technology

Year	Calculation	Net Benefits, 10% Discounted (KShs)
1	$11{,}560{,}000/(1+0.1)^1$	10,509,091
2	$11{,}560{,}000/(1+0.1)^2$	9,553,719
3	$11{,}560{,}000/(1+0.1)^3$	8,685,199
4	$11{,}560{,}000/(1+0.1)^4$	7,895,636
5	$11{,}560{,}000/(1+0.1)^5$	7,177,850
6	$11{,}560{,}000/(1+0.1)^6$	6,525,319
7	$11{,}560{,}000/(1+0.1)^7$	5,932,108
8	$11{,}560{,}000/(1+0.1)^8$	5,392,825
9	$11{,}560{,}000/(1+0.1)^9$	4,902,568
10	$11{,}560{,}000/(1+0.1)^{10}$	4,456,880
NPV, KShs		**71,031,195**

It is clear that from the high 10 years NPV value (Kshs 71,031,195; Table 1.5) that the surface water harvesting technology has large cost benefits and it is therefore viable despite the high initial cost, which was identified as a major barrier.

1.3 Barrier Analysis and Possible Enabling Measures for Roof Rainwater Harvesting Technology

1.3.1 General Description of Roof Rainwater Harvesting Technology

Rainwater harvesting is a method for inducing, collecting, storing and conserving rain water. The technology is an old tradition which has been practiced all over the world for centuries (Pacey and Cullis, 1986). Rainfall can provide some of the cleanest naturally occurring water

to supplement households and institutions water requirements. Rainwater harvesting (RWH) technology is particularly suitable for areas where there is no surface water, or where groundwater is deep or inaccessible due to hard ground conditions or poor water quality. In high rainfall areas, harvested water can effectively supplement household water supply.

The main features of roof RWH system include: a catchment where precipitation lands; a conveyance system of gutters and pipes to transport and direct the water; and containers to store water for later use (Eliot et al. 2011). Harvested rainwater can be used for domestic purposes and watering animals at a household level.

According to (UNEP/SEI, 2009) advantages of the roof rainwater harvesting technology include:

- Simple installation and operation.
- Little training and implementation of the technologies by the local people
- Readily available construction materials
- Convenience of provision of water at the point of use because households have full control of their own systems.
- Promotion of self-sufficiency and minimal environmental impact.
- Low construction, operation and maintenance costs.

Technology Category and Market Characteristics

Roof rainwater harvesting technology is a consumer good and is intended to target, households. The market characteristics of this technology are that:-

- The technology is relatively adaptable to households and institutions
- Requires importation of materials for making iron sheets, gutters, pipes and outlet pipes.
- Tanks for water storage are manufactured locally.
- Supply chain is not complicated as the manufacturers and retailers supply those goods all over the country and can be found in most rural and town centers.
- There is high number of potential consumers
- Adoption depends on consumer awareness and attitudes.

1.3.2 Identification of Barriers for Roof Rainwater Harvesting

While roof rainwater harvesting technology has been in existence for a long time in this country, it has not been sufficiently adopted and developed by households. This section identifies the reasons that hinder the development, transfer and diffusion of the technology. These include missing measures that could have sustained the transfer and diffusion of the roof RWH technology, understanding of the nature of individual barriers and the relationship between individual barriers and the determination of the important barriers and how they can be removed.

Process of Barrier Identification

The process of barrier identification was based on primary and secondary data collection and involved:

- Review of literature including government policy papers and strategy documents to establish the use and barriers to the use of the technology.

- Consultation and brainstorming sessions with the stakeholders and Adaptation Technical Working Group at two workshops held in Nairobi and other expert consultations including on one to one consultations.
- Reference to checklist of generic barriers as identified on Annex A of the TNA Guidebook
- Market mapping tool: The elements in the market environment and the relation to the market chain were used to identify barriers for rainwater harvesting.

The following barriers to the adoption and diffusion of roof rainwater harvesting technology were randomly identified:

- Climate variability
- Poor policy guidance
- High initial cost of installation
- Lack of access to credit
- Inadequate incentives
- Poor governance
- Poor social awareness of water conservation
- Limited awareness of RWH technology
- Poor public acceptance
- Cultural attitudes and preferences
- High cost of water storage facilities
- Inadequate or unsuitable roofing (vegetative)
- Inaccessibility of roof RWH materials
- Lack of space for appropriate water storage containers
- Inadequate institutional capacity

Categorization of Barriers

The barriers were then categorized into broad categories and described so as to enable further analysis and screening (Table 1.6).

Table 1.6: Barrier Categorization and description

Barrier Category	Barriers	Barrier Description
Economic and financial	• High initial cost of installation	• Associated with initial roofing capacity, of increased storage capacity and rainwater storage systems
	• Inadequate incentives and tax rebates	• Lack of GoK subsidy
	• Inadequate access to credit	• There are no credit facilities for buying and installing Roof RWH technology components.
	• High cost of water storage facilities •	• Associated with buying containers for roof water harvesting
Policy, legal and regulatory	• Poor governance • In adequate institutional capacity	• Although there is a water harvesting policy, it has not been adequately operationalized. Institutional capacity to advocate rain water harvesting is inadequate.
Information and awareness	• Poor social awareness of water conservation • Limited awareness on the technology	• While local community are not aware of the significant role, rain water harvesting can play
Social cultural	• Poor public acceptance	• The technology has not been adequately adapted
	• Cultural attitudes and preferences	• Local people have preferences of water from various sources e.g. rivers
Technical	• Lack of suitable roofs • Lack of space for appropriate water storage containers	• The higher percentage of roofing materials used in the country is not suitable for rain water harvesting • The housing design especially for people living in apartments does not making provision for installation of tanks for roof rainwater harvesting.
Environmental	• Climate variability	• Unreliable water source in dry periods leading to limited rainwater harvesting potential.

Screening of Barriers

The barriers listed then screened in order to identify their relative importance and separate key and non-key barriers for the transfer, adoption and diffusion of rainwater harvesting technology. This was done through discussion and brainstorming sessions with stakeholders, review of policy documents and expert knowledge and consensus with Adaptation Technical Working Group. The discussion and brain storming sessions provided a clearer picture of the significance of the barriers to the diffusion of the technology. The following barriers

were identified as the critical barriers that need to be addressed in order to enhance the transfer, adoption, and diffusion of rainwater harvesting technology:

(i) High initial cost of installation

(ii) Poor policy guidance

Although policies and strategies on water harvesting technologies are in place, they have not been implemented adequately. Effective implementation would raise the awareness of rainwater conservation and provide conducive environment for implementation of rainwater harvesting technology.

(iii) Poor social awareness of water conservation

There is general low awareness on water conservation. Many stakeholders do not understand and appreciate the need to conserve water. During the rainy seasons, there is plenty of water which sometimes leads to flooding, but after rains stop, local communities have to travel far and spend a lot of time in fetching water from natural sources.

(iv) Lack of incentives

Financial incentives for rain water harvesting are lacking. Initial installation of water harvesting systems is expensive and the government has no facilities for subsidizing them. There is general lack of political will in popularizing water harvesting technology in this country. Provision of water has been given to other water sources like piped water or borehole water sources. There has therefore been inadequate awareness on the benefits of rainwater harvesting technology.

(v) Inadequate and unsuitable roofs for rainwater harvesting

Type of roofs is determined by prevailing weather conditions, affordability and lifestyle. In hot places like the Kenyan Coastal and North Eastern regions people have biomass thatched houses which are meant to regulate temperatures. Migratory lifestyle of the pastoralist community also dictates their building materials and they mainly thatch their houses with grass or twigs. In other parts of the country people use what they can afford for thatching and roofs range from tiles, corrugated iron and grass thatch. Only about 20% of the population have corrugated iron sheets roof, which is the suitable roof for rain water harvesting.

1.3.2.1 Economic and Financial Barriers

The screened barriers were then decomposed in order to identify the barriers that are components of other barriers, and which stand alone barriers. The main identified economic and financial barrier to the adoption of roof rainwater harvesting technology in Kenya is high initial cost of installation of RWH components. The barrier was further analysed through decomposition (Table 1.7) and problem tree analysis (Boldt et al. 2012) in order to identify the root cause of the barrier.

Analysis of the barriers using a problem tree (Annex 1.2C) showed that the high initial is due to high cost of materials which is as a result of high VAT (16 %) on water harvesting components and lack of government subsidies. The effects of the high initial cost for roof rainwater are inadequate water for domestic use and livestock, which results in poor hygiene and associated poor health for the affected communities. The other effect is negative

impacts on gender and children education since women and children are forced to spend most of the day looking for water leading to loss of opportunities.

Table 1.7: Decomposition of Economic and Financial Barrier

Broad Category	Barrier within Category	Elements of Barrier	Dimension of Barrier
Economic and financial	• High of cost of initial installation • High cost of water storage facilities • Lack of access to credit • Lack of incentives and tax rebates	• High cost of materials (16 % VAT)	• High import duty on raw materials • High electricity tariffs for local manufacturers
		• Lack government subsidy and tax rebates	• Lack of political will
			• Inadequate awareness on importance of technology
			• Government priority to other water sources

1.3.2.2 Non-Financial Barriers

The main identified non-financial barrier to the adoption and diffusion of roof rainwater harvesting in preference for other water sources, inadequate awareness of water conservation and lack of suitable roofs. The barriers were further analysed through decomposition and problem tree analysis in order to identify the root cause of the barriers.

Decomposition of poor policy guidance (Table 1.8) revealed that the elements of this barrier are associated with inadequate policy direction on creation of awareness and adoption of rain water harvesting. Poor social awareness shows that the local people are not sensitised on water conservation and are not concerned with rain water going to waste. Unsuitable rainwater harvesting materials and design means that many houses are constructed using unsuitable materials for rainwater harvesting. Biomass thatched roof are most common rural homes while lead coated and asbestos roofs are in the urban areas. The roofing materials for the existing houses are therefore a barrier to the roof rainwater harvesting

Table 1.8: Non-Financial Barrier Decomposition

Broad Category	Barrier within category	Elements of Barrier	Dimension of Barrier
Technical	• Poor policy guidance	• Policy direction on adopting the rain water harvesting has not been popularised adequately	• Rainwater harvesting technology not adequately adopted
	• Preference for other water sources • Inadequate awareness of water conservation	• Cultural attitudes and preferences • Limited awareness of RWH	• Poor attitudes on RWH
	• Lack of suitable roofs	• Lead coated and asbestos roofs • Biomass thatched roof in most rural homes	• Many houses are constructed using unsuitable materials

1.3.3 Identified Measures

This section looks at measures necessary to overcome barriers identified above. The main methodology used was formulating all the problems as positive statements and developing an objective tree. This was done only for the starter problem which is an economic and financial measure. The measures were identified by the Consultant and verified by the sector working groups during stakeholders' workshops. The identified measures are presented in Table 1.9.

1.3.3.1 Economic and Financial Measures

The government should provide economic incentives and come up necessary policy to facilitate provision of affordable loans by local financial institutions to enable local people install water harvesting facilities. Related water provision agencies should also act as conduit of water harvesting technologies to the grassroots level. These institutions should include government ministries and non-governmental organizations. The government should also put in place financing facilities and introduce tax waivers and rebates for water harvesting facilities.

1.3.3.2 Non-Financial Measures

The identified non-financial measures for overcoming barriers to the adoption and diffusion of roof rainwater harvesting technology are that:- Policy guidance on roof rain water harvesting should be enhanced. The local people should be made aware and motivated to conserve water. This will enable them develop positive attitude towards rainwater harvesting which will enable them, to adopt, design and increase roofs and other rainwater harvesting structures and facilities.

The impact of implementing the identified measures will be adequate water for domestic use and livestock. This will consequently result in improved women welfare and children

education and improved nutrition and health for the communities. It will also result in lower poverty levels and child mortality and improve the local economy. The technology of rainwater harvesting will impact on the environment by controlling flooding and indirectly lead to the health of the environment and the people.

Table 1.9: Measures to overcome identified barriers

Measures	Enabling Environment
Economic and Financial	
• Give incentives for initial installation of rain water harvesting systems • Reduce cost of initial installation of rain harvesting systems by introducing tax rebate and waivers. • Reduce cost of importation of materials for constructing water harvesting components	• Put in place rain harvesting financing policy • Provide climate change financing facility
Non-financial measures	
• Promote construction of special structures for water harvesting	• Manufacture suitable materials for rain water harvesting including plastic papers
• Create awareness on water conservation and rainwater harvesting. • Promote appropriate housing design	• Related institutions to create awareness on variability of weather and diffusion of roof rainwater harvesting should be created • Operationalisation of water harvesting Policy • Promote use of local materials • Promote use of appropriate technology

1.3.4 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. Existing scenario involves fetching water and watering livestock from long distance sources, a situation that negatively affect women and children welfare through reduced productivity and missing out in education respectively. Water stress during dry seasons may also lead to loss of livestock which negatively affects food security and local economy. The other challenge associated with current scenario is use of water from sources with compromised quality leading to water borne diseases.

The cost-benefit analysis 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 done based on costs and benefits of constructing Roof Rainwater Harvesting units for 200 families comprising 4 people (Table 1.10; elements and costs were obtained from expert knowledge during consultation and discussions with stake-holders).

Table 1.10: Elements of Costs and Benefits of the Existing Scenario and of adopting Roof Rainwater Harvesting Technology (Based on expert knowledge

	Item	Amount (KShs)
Costs		
1.0	Existing scenario	
1.1	Opportunity cost for women and children (@ KShs 100/household/day for one year)	7,300,000
1.2	Loss of Livestock (@2 animals/household/per year	1,600,000
1.3	Health treatment costs associated with poor water quality and nutrition (KShs 200/month/household for one year)	480,000
	Total Cost	**9,380,000**
2.0	Cost of Technology	
2.1	Cost installing corrugated iron sheet roof and gutters (@KShs 40,000/10% of total households)	4,000,000
2.2	Tanks (10 m^3) and installation (@70,000/household)	14,000,000
	Total Cost	**18,000,000**
Benefits		
1.0	Existing scenario	
1.1	Social benefits associated social interaction for women and youth	200,000
	Total Benefits	**200,000**
2.0	Technology	
2.1	Increased opportunities for women and children	7,300,000
2.2	Reduced loss of livestock	1,600,000
2.3	Improved health	480,000
2.5	Economic opportunities including kitchen gardens, poultry and zero-grazing	1,000,000
	Total Benefits	**10,380,000**

Net benefits for existing scenario = KShs (200,000-9,380,000) = -KShs 9,180,000 (1)
Net benefits for technology = KShs (10,380,000-18,000,000) = -KShs7,620,000 (2)

= -7620000 - (-9,180,000) = KShs 1,560,000

Net present values for the technology (NPV) = $\sum \frac{NetBenefit_t}{(1+i)^t}$

Where t is the year and *i* is the discount rate (10%)

NPV for year 1 = $\frac{1{,}560{,}000}{(1+0.1)^1}$

= Kshs 1,418,182

NPV for year 2 = $\frac{1{,}560{,}000}{(1+0.1)^2}$

= Kshs 1,289,256

Similarly, calculations were done for the next 8 years (total 10 years) and the NPV values are presented in Table 1.11.

It is clear from the total, 10 years, NPV value in Table 1.11 that the roof rainwater harvesting technology has large cost benefits and it is therefore viable.

Table 1.11: 10 years NPV values for Roof Rainwater Harvesting Technology

Year	Calculation	Net Benefits, 10% Discounted (KShs)
1	$1,560,000/(1+0.1)^{1}$	1,418,182
2	$1,560,000/(1+0.1)^{2}$	1,289,256
3	$1,560,000/(1+0.1)^{3}$	1,172,051
4	$1,560,000/(1+0.1)^{4}$	1,065,501
5	$1,560,000/(1+0.1)^{5}$	968,637
6	$1,560,000/(1+0.1)^{6}$	880,579
7	$1,560,000/(1+0.1)^{7}$	800,527
8	$1,560,000/(1+0.1)^{8}$	727,752
9	$1,560,000/(1+0.1)^{9}$	661,592
10	$1,560,000/(1+0.1)^{10}$	601,448
NPV, KShs		**9,585,525**

1.4 Linkages of the Barriers Identified in water sector

This section looks at linkages of different barriers faced by surface run-off water and roof rainwater harvesting technologies in the water sector and is presented in the table below.

Table 1.12: Linkages of barrier faced by different prioritized technologies in the Sector

Barrier Category	Barriers
Economic and financial	• High initial cost
	• Lack of incentive
Information and awareness	• Limited awareness on the technology
	• Traditional habits/cultural preferences
Social cultural	• Poor public acceptance
	• Cultural attitudes and preferences
Environmental	• Climate variability

The two technologies will be influenced by the climate variability. It is assumed that local communities can adopt both technologies for water harvesting. Measures for reducing initial cost of including provision of credit facilities, reduced interest rates and tax rebates will enhance diffusion and transfer of both technologies. On barriers related to information and awareness for adaptation and diffusion of technologies will target barriers on limited awareness and traditional and cultural habits. It will also influence barriers related to social cultural behaviours.

1.5 Enabling Framework for Overcoming the Barriers in the Water Resources Sector

The enabling framework for overcoming barriers to climate change adaptation technologies in the water resources sector are presented in Table 1.13. The identified common enabling

environment frameworks are the introduction of low interest rates and introducing appropriate subsidies.

Once the enabling framework and measures are put in place, the outcome will be improved water supply, improved hygiene and livelihoods which will set pace for the communities' social and economic development.

Table 1.13: Enabling Environment

Category	Measure	Outcome
Surface run-off water harvesting technology		
Policy	Introduce appropriate land policy	Access of dams is legitimized
	Prioritise use of community land	More community are constructed
Socio-cultural	Change of Cultural Values	Optimise use of the harvested water
Roof rainwater harvesting technology		
Technical	Quality control of roofing materials	More communities are able to harvest roof rain water
Information and Awareness	Acceptance of cultural change	Optimize use of the harvested water
Common Enabling Framework		
Financial and economic (Finance policy)	Introduction of low interest rates Introducing appropriate subsidies	More households access the technologies
	Introducing appropriate subsidies	

CHAPTER 2
AGRICULTURE SECTOR

2.1 Preliminary Targets for Technology Transfer and Diffusion

The preliminary target for the transfer and diffusion of drought tolerant sorghum varieties is to introduce the technology to 1 million farmers by the year 2017. The preliminary target for the drip irrigation technology is introduction of 500,000 and 1000 drip irrigation systems to individual farmers and institutions, respectively by the year 2017.

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, Agriculture, Housing and Human Settlements. 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.

2.2 Barrier Analysis and Possible Enabling Measures for Drought Tolerant Sorghum Variety Technology

2.2.1 General Description of Drought Tolerant Sorghum Variety Technology

Due to global warming and climate change, the country has frequently been faced with drought and hence there is need to lay emphasis on drought tolerant plants and crops especially in areas where rains are not sufficient. Sorghum is grown in areas with as little as 250mm of rainfall. The drought tolerant sorghum varieties such as Serena, Seredo, super sorghum are produced as a result of plant breeding to enhance their resistance or tolerance to stresses that result from climate variability. Drought is a major constraint to rain-fed crop production. Yield losses vary according to severity and type of drought. Prolonged drought at any stage will result into crop failures.

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. The other strength of sorghum besides being drought tolerant is that it is less affected by crop pests compared to maize.

Sorghum crops grow well in semi-arid and arid areas (ASALs) which occupy the great geographical area of Kenya. The ASALs occupy about 80% of Kenya's land mass. Hence the crop is very much applicable to dry areas of the country such as parts of Eastern Province, parts of Rift Valley, parts of Nyanza and Western.

The technology has been developed and adopted by some farmers in the country. Farmers are already using the drought tolerant varieties in drought prone areas to improve sorghum production under drought conditions. Extension agents and NGOs are promoting drought tolerant sorghum for food security and beer brewing. However, studies on the extent of adoption by farmers in the country are still on-going.

Sorghum is Africa's oldest food crop. It is full of energy-giving nutrients and its flour is known to have high nutritional value because when processed and packaged, sorghum does

not loose their nutrients very fast. Trials are on for forage sorghum variety that is capable of multiple cutting for over 3 yeas.

The direct and indirect benefits of drought tolerant sorghum include water use efficiency improved; expands arable land; reduce soil erosion, improvement of soil fertility and improvement in food security.

It is estimated that it costs US $ 115 for the adoption of the drought tolerant seeds by a farmer, but this amount does not include the research and development of the drought tolerant sorghum variety by KARI which is estimated to cost about KShs 3 million over a period of about 7 years.

Technology Category and Market Characteristics

Drought **Tolerant Sorghum Variety Technology** is both a market and non-market good. Development of the drought resistant sorghum seed is a non-market good. The seed is transferred and diffused by Government, private or non-profit institutions, international donors and research institutions. It is a public good because it is not transferred as part of market but within public non-commercial domain. It becomes a market good when the sale and distribution of the seed is done by commercial institutions and transferred and diffused through private institutions as part of the market within commercial domain.

Market Mapping for Drought Tolerant Sorghum

Market mapping was done for the technology in order to identify the various players in the market (Annex 1.1 B). The market the linkage area as follows:

- The technology is initiated at the research level by Kenya Agricultural Research Institute (KARI) which undertakes the breeding of sorghum varieties to come up with drought tolerant sorghum variety. The research produces the drought tolerant sorghum seeds which are taken up by the seed multiplication, bulking, and processing companies such as Kenya Seed Company, Kenya Breweries. These companies distribute the seed to wholesalers, distributors, stockists, retailers and traders down to the farmers who grow the crop. However, Kenya Breweries supplies the certified seeds to their contracted farmers. The farmers harvest the crop which is sold to traders, retailers, millers, stockists and the consumers.
- The millers use the sorghum to make feeds for livestock and chicken. The millers also produce sorghum flower used for baking and human consumption. The harvested crop is also sold to export markets besides the local market.
- Seed retailers include Kenya Seed Company, Simlaw Company, stockist (e.g. agro-dealers).
- Enabling environment entails offering subsidies to the seed breeders, which involved government support through grants to research institutions such as KARI and Universities.
- Service providers include financial institution such as Agricultural Finance Cooperation (AFC), Faulu Kenya, Jamii Bora and financial and micro-finance institutions. Kenya Breweries also provide inputs for growing sorghum (e.g. in Siaya).

However barriers exist in each market levels and players and are considered in the following sections.

2.2.2 Identification of Barriers to Drought Tolerant Sorghum Variety Technology

The following barriers were randomly identified by the consultants through literature review, expert knowledge, consultation with the stakeholders and Adaptation Technical Working during workshops and brain storming sessions:

- Inadequate early involvement of farmers in varietal selection.
- Delayed release of varieties.
- Inadequate Government commitment to rapid multiplication and effective dissemination of high quality seed.
- Inefficient seed production, distribution and delivery system.
- Inaccessibility of the seeds by farmers.
- Insufficient capital to buy seeds from commercial companies.
- Insufficient seed production, distribution and delivery system
- Undeveloped of a functional seed market.
- Uncertainty in demand for seed hence reluctance by commercial stockiest to stock seeds.
- Non-integration between formal and informal seed systems.
- Inadequate training on seed multiplication.
- Lack of physical infrastructures.
- Unreliable supplies of inputs.
- Less preferred grain quality.
- New pest problems.
- Inappropriate communication /extension approaches.
- Inadequate of agricultural credit /loans.
- Inadequate collaboration between National Agricultural Research stations (NARs), Extension and other stakeholders involved in agriculture.
- Inadequate technological information.
- Under utilization of agricultural research funds.
- Inadequate institutional capacity on agricultural research.
- Inadequate capacity and basic legislation and institutional factors.
- Inadequate patenting of Research findings and at times disagreements over intellectual property rights.
- Complexity of the technology in terms of what people need to learn to make it work.
- Difficulty in observability and triability of the technology.
- Non-promotion of unreleased varieties by private sector.
- Not taking farmers preferences into account in research activities.
- Inadequate training and education.
- Low seed demand.
- Inadequate participation by farmers.
- Inadequate financial resources
- Market failures
- Inadequate awareness
- Insufficient popularisation of sorghum as an important food crop and the various uses of the crop

The barriers were then categorized into broad categories and described in order to enable further analysis (Table 2.1).

Table 2.1: Barrier Categorisation and description

Barrier Category	Barrier	Barrier Description
1. Economic and Financial Barriers	Inadequate financial resources	• Lack of available capital to buy seeds • Lack of agricultural credit and loans • Low affordability amongst rural farmers
2. Market failures	Inaccessibility of seeds by farmers	• Insufficient seed production, distribution and delivery systems • Unreliable supplies • Uncertainty on demand for seeds and low seed demand • Some varieties not having entered official seed production system • Lack of promotion of unreleased technology
3. Policy, legal and regulatory	Inadequate government commitment	• Inadequate patenting of research findings • Lack of capacity and basic legislations • Disagreement over intellectual property rights
4. Technical	Inefficient seed production, distribution and delivery	• Delayed release of varieties • New pest problem • Complexity of the technology
5. Human Skills	Lack of human capital	• Inadequate training on seed multiplication • Lack of early involvement of farmers in variety selection
6. Social, Cultural and Behavioural	Less preferred grain quality	Lack of taking preference of the people into account
7. Information and awareness	Inappropriate communication and extension approaches	Low adoption rate
8. Institutional and organization capacity	Inadequate institutional capacity on agricultural research	Under-utilization of agricultural research funds
9. Network failures	Lack of collaboration between NARS, Extension Offices and other stakeholders	Non- integration between formal and informal seed systems
10. Others	Inadequate of physical infrastructures	Inadequate funds

The barriers were then screened in order to identify their relative importance and separate key and non-key barriers for the transfer, adoption and diffusion of the technology. This was done through discussion and brainstorming sessions with stakeholders, review of policy documents and expert knowledge and consensus with Adaptation Technical Working Group. The discussion and brain storming sessions provided a clearer picture of the significance of the barriers to the diffusion of the technology. The following barriers were identified as the critical barriers that need to be addressed in order to enhance the transfer, adoption, and diffusion of drought tolerant sorghum technology in Kenya:

- Inadequate financial resources
- Market failures in relation to seed production, distribution and delivery systems
- Inappropriate communication and extension approaches
- Inadequate awareness/training for farmers

2.2.2.1 Economic and Financial Barriers

The main identified economic and financial barrier to adoption and diffusion of drought tolerant sorghum varieties is inadequate financial resources leading to low adaptation of drought tolerant sorghum varieties by farmers.

The inadequate financial resources is due to lack of available capital to buy seeds; lack of agricultural credit and loans and low affordability amongst rural farmers. These hinder the adoption of the drought tolerant sorghum technology as illustrated in table 2.2 below.

Table 2.2: Economic and Financial Barrier Decomposition

Barrier Category	Barrier	Elements of Barriers	Dimensions of Barrier Elements
Economic and Financial	Inadequate Financial Resources	• Inaccessibility of financial resources by farmers	• Lack of available capital, credit and loans. • High prices of seeds • Low affordability of farmers

2.2.2.2 Non Financial Barriers

The main identified non-financial barrier to adoption and diffusion of drought tolerant sorghum technology is related to market failures. The barriers of further analysed through decomposition as shown in Table 2.3. The elements of this barrier are associated with unreliable supplies due to absence of stockists; lack of functional markets at times in Arid and Semi-Arid areas; uncertainty on the demand for seeds; low seed demand; poor infrastructure.

Table 2.3: Non-Financial Barrier Decomposition

Barrier Category	Barrier	Elements of Barriers	Dimensions of Barrier Elements
Market Failures	Low adoption of due to market barriers	Inaccessibility of seeds by farmers	• Lack of stockists • Unreliable supplies • Inefficient seed production, distribution and delivery systems

2.2.3 Identified Measures

The identified measures for addressing the barriers include provision of agricultural credit and loans; establishing reliable supplies of inputs, functional seed market and efficient seed production and mounting adequate training and education on seed multiplication and awareness campaigns for sorghum. The others are, improving communication and extension techniques; involvement of farmers in varietal selection; integration between formal and informal seed systems; improving agricultural research, and timely release of varieties.(Khamsin, 2011).

2.2.3.1 Economic and Financial Measures

The economic and financial measures are explained in the Table 2.4 below.

Table 2.4: Economic and Financial Measures

Measures	Enabling Environment
• Provision of agricultural credit and loans to farmers and ensuring access on terms of farmers	• Provide loans and credit to farmers
• Provision of affordable capital for buying seeds	• Establish financial institutions to provide capital

2.2.3.2 Non-Financial Measures

The non-financial measures are highlighted in the Table 2.5 below.

Table 2.5: Non-Financial Measures

Barrier	Measures
Market failures	Establishing functional markets
Policy, legal and regulatory	Formulate and enact appropriate legislations and regulations
Network failure	Intensify co-ordination
Institutional and Organizational Capacity	Develop institutional and organizational capacity
Human Skills	Provide adequate training
Social, Cultural and behavioural issues	Taking into account cultural and social aspects in promoting the technology
Information and Awareness	Create awareness
Technical	Intensify Research efforts

Some of these measures were also identified through the market chain analysis. The enabling environment comprises of such factors, aspects and issues as land issues, customer trends, quality control, business permits, business ethics, financial policies, contract agreement, good agricultural practices and taxation matters.

The business and extension services comprise of such aspects as financial services, input supplies, market information, grading standards, facilitation linkage and product coordination as illustrated in Annex 1.1B

2.2.4 Cost Benefit Analysis

A cost benefit analysis was done in order to asses the economic benefits associated with adoption and diffusion of Drought Tolerant Sorghum technology compared to the existing scenario. Existing scenario involves the use of local traditional seed varieties which have low yields and are less tolerant to drought and pest leading. This result in crop failure and low yields which results in food insecurity, malnutrition and associated health problems and social instability.

The cost-benefit analysis was done by first identifying both direct and indirect costs and benefits associated with current water sources and the implementation of the Drought Tolerant Sorghum technology. The elements of costs and benefits of growing traditional and Drought Tolerant Sorghum in a one acre plot of land per year are presented in Table 2.6 and were used as input during cost-benefit analysis.

Table 2.6: Elements of Costs and Benefits of the Existing Scenario and of adopting Drought Tolerant Sorghum Technology (From expert knowledge during stakeholders' consultations

	Item	**Amount (KShs)**
Costs		
1.0	Existing scenario	
1.1	Cost of seeds	4,000
1.2	Fertilizer	6,000
1.3	Labour (Land preparations, weeding, planting and harvesting)	16,000
1.4	Crop failure	80,000
1.5	Food insecurity and associated malnutrition for children and aged	10,000
1.6	Social problems associated with poverty	5,000
	Total Cost	**121,000**
2.0	Cost of Technology	
2.1	Public awareness	50,000
2.2	Labour (Land preparations, weeding, planting and harvesting)	20,000
2.3	Fertilizer	6,000
2.4	Seeds	5,000
	Total Cost	**81,000**
Benefits		
1.0	Existing scenario	
1.1	Crop harvest	40,000
1.2	Employment opportunities	10,000
	Total Benefits	**50,000**
2.0	Technology	
2.1	Increased yield per acre	160,000
2.2	Food security and improved health	10,000
2.3	Social stability	5,000
2.5	Employment creation	20,000
	Total Benefits	**195,000**

Net benefits for existing scenario = KShs (50,000-121,000) = -KShs 71,000 (1)

Net benefits for technology = KShs (195,000-81,000) = KShs 114,000 (2)
Net Benefits for the technology = (2)-(1)
= 114,000- (-71,000) = KShs 185,000

Net present values for the technology (NPV) = $\sum \frac{NetBenefit_t}{(1+i)^t}$

Where t is the year and *i* is the discount rate (10%)

NPV for year 1 = $\frac{185{,}000}{(1+0.1)^1}$
= KShs 168,182

NPV for year 2 = $\frac{185{,}000}{(1+0.1)^2}$
= KShs 152,893

Similarly, calculations were done for the next 8 years (total 10 years) and the NPV values are presented in Table 2.7.

Table 2.7: 10 years NPV values for Drought Tolerant Sorghum Technology

Year	Calculation	Net Benefits, 10% Discounted (KShs)
1	$185{,}000/(1+0.1)^1$	168,182
2	$185{,}000/(1+0.1)^2$	152,893
3	$185{,}000/(1+0.1)^3$	138,993
4	$185{,}000/(1+0.1)^4$	126,357
5	$185{,}000/(1+0.1)^5$	114,870
6	$185{,}000/(1+0.1)^6$	104,428
7	$185{,}000/(1+0.1)^7$	94,934
8	$185{,}000/(1+0.1)^8$	86,304
9	$185{,}000/(1+0.1)^9$	78,458
10	$185{,}000/(1+0.1)^{10}$	71,326
NPV, KShs		1,136,745

It is clear from the above 10 years, NPV value that the Drought Tolerant Sorghum technology has positive cost benefits and it is therefore viable.

2.3 Barrier Analysis and Possible Enabling Measures for Drip Irrigation Technology

2.3.1 General Description of for Drip Irrigation Technology

Irrigation is an agricultural operation involving supplying the need of a plant for water. Irrigation is necessary in a dry climate where natural rainfall does not meet plant water requirements during all or part of the year. In Kenya, land and water resources are becoming scarce and arable land has decreased tremendously due to population increase, unreliable rainfall caused by periodic droughts and lack of appropriate technologies to cope with the situation. Persistent droughts due to climate change have led to persistent threat of household food security and exacerbated poverty in the country. The importance of irrigation and efficient use of water due to water scarcity is being addressed through development of more efficient irrigation systems and methods such as drip irrigation.

Drip Irrigation, is a technique of application of specific and focused quantities of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources to the root area and applying it under particular quantity and pressure specifications. Drip irrigation can provide as much as 90 per cent water-use efficiency in contrast to surface irrigation and sprinkler systems, which provide 60 per cent 75 per cent efficiency respectively, and can therefore enable farmers to adapt to climate change in crop production under erratic rainfall pattern (Clements et al. 2011).

A wide range of components and system design of drip irrigation are available. Types of drip irrigation technologies include bucket and drum or mini-tank drip, Chapin (types of bucket), dream drip kits, captain brand and gravity (Alam et.al, 2006). A bucket and drum or mini-tank drip kit is used in this analysis and it is one of the low head drip irrigation system. With low-head drip irrigation the over sophisticated and over engineered control elements used in the conventional drip systems are minimized and replaced by simple do-it-yourself equipment— low-head drip irrigation technologies(Gilead 1985). Small reservoirs such as oil drums can be used as header water tanks. These are supported on blocks so that the water pressure falls within the required range. Perforated flexible plastic piping conveys water to the plants.

Drip irrigation provides:

- Maximum efficiency in water use
- Reliable heavy duty lines and high quality drippers with wide water passage
- Easily filled and drained
- Enables fertilization through the system
- Simple in installation and maintenance
- Gravity fed or low-head drip irrigation technologies

The bucket kit is a small-scale drip irrigation system with high water use efficiency that operates at low pressure heads of 0.5 to 2.0 m (0.05-0.2 bar). It consists of a 20-liter bucket or a 200-liter drum, drip tape, filters, rubber washers, male and female adapters, two supply tubes and barb fittings. A screen filter and flow regulator is usually used with the drip kit. The bucket is mounted on a stand, which holds it one meter above the ground. The drip lines are supplied in lengths of 15 m, and, for best results, they are laid on level ground.

Water for drip irrigation systems may come from wells ponds, lakes, harvested water (roof and surface run off), piped water and rivers. Drip irrigation zones can be identified based on factors such as topography, field length, soil texture.

The type discussed and analysed in barrier analysis is for drip irrigation using a bucket and drum, which is suitable for small scale farmers and institutions.

Status of drip irrigation in the country

Initially, drip irrigation technology was adopted by large scale farmers growing high value fruit, vegetables and ornamental crops. This was because of high costs (KShs. 200,000 - 300,000) per hectare for infield equipment alone without considering filters and water delivery services (Sijali and Okumu, 2002). This cost was out of reach for most small scale farmers. The small scale farmers including Women Groups adopted the technology through

donor supported programmes but these were not sustainable, when the support came to an end.

Available statistics show a very low adoption level of drip irrigation in the country. According to GoK (2012), all National Irrigation Board (NIB) schemes are surface irrigated while 88% of the smallholder schemes are surface irrigated, 9% are sprinkler irrigated and the remaining 3% are drip irrigated. The apparent small number of farmers using drip irrigation can be attributed to the high capital investment cost and to some extent the low technical knowhow of the farmers regarding the use of the technology (GoK 2012).

Since 1996, the Government of Kenya through KARI developed low-head drip irrigation which could be adopted by small scale farmers. KARI has established various on-station demonstration sites including at National Agricultural Research Laboratory (NARL) Nairobi, National Dryland Research Centre in Katumani, Regional Research Centre in Mtwapa and Regional Research Centre in Perkerra (Sijali and Okumu, 2002. These centres also stock the kits for sale.

Technology Category and Market Characteristics

Drip irrigation can be categorized as market consumer good, capital or public good depending on the level of application; whether undertaken by small or large scale farmers. It is a consumer good when it involves small scale households and becomes capital good if undertaken by large institutions. It can also be a public good through research by public institutions and in the case KARI. In our case we are dealing with small scale drip irrigation for local communities.

Market Characteristics for Small Scale Drip Irrigation are:-

- It is relatively adaptable to small scale farmers including women.
- Requires importation of pumps.
- Local manufacturing of pipes, tanks
- Can be used in green houses or open garden
- Awareness on the technology is carried out by the relevant government institutions,) private sector and civil society organizations.
- Though some of inputs for drip irrigation are available locally. Some components are imported. Barriers exist in the supply chain which hinders wide adaptation and diffusion of the technology at local levels.

2.3.2 Identification of Barriers for Drip Irrigation Technology

Despite the research and over 25 years of drip irrigation technology in the country the adoption and diffusion has been low due to several barriers. Barrier identification can be defined as the process of tracing reasons that hinder the development, transfer and diffusion of a technology. This includes the following:

- Identification of any failed or missing measures that could have sustained the transfer and diffusion of the drip irrigation technology
- Understanding the nature of individual barriers
- Understanding the relationship between individual barriers
- Determination of which barriers are important and how they can be removed.

Process of Barrier Identification

This process was based on consultants own knowledge, literature review and stakeholder consultations as follows:

- A desk study of policy papers and other pertinent documents to identify the primary reasons why the technology is not currently widespread and why neither the private nor the public sectors have significantly invested in it
- Economic and other relevant assessments of the drip irrigation technology were included in the desk study
- Consultation with the stakeholders including brain storming sessions by Adaptation Technical Working Group during a workshop held on 25th July 2012 in Nairobi and other expert consultations on one to one basis. The barriers identified were redefined at another stakeholders' workshop held on 29th November 2012 (Workshop reports are presented in Annex4).
- Reference to checklist of generic barriers as presented in Annex A of the TNA Guidebook
- Through use market mapping tool the elements in the market environment and the relation to the market chain analysed and were used to identify barriers for drip irrigation consumer goods (Boldt et al. 2012).

The barriers were discussed using a participatory market chain analysis approach (Boldt et al. 2012). Drip irrigation technology which is used by small scale farmers is a consumer good which deals with technologies traded in market place. The barriers were discussed by looking at the technology linkages at three levels:

(i) **Enabling business environment** which charts the critical factors and trends that shape the market chain environment and operating condition such as policies, strategies and action plans. These include:

a) Irrigation Policy in Kenya is anchored on the Vision 2030 and the Constitution of Kenya 2010. The Constitution of Kenya, 2010 guarantees the *"Right of Food"* in the Bill of Rights while the Vision 2030 aims at transforming the nation into a *"Newly Industrialized Country by 2030"*. In addition, under the Millennium Development Goals (MDG) the country policy has also set goals for achieving food securing and reducing poverty by the year 2015. All these policies identify the need for irrigation development including drip irrigation as a key to achieving the country's development goals of food security and industrial development. This will contribute to economic development, job creation and poverty alleviation.

b) Finance – Though there are financial policies they do not specify the action to be taken in order to give incentives and tax rebates in irrigation technologies. Although there are soft loans from the government like Women and Youth Enterprise Funds, these are not specific for drip irrigation but can, however be used for the same purpose.

c) Laws and Regulations (or transaction activities): Standards of kits, business regulations including licensing which determine the cost of doing business; technological development

d) Ethical issues like corruption control, attitudes among others

The enabling environment can create barriers to market chain actors

(ii) **Market chain actors and linkages.** These are the economic actors who produce and transact drip irrigation technology at various levels. They include:

a) Importers of materials for making drip irrigation kits – these are mainly research institutions like KARI and private sector like Amiran and Fresh Produce Exporters Association of Kenya (FPEAK). After these materials have been imported the kits are manufactured using local technical expertise. Currently the importer and manufacturers are few in relation to the demand.
b) Manufacturers of water storage containers such as buckets, drums and tanks. – these are mainly private sector entrepreneurs
c) Manufacturers of water pumps for water abstraction and distribution to users in this case the small scale farmers and institutions – these are mainly private sector actors
d) Wholesalers who provide water storage containers and pumps to the retailers, which enables sufficient supply of goods. These are widely spread all over the country
e) Retailers of kits, pumps and storage containers these are also mainly private sector and KARI

Since these intermediaries are important in making the market function, there are constraints at this level, which include high costs because materials for making the kits are imported. There are also few suppliers of these kits and farmers have to pay high prices there need to be addressed. In addition there may be one or two actors controlling the market.

(iii) **Service Providers.** Service providers are responsible for providing services to enable overall market chain efficient. These include:

a) Research and development by KARI which also gives technical services.
b) Private sector actors like Amiran who provide technical services such as development of demonstration plots, financial and legal services, capacity building and public awareness.
c) Some civil societies have also offered training services to farmers but they rely on donor funding which is not sustainable.

Detailed market map for drip irrigation technology is presented in Annex 1.3.

Gross Barriers for Drip Irrigation Technology

Using the methodology discussed the following barriers were identified by the consultants and stakeholders:

- High cost of initial installation
- Inadequate credit and loan facilities for farmers
- Fear of loans and lack of collateral especially among the female gender
- Lack of appropriate research and affordable technology geared towards poor farmers on small plots
- Inadequate water supply
- Inadequate water harvesting and storage facilities
- Water quality - low suspended sediment - salty water
- Resistance to change especially in ASALs
- Inadequate awareness of the existence of technology

- Limited technical know how by the farmers regarding the use of this technology
- Extensive maintenance requirements
- High human skills requirement (Low capacity to sustainable use of technology)
- Inadequate training of the majority of farmers
- Preference to other irrigation methods
- Pest attraction: being the only green spot, especially during the prolonged dry spells, insects, rodents, squirrels, aphids etc find refuge in the drip gardens.
- Damage by animals looking for water (squirrels and porcupines)
- Inadequate pest and disease control
- Breakage of filter plug due to brittleness of the plastic used
- Less flexibility in terms of emitter spacing and lateral lengths
- Easily punctured by sharp objects if poorly handled
- Clogging of some emitters
- Non uniformity of emitter discharge along the lateral, especially where land is not well levelled
- Lack of spare parts and inadequate extension services
- Low education levels of farmers
- Lack of extension policy and extension services staff
- Leakage, especially at bucket connections, if fittings are not done properly, i.e. if the hole is bigger than the adapter, other causes of leakage are punctures, cracks
- Insecurity: fear of theft if the system is installed far from the house
- Uneven water distribution especially on sloping land, which can drastically affect yields due to under irrigation of so
- Inadequate incentives
- Cultural biases

The barriers were then grouped into various categories and described in order to facilitate analysis and screening (Table 2.8).

Table 2.8: Barrier Categorisation and Description

Barrier Category	Barrier	Barrier Description
Economic and Financial	• High Cost of initial installation • Inadequate credit and loan facilities for farmers • Fear of loans by small scale farmers • Lack of collateral especially among the female gender • High maintenance cost • Inadequate incentives	• Implementation is constrained by lack of access to higher amount finances for initial investments and maintenance. This is due to many systems component requirements including pumps, pipes, tubes, emitters and installation.. • The cost is increased further by the need for training the practitioners of drip irrigation for proper utilization of the technology. Furthermore some of the components are imported increasing costs. • Materials for making system are imported and costly
Technical	• Water quality - high suspended sediment and salty water • Extensive maintenance requirements • Inadequate water harvesting and storage • Damage by animals looking for water (squirrels and porcupines) • Inadequate pest and disease control • Breakage of filter plug due to brittleness of the plastic used • Less flexibility in terms of emitter spacing and lateral lengths • Easily punctured by sharp objects if poorly handled • Clogging of some emitters • No uniformity of emitter discharge along the lateral, especially where land is not well levelled • Lack of spare parts and inadequate extension services • Leakage, especially at bucket connections, if fittings are not done properly, i.e. if the hole is bigger than the adapter, other causes of leakage are punctures, cracks • Uneven water distribution especially on sloping land, which can drastically affect yields due to under irrigation of some plants and over irrigation of others	• Limited technical know-how for lowering suspended solids and water desalination • Limited technical know how for repair and maintenance of the kits and dealing with pests and animal menace • Shortage of kits and spare parts at both farmer as well as at the national level • Difficult to combine with mechanised production like tractors and other farm machinery which can damage pipes, tubes or emitter. • Pest attraction: being the only green spot, especially during the prolonged dry spells, insects, rodents, squirrels, aphids etc find refuge in the drip gardens. • Lack of appropriate and affordable technologies (Sijali and Okumu 2002).

Barrier Category	Barrier	Barrier Description
Socio-Cultural	• Resistance to change especially in ASALs • Preference to other irrigation methods • Insecurity • Gender biases • Poverty	• ASAL communities are mainly pastoralists and may have resistance to change to mixed farming and permanent settlements • Other irrigation methods like furrow irrigation are less complicated and therefore easier to use • Fear of theft if the system is installed far from the house • African women and not men bear the burden of fetching water. Yet men own resources of production might not appreciate the need to invest in affordable labour-saving technologies • Poverty . Resource poor farmers living below poverty line do not resources to take off; the initial problem is access to capital
Information and Awareness	• Inadequate awareness of the existence of technology • Inadequate Information and networking • Inadequate market and market information	• This technology in Kenya but it has not been disseminated fully so many farmers are not aware of its existence. • As small scale drip irrigation users take off, they have to face new challenges and information and networking is inadequate • Inadequate strategic market targeting off-season and export market lead to exploitation by middlemen and low returns which discourage investment in drip irrigation technology
Human Skills	• High human skills requirement (Low capacity to sustainable use of technology) • Inadequate training of the majority of farmers • Low level of education	• This is associated with skills to accurately manage and maintain water flow control, carefully maintained for maximum efficiency. This includes issues of proper maintenance in order to avoid leaking or plugging and emitters must be regularly cleaned to avoid blockage from chemicals. This capacity is usually not available and requires heavy investment • There is general lack of skills in installation, operation, maintenance and repairer of drip systems • Low education levels are a possible cause for the poor management which was found to be a major problem during implementations and confirmation stages. The cumulative effect is likely to lead to discouragement of the introduction and adoption of the new technology

Barrier Category	Barrier	Barrier Description
Environmental issues	• Water scarcity	• The main sources of irrigation water were streams and small rivers. These sources do not store water for dry periods. This is an unlikely incentive for the adoption of water-saving irrigation methods such as LCDI; on the contrary, it is likely to be an inhibiting factor, as any water saved could not be stored.
Policy	• Inadequate policy and extension staff for irrigation	• local extension budgets and programmes

Screening of Barriers

The categorized identified barriers were screened according to their significance in the adoption and diffusion of drip irrigation technology and identify those that definitely need be addressed for effective transfer and diffusion of drip irrigation technology. This was done through brainstorming and discussion sessions with stakeholders in a workshop. In addition, this was reviewed by Adaptation Technical Working Group and NEMA coordination unit. Policy documents were reviewed in the buildup of consensus with. The discussion and brain storming sessions gave a clear picture of how critical barriers were to the diffusion of drip irrigation. The following barriers were selected for further analysis:

(i) High Cost of initial installation
(ii) High human skills requirement/Trained labour
(iii) Water scarcity
(iv) High maintenance costs
(v) Insecurity
(vi) Inadequate extension services

2.3.2.1 Economic and Financial Barriers

The screened barriers were decomposed through discussion to check whether some barriers are actually composed of some of the other barriers, or whether one barrier is just more concrete. Economic and financial barriers were identified as key and decomposed in four levels (Table 2.9). Decomposition of the economic and financial barrier revealed that the high cost of initial installation is associated with high cost of unit kits because of few local manufacturers of local kits and lack of incentives.

Table 2.9: Decomposition of Economic and Financial Barriers

Broad category	Barrier within category	Elements of a barrier	Dimension of a barrier
Economic and Financial	• High Cost of Initial Installation	• High Cost of unit kits	• Few Local manufacturers of kit • High cost of importing some of the components • Lack of incentives and tax rebates
		• Inadequate credit/ Inaccessibility to credit facilities • Fear of loans by small scale farmers	• High interest rates
	• High maintenance cost	• High cost of the de-clogging of emitters	• Dissolved solids in water due to poor piping standards
		• High replacement costs of broken pipes and breakage of filters	• Poor quality pipes • Brittleness of plastic used.
		• Insecurity	• Pipes and storage tanks stolen. • Animals damaging pipes in search of water

After the decomposing the barriers the consultants took another step by analysing the causal relations between the decomposed barriers by looking at the main barrier or the starter problem which is initial high cost of initial installation. The casual relationship was done by looking at root causes of barrier and the effects of the barriers on the target communities.

The analysis showed that the high cost of initial installation of drip irrigation kit is due to cost of components as a result of high cost of credit facilities, which is a result of inadequate credit facilities and high interest rates. The cost is increased further by the need for specialized human skills since training is required. As consequence a few farmers are adopting drip irrigation resulting in reduced acreage in drip irrigation and inadequate income from farmers leading to overall food insecurity. Refer to Annex 1.2E for the detailed logical problem analysis on barriers for drip irrigation technology.

2.3.2.2 Non Financial Barriers

The main non-financial barrier is human skill which is associated with highly skilled manpower requirement for planning, installation and maintenance of drip irrigation (Table 2.10). These include specialized skills for preparing pipes and filters, laying the pipes, technician for repairing the pipes. There are few trained technicians to carry out the activities mentioned above Also there is inadequate awareness by farmers on how to align the pipes with crops. The main requirement is training of farmers to enable them to adapt to this technology which requires financial resources. This barrier is subsumed in the economic and financial barrier.

Table 2.10: Decomposition of Non Financial Barriers

Broad category	Barrier within category	Elements of a barrier	Dimension of a barrier
Human Skills	• High human skills requirement	• Specialized skills for preparing pipes and filters, laying the pipes, technician for repairing the pipes	• Few trained technicians. • Inadequate awareness by farmers on how to align the pipes with crops. • Labour intensive for checking whether the pipes have clogged
	• Inadequate Extension services	• Lack of extension policy	• Limited knowledge of drip irrigation by extension services staff (general agricultural extension staff with limited knowledge on drip irrigation) • Financial and equipment constraints
Water Scarcity	• Inadequate water harvesting and storage facilities • Frequent Droughts (Climatic variability)	• Inadequate policy in water harvesting and storage • Inadequate awareness	• Limited awareness of water harvesting technologies • Lack of capital for establishing water harvesting and storage facilities

Since generally Kenya is classified as water scarce country, there is insufficient water for drip irrigation. Access to available water resources is hampered by the need to use other technologies for harvesting and storage. For example, underground water resources require use of borehole technologies which are costly. The erratic nature of the rainfall exacerbates this problem. Since during drought there is no water and during the rainy season the excess water is wasted due to inadequate water harvesting and storage facilities. Though the Water Act, 2002 has provisions for irrigation, the policy for its implementation of now under preparation (Gok, 2002)

2.3.3 Identified Measures

This section looks at measures to overcome barriers identified in the previous section. The main methodology used was reformulating all the problems as positive statements and developing an objective tree (Annex 1.3E). The process of identification of measures was arrived at by consultants and stakeholders during the 3rd Stakeholder workshop. These measures were also evaluated by the Adaptation Technical Working and the Project Coordination Unit. The consultants own knowledge and literature review including a study of market chain analysis also contributed to this process. This has been done only for the starter problem which is an economic and financial measure.

2.3.3.1 Economic and Financial Measures

This was analysed using an objective which gives the measures to overcome the root cause barrier and the resultant effects (Annex 1.3E).

Economic and financial measures should be put in place to reduce interest rates and increase credit facilities leading to adequate credit. Furthermore if tax rebates and incentives (tax waiver) are provided, the cost of importing kits will be reduced. If measures to train more technicians at subsidized rates are put in place, it will result in more specialized manpower leading to more manufacturers of kits and better service delivery. This will contribute to lowering the cost of initial installation.

The implementation of these measures will result in more farmers adopting drip irrigation and increased acreage under drip irrigation. Consequently there will be more income from farming and food security.

2.3.3.2 Non-Financial Measures

Non financial measures include development of human skill involving capacity building for both farmers and technicians. Enhancement of information and awareness will promote use of drip irrigation and reduce social and cultural barriers and enhance community participation.

2.4 Cost Benefit Analysis for Drip Irrigation

A cost benefit analysis was done in order to asses the economic benefits associated with adoption and diffusion of Drip Irrigation technology compared to the existing scenario. Existing scenario practicing rain-fed agriculture, a situation that leads to crop failure and low yield due to unreliable rainfall associated with climate variability. This result in economic loss and food insecurity, and associated malnutrition for children and the aged.

The cost-benefit analysis 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 a tank irrigation kit for irrigating one acre of land. The costs and benefits for current scenario and technology application are per year.

Table 2.11: Elements of Costs and Benefits of the Existing Scenario and of adopting Drip Irrigation Technology

	Item	**Amount (KShs)**
Costs		
1.0	Existing scenario	
1.1	Cost of seeds	5,000
1.2	Agrochemicals	10,000
1.3	Labour (Land preparations, weeding, planting and harvesting)	20,000
1.4	Crop failure	60,000
1.5	Food insecurity and associated malnutrition for children and aged	10,000
1.6	Poverty associated Environmental destruction (deforestation, overgrazing)	15,000
	Total Cost	**120,000**
2.0	Cost of Technology	
2.1	Drip irrigation kits	120,000
2.2	Tanks (1 m^3) and installation	10,000
2.3	Water pump and accessories	10,000
2.4	Fencing (for security and animals)	60,000
2.5	Labour	40,000
2.6	Seeds	5,000
2.7	Agro-chemicals	10,000
2.8	Capacity building	10,000
2.9	Cost of water	5,000
3.0	Environmental degradation (soil salinisation)	5,000
	Total Cost	**275,000**
Benefits		
1.0	Existing scenario	
1.1	Crop harvest	40,000
1.2	Existing human capacity (traditional knowledge)	5,000
	Total Benefits	**45,000**
2.0	Technology	
2.1	Increased yield per acre	180,000
2.2	Food security and improved health	10,000
2.3	Environmental conservation	15,000
2.5	Employment creation	80,000
	Total Benefits	**285,000**

Net benefits for existing scenario = KShs (45,000-120,000) = -KShs 75,000 (1)
Net benefits for technology = KShs (285,000-275,000) = KShs10,000 (2)
Net Benefits for the technology = (2)-(1)
= 10,000- (-75,000) = KShs 85,000

Net present values for the technology (NPV) = $\sum \frac{NetBenefit_t}{(1+i)^t}$

Where t is the year and *i* is the discount rate (10%)

NPV for year 1 = $\frac{85000}{(1+0.1)^1}$
= Kshs 77,273
NPV for year 2 = $\frac{85000}{(1+0.1)^2}$
= Kshs 70,248

Similarly, calculations were done for the next 8 years (total 10 years) and the NPV values are presented in Table 2.12.

Table 2.12: 10 years NPV values for Drip Irrigation Technology

Year	Calculation	Net Benefits, 10% Discounted (KShs)
1	$85,000/(1+0.1)^1$	77,273
2	$85,000/(1+0.1)^2$	70,248
3	$85,000/(1+0.1)^3$	63,862
4	$85,000/(1+0.1)^4$	58,056
5	$85,000/(1+0.1)^5$	52,778
6	$85,000/(1+0.1)^6$	47,980
7	$85,000/(1+0.1)^7$	43,618
8	$85,000/(1+0.1)^8$	39,653
9	$85,000/(1+0.1)^9$	36,048
10	$85,000/(1+0.1)^{10}$	32,771
NPV, KShs		**522,287**

It is clear from the above total, 10 years, NPV value that the Drip Irrigation technology has positive cost benefits and it is therefore viable since the main identified barrier is initial cost associated with high cost of installation.

2.5 Linkages of the Barriers Identified

This section looks at linkages of different barriers faced by drought tolerant sorghum and drip irrigation technologies in the agriculture sector and is presented in the table below.

Table 2.13: Linkages of barrier faced by different prioritized in the sector

Barrier Category	Barriers
Economic and Financial	• Inadequate financial resources
	• Inadequate credit and loans
Human skills	• Inadequate training
	• Low adoptive capacity
Information and Awareness	• Inadequate awareness of the existence of technology
	• Inappropriate communication and extension approaches

It is expected that local communities can adopt both technologies in the agriculture sector. If measures for provision of credit facilities, reduce interest rates and tax rebates are undertaken. Undertaking of adequate training will enhance farmer's skills. On barriers related to information and awareness for adaptation and diffusion of technologies will target inadequate awareness of the existence of the technologies and inappropriate communication and extension approaches.

2.6 Enabling Framework for Overcoming the Barriers in the Agriculture Sector

Common measures of overcoming the barriers on drought resistant and drip irrigation technologies and expected outcomes in agricultural sector are listed on Table 2.14 below.

Table 2.14: Common Measures for overcoming Barriers in Agricultural Sector

Category	Measures	Expected outcome
Economic and Financial (Financial Policy)	• Provision of adequate financial resources including credit and loans	• Enhanced adoption and diffusion of technologies • Improved incomes and food security
	• Reduction of interest rates on credit and loans	• Improved access to credit and loans thus enabling more farmers to adopt the technologies
	• Rebate on taxes on tools and machineries, equipment, inputs among others	• Improved acquisition of machineries, equipment, tools and inputs for the new technologies
Human skills	• Provide adequate training to enhance capacity and skills for farmers	• More trained farmers with improved skills who are capable of using and diffusing technologies
Information and Awareness	• Create sufficient awareness on the existence and use of technologies	• Improved response in the adoption and diffusion of the technologies
	• Promote effective extension services	

Technology specific to drought tolerant sorghum technology

The measures which are specific to drought tolerant sorghum technology are listed on Table 2.15.

Table 2.15: Non-Financial Measures

Category	Measures	Outcomes
Market	Establishing functional markets	Ease of access to seeds and inputs on one hand and market outlets for produce
Policy, legal and regulatory	Formulate and enact appropriate legislations and regulations on good agricultural practices	Compliance with legislations and regulations relating to crop husbandry, post harvest handling and agribusiness including crops storage, processing, transport and local and export marketing
Network	Intensify co-ordination	Coordinated segments for the market chain
Institutional and Organizational Capacity	Develop institutional and organizational research capacity	Improved release of drought tolerant sorghum varieties due to intensified research efforts
Social, Cultural and behavioural issues	Taking into account cultural and social aspects in promoting the technology	Wider acceptance of the technology

Technology specific to drip irrigation technology

The measures which are specific to drip irrigation technology are listed on Table 2.16.

Table 2.16: Measures specific to Drip Irrigation Technology

Category	Measures	Outcomes
Human skills	Training on special skills	More farmers with increased knowledge on the use of drip irrigation. Socio-cultural barriers will also be removed
Technical	More manufacturers of kits	Accessibility of kits by farmers
	Training of more technicians	Enhanced outreach at the local level

Once these measures are put in place the overall outcome are improved incomes, food security and livelihoods leading to poverty reduction and diversification of income generating activities.

The suggested measures in both Water and Agriculture Sectors are in some key polices cited in the fact sheets (Annex 3)

CONCLUSION

The Barrier Analysis and Enabling Framework for Climate Change Adaptation Technologies report looked at key sectors of water and agriculture which were prioritised in the TNA report. Technologies prioritised in the Water Resources sector were Surface Run-off and Roof Rainwater Harvesting and in the Agriculture sector Drought Tolerant Sorghum and Drip Irrigation Technologies were prioritised.

In each technology barriers for adoption and measures to overcome them were identified in participatory and consultative forums that involved key stakeholders. These barriers and measures, both financial and non-financial are discussed in this report.

If the enabling framework for overcoming the barriers is put in place in the water resources sector, there will be improved water supply, improved hygiene and livelihoods and if the same is done in agriculture sector there will be improved incomes, food security and livelihoods leading to poverty reduction and diversification of income generating activities. The anticipated outcome is improved social and economic development for sustainable development.

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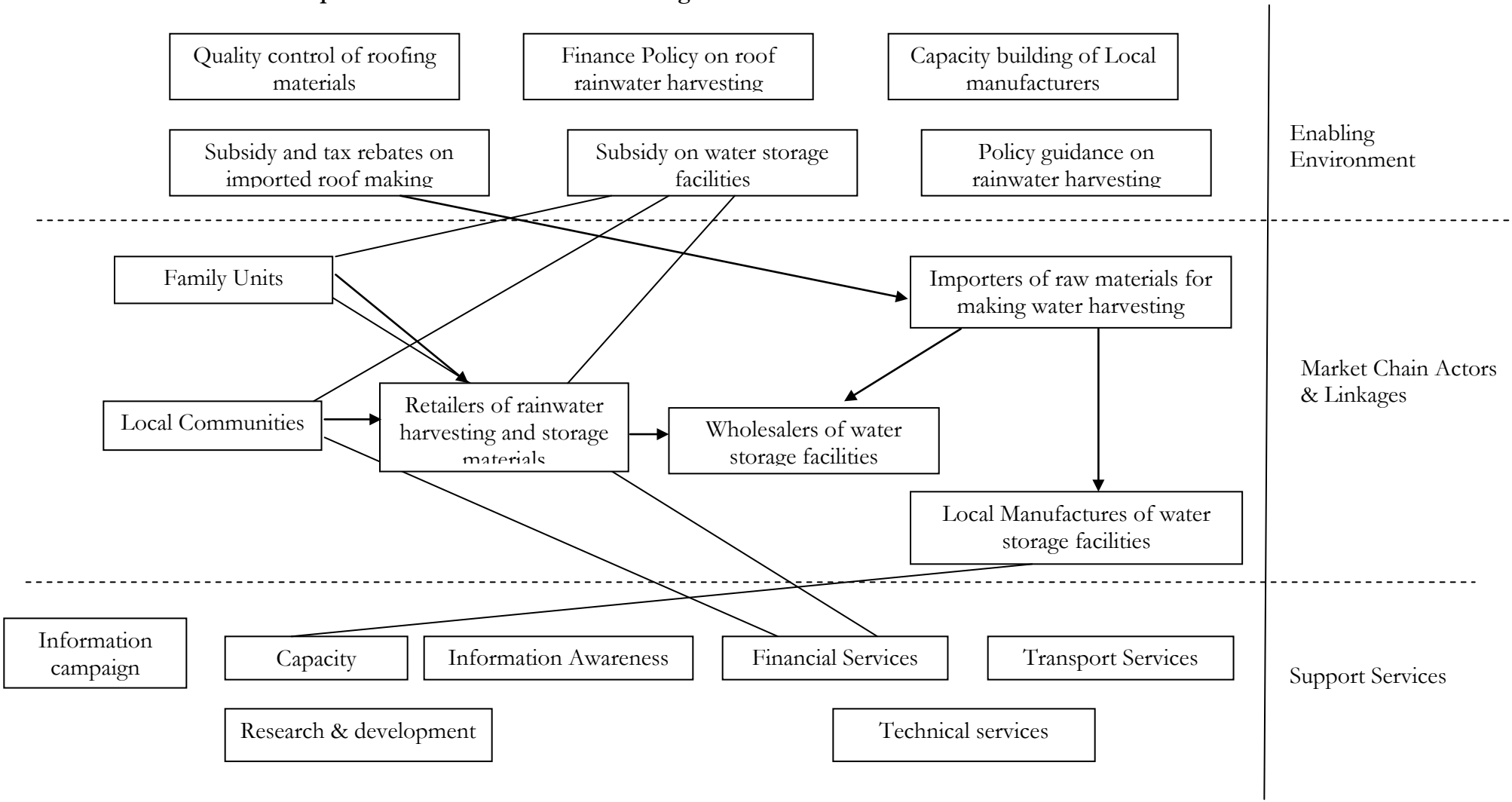
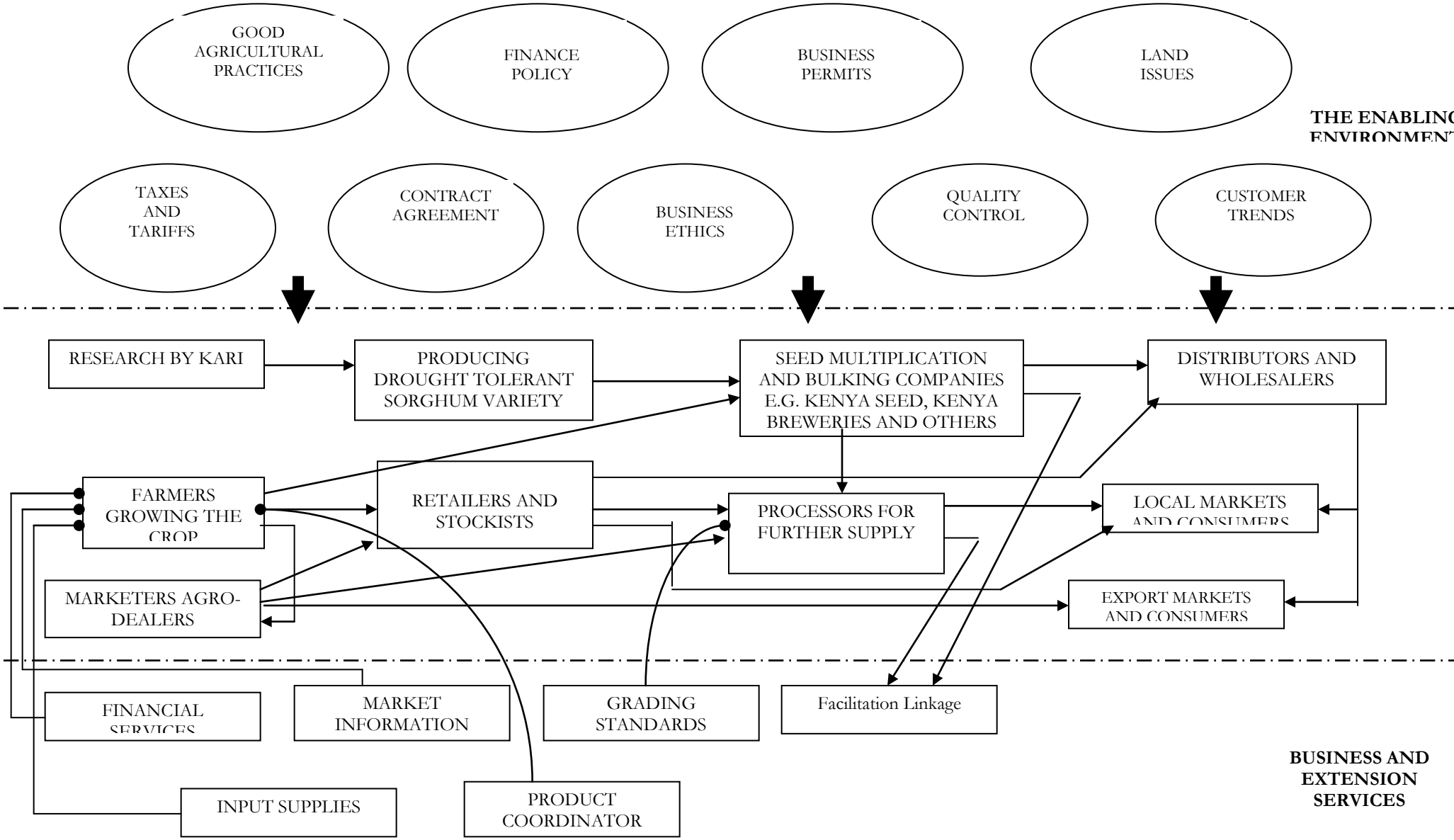
ANNEXES

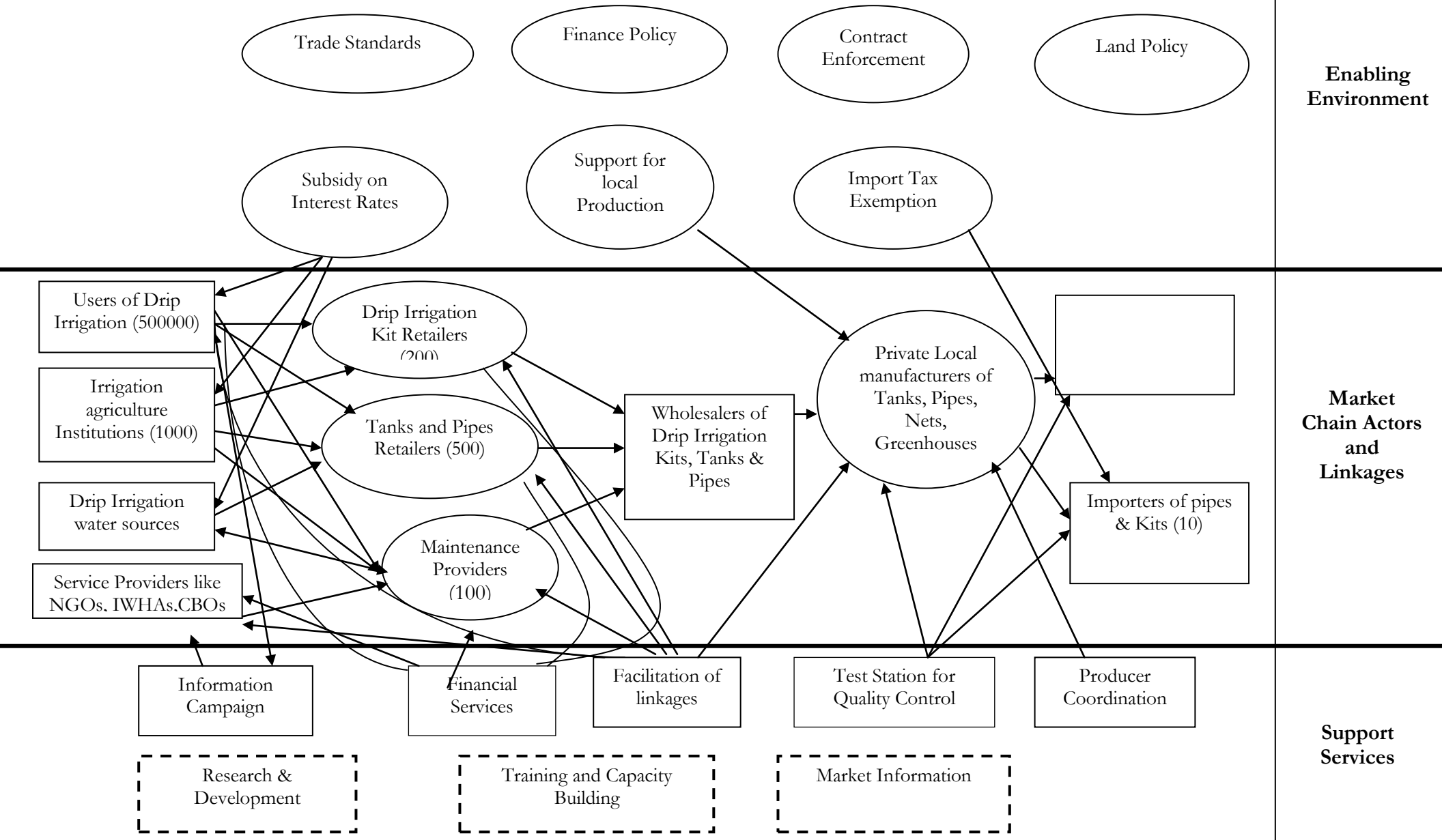
ANNEX 1: MARKET MAPS AND PROBLEM TREES
Annex 1.1 Market Maps
Annex 1.1A: Market Map for the Roof Rainwater Harvesting Chain



Annex 1.1B: Market Map for the Drought Tolerant Sorghum Chain

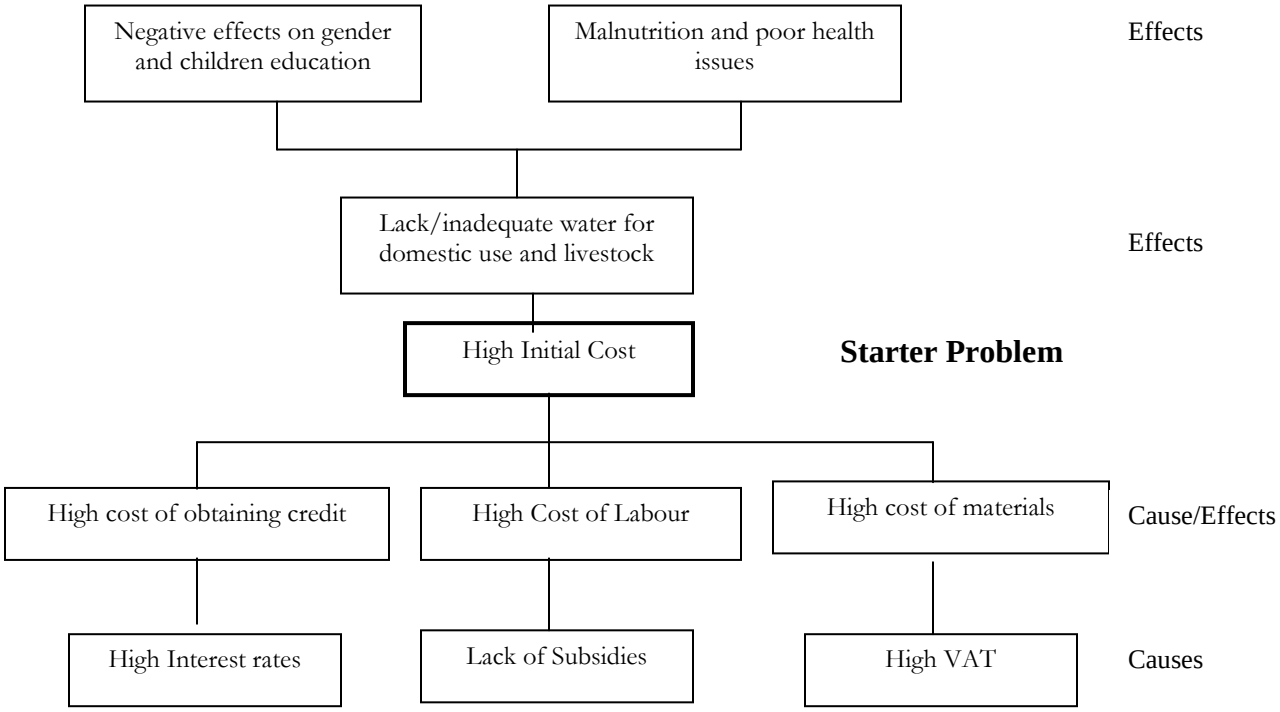


Annex 1.1C: Market Map for the Drip Irrigation Chain

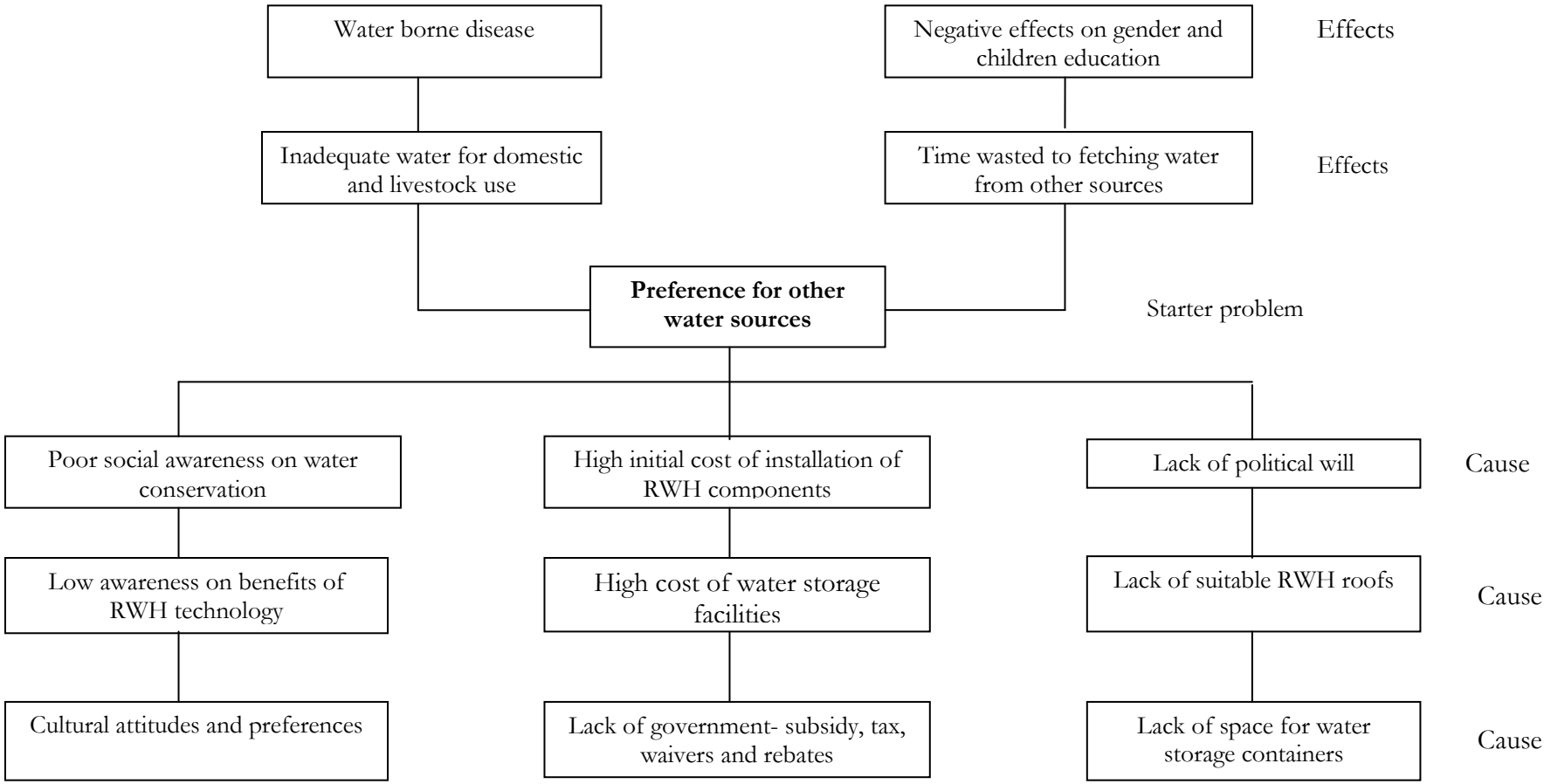


Annex 1.2: Problem Trees

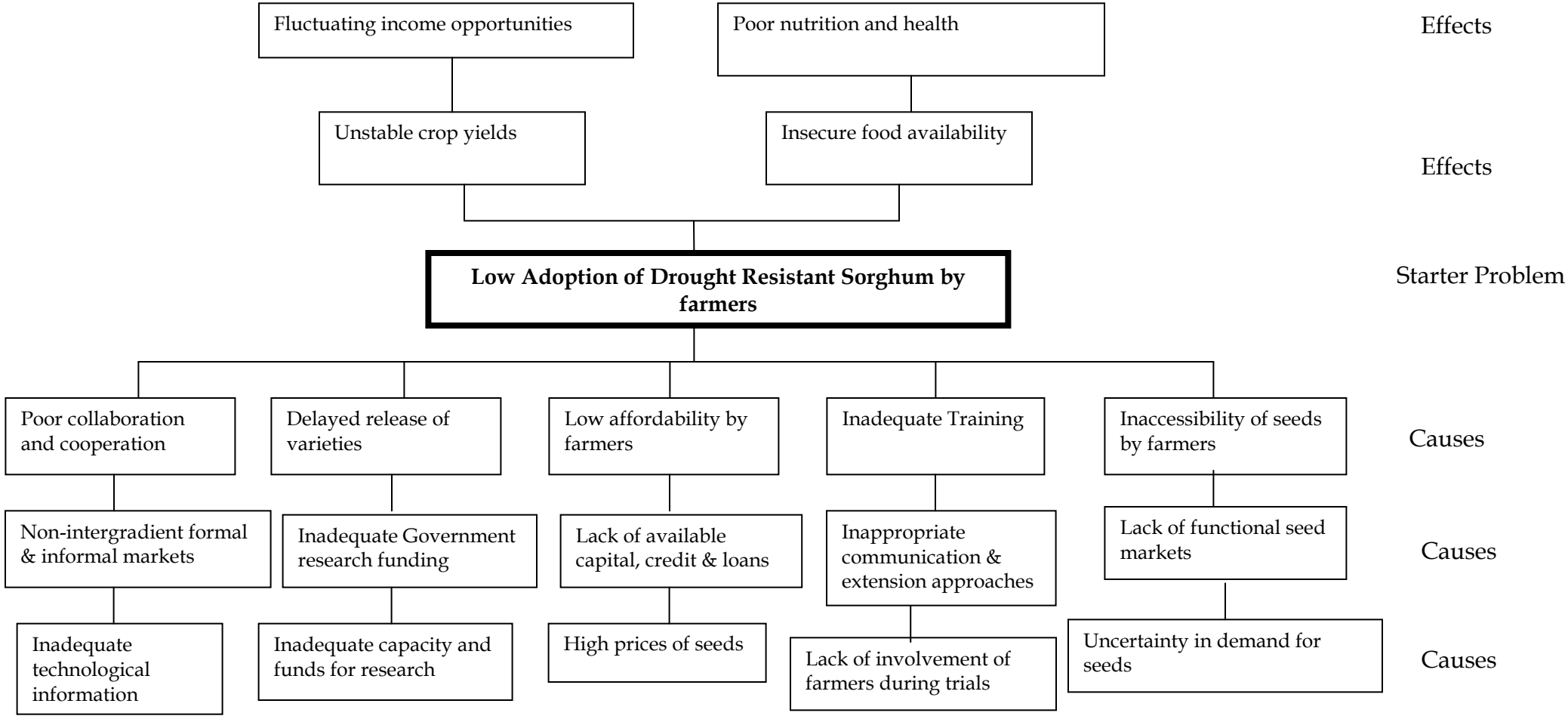
Annex 1.2A: Problem Tree for Surface Runoff Water Harvesting Technology



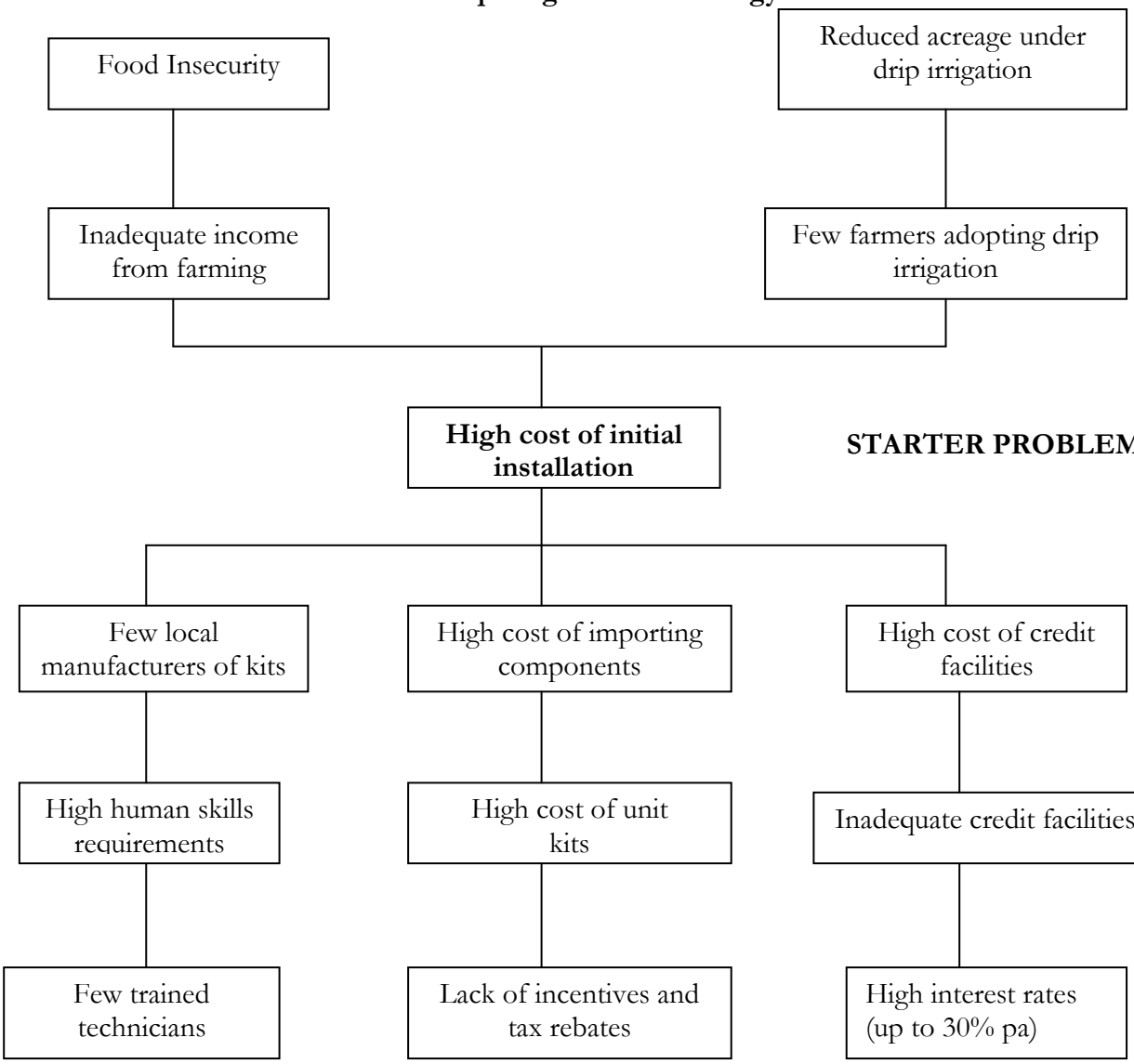
Annex 1.2C: Problem Tree Roof Rainwater Harvesting Technology



Annex 1.2D: Problem Tree for Drought Resistant Sorghum

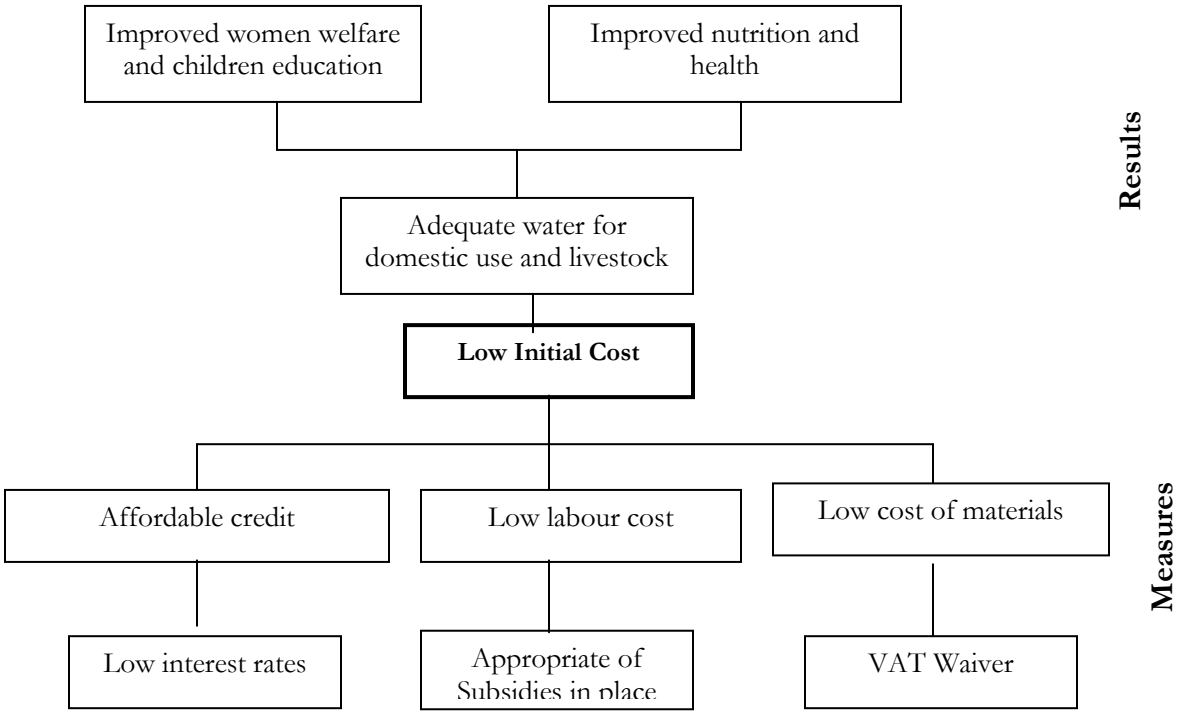


Annex 1.2E: Problem Tree for Drip Irrigation Technology

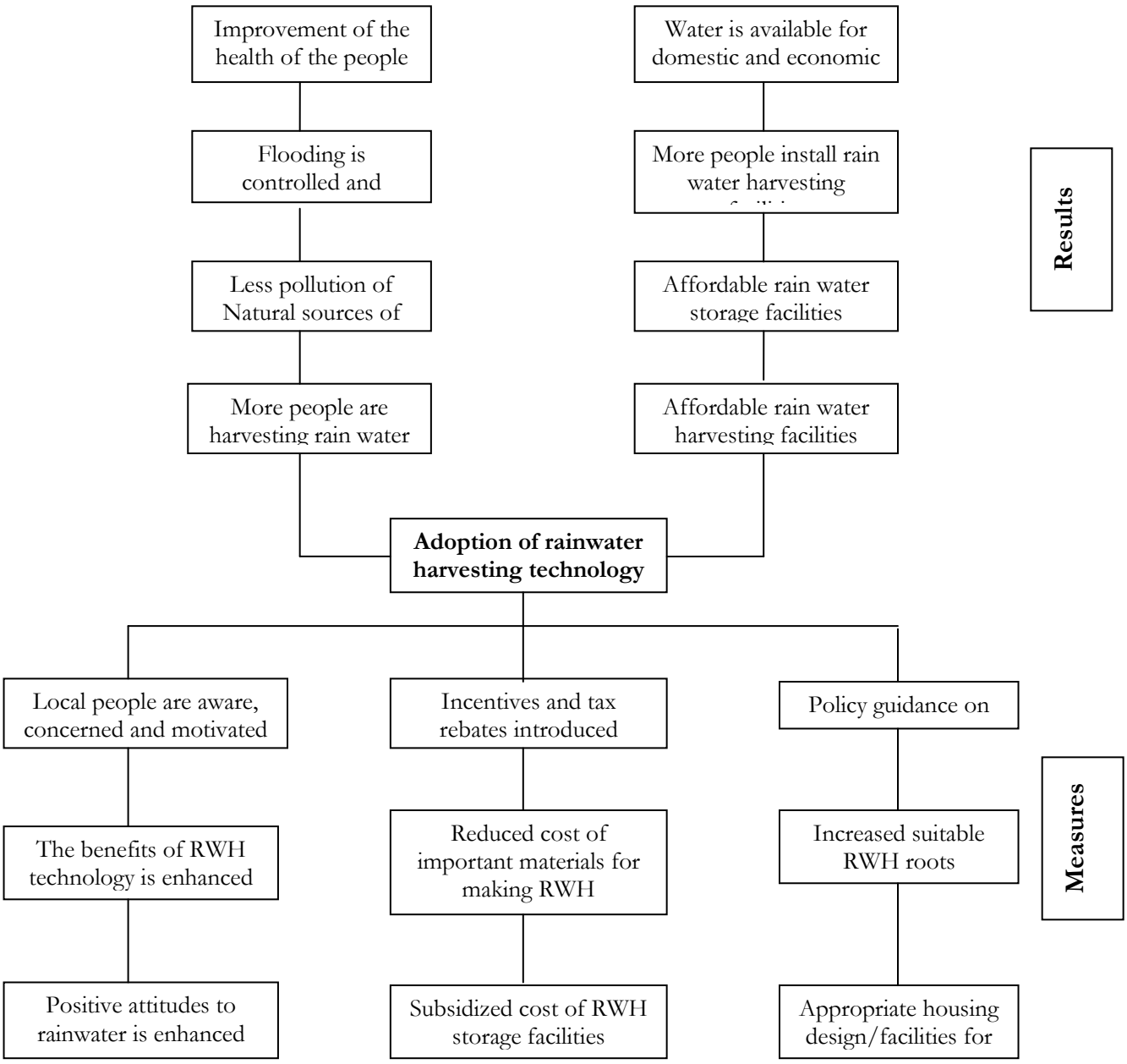


Annex 1.3: Objective Trees

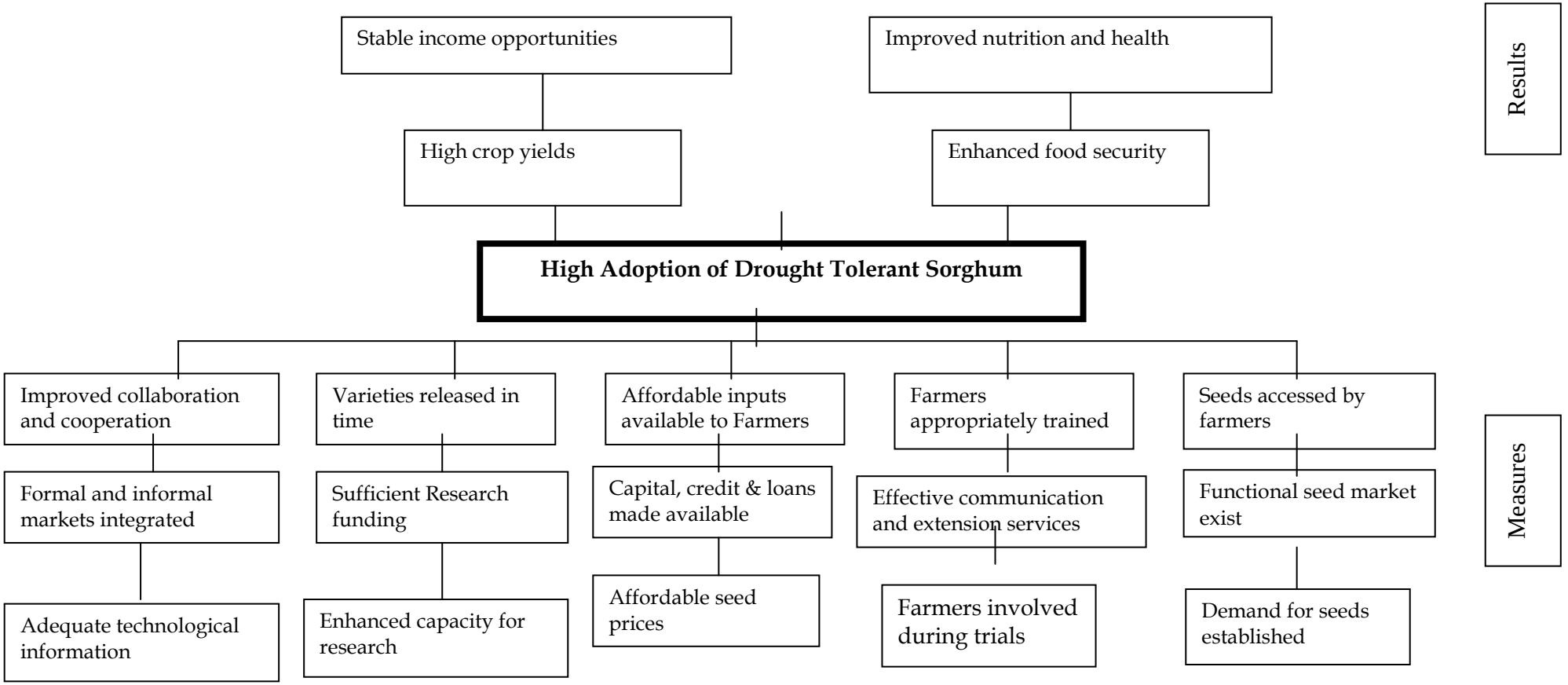
Annex 1.3A: Objective Tree for Surface Runoff Water Harvesting Technology



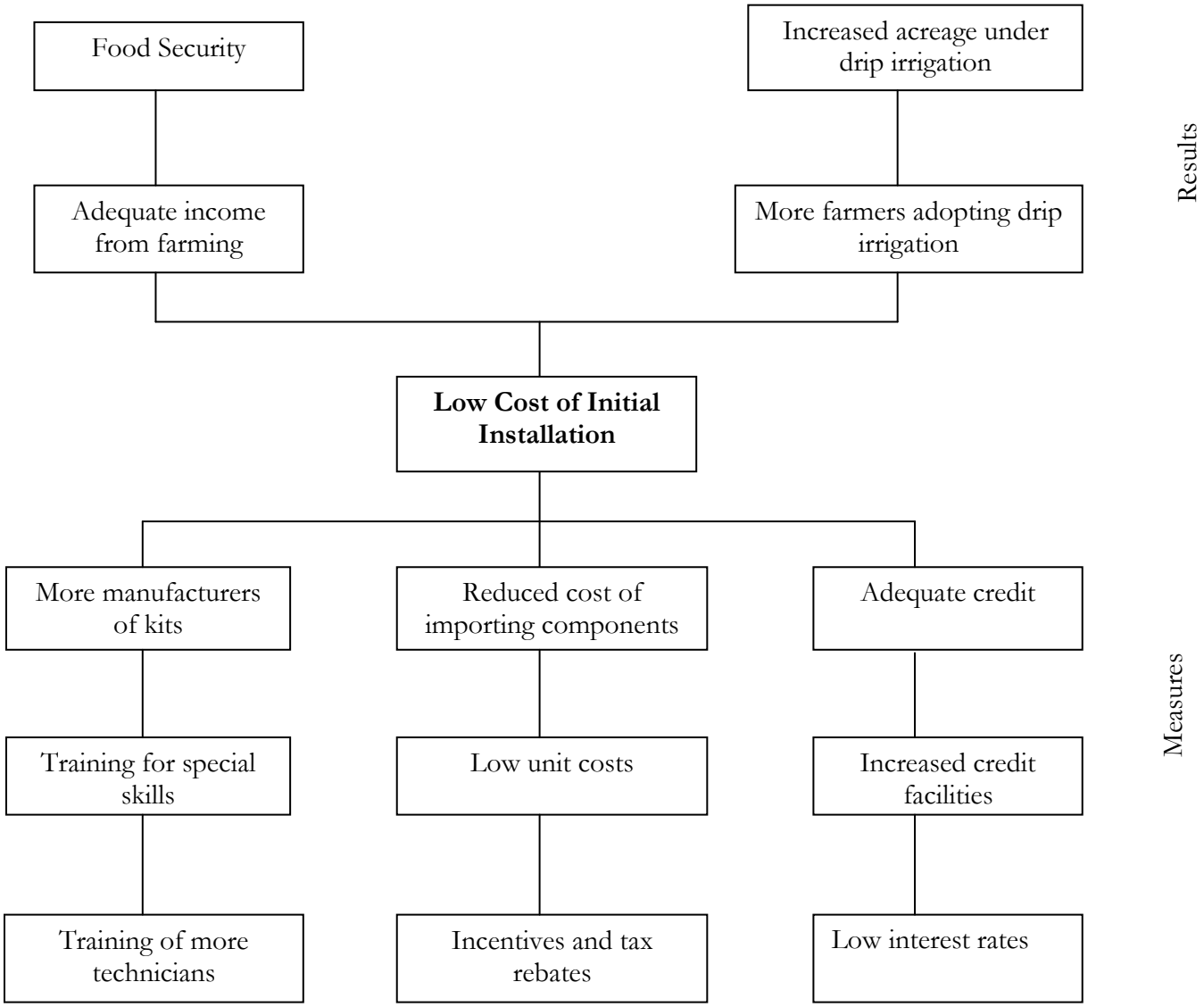
Annex 1.3C: Objective Tree Roof Rainwater Harvesting Technology



Annex 1.3D: Objective Tree for Drought Tolerant Sorghum



Annex 1.3E: Objective Tree for Economic and Financial Measures for Drip Irrigation Technology



ANNEX 2: LIST OF STAKEHOLDERS INVOLVED AND THEIR CONTACTS

Annex 2.1: List of Stakeholders and their Institutions and Contacts

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32.	Peter Njuru	PTC	0724147913	njurupg@yahoo.com

ANNEX 3: POLICY FACTSHEETS

Annex 3A: National Water Harvesting and Storage Management Policy

POLICY:	National Water Harvesting And Storage Management Policy
Name of Field:	Water
Date Effective:	May 2010
Date Ended:	Ongoing
Unit:	Water Resources and Irrigation
Country:	Kenya
Year:	2012
Policy Status:	Under review
Agency:	Ministry of Water and Irrigation
Funding:	GoK
Related Policies:	Vision 2030; Agriculture Policy
Stated Objective:	The overall policy goal, in line with Vision 2030, is to sustainably facilitate the expansion of water harvesting, storage and development of flood capacity to contribute to wealth and employment creation, food security and poverty reduction for national prosperity.
Policy Type:	Water Resources
Policy Target:	Communities, Development partners, NGOs, PPPs, and other stakeholders
URL:	www.water.go.ke
Description:	The policy objectives include to provide a framework for expansion of infrastructure for national water storage capacity from the current 124 Mm3 to 4.5 Bm3 to ensure an increase in per capita storage from 5.3m3 to 16m3 over the next ten years; To improve participation in planning, financing and investment by communities, development partners, NGOs, PPPs, and other stakeholders' contributions; To create an enabling environment for the participation of farmers and/or land owners, water user groups, and all water sector stakeholders in planning, implementation and management of water harvesting, storage and flood infrastructure; To enhance flood mitigation preparedness in affected areas; To build human resource capacity to enhance innovation, research, science and technology, adoption and management of water harvesting and storage systems and flood control structures; To enhance stakeholders-driven multi-sectoral approach to sustainable water harvesting and storage systems and flood control structures, as well as expansion and protection of water catchment areas; To ensure integrated coordination of stakeholder activities for development of water harvesting, storage and flood control infrastructure; and to establish responsive institutional, legal, and regulatory framework for water harvesting, storage and flood control.

Annex 3B: Agriculture Sector: Strategy for Revitalizing Agriculture: 2004-2014

POLICY:	Strategy for Revitalizing Agriculture: 2004-2014
Name of Field:	Agriculture
Date Effective:	February 2005
Date Ended:	Ongoing
Unit:	Agriculture and Food Security
Country:	Kenya
Year:	2012
Policy Status:	On going
Agency:	Ministry of Agriculture
Funding:	GoK
Related Policies:	Vision 2030; Agriculture Policy, National Arid and Semi-Arid Policy, Water and Irrigation, Draft Irrigation Policy, Environment Policy, National Climate Change Response Strategy
Stated Objective:	The overall policy goal, in line with Vision 2030, is to sustainably facilitate the expansion of water harvesting, storage and development of flood capacity to contribute to wealth and employment creation, food security and poverty reduction for national prosperity.
Policy Type:	Agriculture and Irrigation
Policy Target:	Farming community, cooperatives, Policy makers in various related Ministries and organizations, Development partners, NGOs, PPPs, and other stakeholders
URL:	www.agriculture.go.ke
Description:	The Strategy aims at transforming the agricultural sector into a profitable economic activity that is capable of attracting private investment and provides gainful employment with an ultimate goal to ensure food security. Key activities in the strategy include revision of the regulatory and legal framework in agriculture in order to enhance private sector participation and create an enabling environment for enhanced trade; promotion of research and technology development including irrigation and drought resistant crops;, reforming the extension services; establishment and development of a market based agricultural credit and inputs system and promotion of domestic processing of agricultural produce in order to increase opportunities for value adding and create employment. Some of the technologies

ANNEX 4: WORKING GROUP REPORT FOR ADAPTATION HELD ON 29TH NOVEMBER, 2012 AND LIST OF PARTICIPANTS

Members of Adaptation Working Group

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TOR FOR BARRIER ANALYSIS AND TECHNOLOGY ACTION PLAN FOR ADAPTATION TECHNOLOGIES

1. The Consultants and Stakeholders identified some barriers and categorized them as shown in the report.
   - Review both the barriers and categorized barriers and identify omissions and address them.
2. The same was done for measures – Are these measures sufficient for the absorption and diffusion of the identified technologies? Add more measures, where there is an emission.
3. For each Technology identify the main players who can positively influence the absorption and diffusion of the technologies
4. Four Draft Action Plans for the transfer and diffusion of the technologies have been prepared. Review each action plan, deleting the measures which are irrelevant and suggest more actions where necessary.
5. With reference to the Action Plans (including your additions) suggest four to five bankable project ideas for each technology which can be utilized to prepare project proposals for the implementation of each technology (be visionary)

REPORT OF THE WORKING GROUP

1. WATER SECTOR

A: SURFACE RUN OFF

TOR 1: Identify Omissions in the Identified Barriers for Adaptation Technologies

1. Inadequate Knowledge/Technical Expertise
2. Topography of an area
3. Geology of an area
4. Introduce a category on physical features
5. Implementation of relevant policies
6. Information and Awareness

Information and Awareness also a key barrier to Technology uptake

TOR 2: Appraise the Adequacy of The Proposed Measures on Diffusion and Absorption And Address Any Inadequacy

The additions proposed are:

1. Partnership with Private Sector
2. Encourage Community Involvement
3. Creation of a specific fund to take care of water harvesting
4. Introduce Water harvesting Technologies Loans

TOR 3: Identify Main Players Who Can Positively Influence Diffusion and Absorption of the Technologies

1. WRMA
2. WRUAs
3. Ministry of Planning
4. International NGOs
5. National Council for Research and Technology
6. Identify the key player on Awareness Creation
7. Multisectoral approach

TOR 4: Review Action Plan deleting the measures which are irrelevant and suggest More Actions

1. VAT Waiver – The figure of 40 M IS not indicative.
2. Appropriate Subsidies
3. Low interest rates – Include Private Sector
4. Community land in private land –

- Repossessing land is a hard exercise. Drop the word illegal
- Explore possibility of legal acquisition
- Involve communities in acquiring appropriate land for surface run off harvesting

- Include the Land commission

B: RAIN WATER HARVESTING

TOR 1: Identify Omissions in the Identified Barriers

1. Inaccessibility of materials eg. Water Gutters
2. Poor Governance
3. Lack of access to credit

TOR 2: Identify Omissions in the prioritised Barriers

1. Lack of credit should be included

TOR 3: Identify Omissions in the Measures Proposed

2. Promote construction of special structures for water harvesting
3. Include Tax waiver
4. Operationalisation of policy : Inadequate political good will is the risk
5. Encourage competition: What is the measure?
6. Include Promote use of local materials
7. Include/Promote use appropriate technology

2. AGRICULTURAL SECTOR –

A. DROUGHT TOLERANT SORGHUM

TOR 1: Identify Omissions in the Identified Barriers for drought tolerant Sorghum Variety technology uptake

1. Inadequate awareness

TOR 2: Identify Omissions in the Identified prioritised Barriers for drought tolerant Sorghum Variety technology uptake

1. Include inadequate awareness
2. Inefficient seed production distribution and delivery system
3. Popularise sorghum as an important food crop – various uses of sorghum

TOR 3: Identify Measures for overcoming barriers

1. Drop the measure on human labour and draught animals – its not a challenge

TOR 4: Review Action Plan deleting the measures which are irrelevant and suggest More Actions

1. Give more details on the costing – 2Billion
2. All indicators to be made smart
3. Integrate uptake of this crop in the current policy formulation in the agricultural sector
4. Intensify PPPP Coordination
5. Specify the government ministries
6. Relook at the costings

7. Move item on technological information in measure no. 5
8. Indicators should be smartened
9. Increase funding to intensify research SO THAT WE acquire improved varieties
10. Indicators to be smartened

B. DRIP IRRIGATION

TOR 1: Identify Omissions in the Identified Barriers for DRIP IRRIGATION uptake

1. Cost of installation
2. Trained labour
3. Technical gaps in the drip irrigation technology
4. Inadequate credit
5. Extension services
6. Lack of ownership
7. High maintenance costs
8. Inaccessibility to credit facilities

TOR 2: Identify Omissions in the Identified prioritised Barriers for DRIP IRRIGATION uptake

1. Cost of installation
2. Trained labour
3. Technical gaps in the drip irrigation technology
4. Inadequate credit
5. Extension services
6. Lack of ownership
7. High maintenance costs
8. Inaccessibility to credit facilities

TOR 3: Identify Measures for overcoming barriers

1. Include Tax Waiver and rebates on equipments
2. Community Participation
3. PPPP

TOR 4: Review Action Plan deleting the measures which are irrelevant and suggest More Actions

1. Include units and components in measure no. 1
2. Check on the costings
3. Establishment of low interest drip irrigation loan
4. Introduce duty waiver
5. Merge no3 and 1
6. Remove the second measure on base lending rate
7. Remove partners willing to cooperate as a risk

3. Suggest four to five bankable project ideas for each Technology.

1. Awareness creation and Research Enhancement
2. Capacity Building projects for all technologies – can combine 2 technologies.