Government of Pakistan

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION

BARRIER ANALYSIS AND ENABLING FRAMEWORK

DECEMBER 2016

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BARRIER ANALYSIS AND ENABLING FRAMEWORK (BAEF) FOR CLIMATE CHANGE ADAPTATION TECHNOLOGIES

REPORT II

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Foreword

Pakistan’s high vulnerability to adverse impacts of climate change, in particular extreme climatic events, means that the country is in dire need of innovative adaptation technologies to lessen damage to life, property, natural eco-systems and economy of the country.

I am confident that the Technology Needs Assessment (TNA) project initiated by the Ministry of Climate Change in partnership with the United Nations Environment Program (UNEP), Climate Technology Centre & Network (CTCN) and Technical University of Denmark (DTU) will play an effective role in increasing resilience against climate change vulnerabilities through transfer and diffusion of prioritized technologies in agriculture and water sectors and removing barriers in their adoption.

I am pleased to note that the entire process to set preliminary targets for transfer and diffusion of technologies, identify barriers and suggest an enabling framework for overcoming the barriers in this phase-II of the TNA project has been country-driven. Being highly consultative, it involved a number of stakeholders and experts from the government, private sector and civil society. I strongly believe that the implementation of adaptation technologies prioritized in TNA Adaptation Report phase-I will help the country in building resilience to the impacts of climate change.

I would like to thank the members of the TNA National Team and my colleagues in the Ministry and experts of the Adaptation Working Group for their invaluable contributions to the preparation of this Report.

I also thankfully acknowledge the contributions of Dr. Qamar-uz-Zaman Chaudhry, Lead-Expert and other experts of Global Environment Facility (GEF), United Nations Environment Program (UNEP), UNEP-DTU Partnership and the Asian Institute for Technology (AIT) for their constant support and guidance for implementation of the TNA project.

(Zahid Hamid)
Federal Minister
Ministry of Climate Change
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PREFACE

Climate change is one of the most daunting threats that humankind faces today. For Pakistan, it is a colossal challenge to achieve its sustainable development goals without compromising on its socio-economic development needs. Due to its exposure to the recurrent episodes of drought, flooding, heatwaves, and glacial lake outburst floods in the past few decades, the country is consistently ranked by multiple climate change vulnerability indices as being one of the most vulnerable to the impacts of climate change.

Building resilience and adaptation to climate change is becoming indispensible for Pakistan. Fortunately, environmentally sound technologies are gaining a high priority in sustainable development policy dialogue and implementing frameworks. Technology Needs Assessment (TNA) is one of the critical steps towards identifying and assessing climate change adaptation challenges for Pakistan in order to align its adaptation needs and opportunities with goals and objectives of its sustainable development. As a climate change adaptation tool this TNA would help the country identify the needs for new equipment, techniques, practical knowledge and skills, which are necessary to successfully pursue climate resilient development.

This report on 'Barrier Analysis & Enabling Framework' of technology needs assessment is the part of TNA project outputs, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Program (UNEP) and the UNEP DTU Partnership in collaboration with Asian Institute of Technology (AIT). The TNA process in Pakistan is being undertaken since June 2015, with the Ministry of Climate Change in lead.

This report identifies and provides a list of barriers and enabling measures for adoption of prioritized adaptation technologies in climate vulnerable water and agriculture sectors of Pakistan. The report is the result of a fully country driven, participatory process. Views and information in this report is the product of extensive discussions with technology expert team and stakeholders.

I extend my appreciation to all stakeholders for their constant support and valuable comments throughout the development of this report. I hope that this assessment will go a long way in mitigating the country's climate change vulnerabilities.

(Syed Abu Ahmad Akif)
Federal Secretary
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ABBREVIATIONS

EPD	Environmental Protection Department
FSC&RD	Federal Seed Certification and Registration Department
GOP	Government of Pakistan
GEF	Global Environment Facility
GWRF	Groundwater Regulation Framework
HEIS	High efficiency irrigation system
IBIS	Indus Basin Irrigation System
LID	Low impact development
PCRWR	Pakistan Council of Research in Water Resources
PIDA	Punjab Irrigation and Drainage Authority
PHED	Public Health Engineering Department
PMD	Pakistan Meteorological Department
PSDP	Public sector development program
RWH	Rain water harvesting
R & D	Research and development
SCARP	Salinity Control and Reclamation Program
TNA	Technology Needs Assessment
UNEP	United Nation Environment Program
UNFCCC	UN Framework Convention on Climate Change
WAPDA	Water and Power Development Authority
WASA	Water and Sanitation Authority
WB	World Bank

WEIGHTS AND MEASURES

ha	hectare
km^2	square kilometer
m^3/yr	cubic meters per year
MAF	million acre foot
Mh	million hectares
MA	million acres

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EXECUTIVE SUMMARY

Technology Needs Assessment (TNA) is a country-driven participatory process aiming to identify and prioritize environmentally sound technologies in the sectors of water and agriculture in Pakistan. The purpose is to increase the coping capacity of individuals and communities to better prepare for the potential negative consequences of the impacts of climate change. During the first phase of TNA, through stakeholder's consultative meetings, Pakistan selected and prioritized six climate change adaptation technologies in water and agriculture sectors. The technologies prioritized in the water sector included rainwater harvesting (surface runoff), groundwater recharge and urban stormwater management. In agriculture sector, the technologies included high efficiency irrigation systems for irrigated and rainfed areas, drought tolerant crop varieties, and climate monitoring and forecasting early-warning system.

This barrier analysis and enabling framework (BAEF) report is 2nd in the TNA series, which is the output of key stakeholder meetings, and expert opinion and review by the Adaptation Expert Group that serves as a main institutional entity in Pakistan to guide and monitor the development of the whole TNA process. The BAEF process followed certain crucial steps which is given below:

1. Identify preliminary targets for the technology development and diffusion at sectoral scales.
2. Describe technology properties and its potential adaptation benefits, categorize technology either as a market or a public good and briefly elaborate on its current status in the country.
3. Identify important barriers to the diffusion of technologies through expert opinion, literature review and brainstorming sessions with important stakeholders; development of barrier analysis tools including problem and objective trees and market mapping tool; categorize the barriers into financial and non-financial barriers.
4. Identify measures for overcoming the barriers, possible linkage between different technology barriers within a sector and outlines a technology enabling framework that would help to overcome barriers and create a supporting environment for the development and successful diffusion of the selected technologies.

The technology barrier analysis process identified crucial economic and financial barriers and non-financial barriers. The latter was further broken down into many other sub-barrier categories including: policy, legal and regulatory, institutional and organizational capacity, technical, information and awareness, social, cultural and bahvioural and market imperfection.

Technology barriers and measures in water sector

The adaptation technologies identified for water sector, namely rainwater harvesting, groundwater recharge and urban stormwater management, were categorized as a public good which requires public sector support for its deployment and successful replication at different implementation scales. The review of barriers recognized that economic and financial barriers were associated with high initial cost of development of the technologies which were due to the lack of incentives like subsidies or soft loans offered to individuals or communities, high cost of construction material and available technical expertise, and labor at the local levels. The non-financial barriers included absence of or weak regulatory measures, lack of integrated and coordinated approach towards the management and monitoring of technologies by relevant line departments, absence of a strong resource management authority, weak institutional capacity in the form of low budget or funding, poor technical strength, and lack of information and awareness on potential benefits of technologies in the face of climate change.

The barriers in water sector can be overcome by putting in place appropriate financial and technical resources for the development and diffusion of these technologies at local level. The non-financial barriers can be tackled through devising strong regulatory framework that would be supported by cross-sectoral policies and strategies, promoting collaborative research among R&D institutions.

Technology barriers and measures in agriculture sector

For the agriculture sector of Pakistan, three important adaptation technologies identified were drip and sprinkler irrigation systems, drought tolerant crop varieties and climate monitoring and information-early warning system. During the consultation processes with various stakeholder groups, high initial cost of installation and maintenance for drip and sprinkler systems and early warning system were identified as the key financial barrier in the wide spread adoption of technology by the farmers and communities. The main element of this barrier identified was the lack of trained technical staff locally available for the design, installation and maintenance of the technologies, high rate of taxes and custom duty imposed on import of technology parts, and a small, underdeveloped market for technology importers and suppliers in the country.

In case of drought tolerant crop varieties, the obstacles recognized were lack of strong policy support, conflicting and controversial amendments in the existing seed policies, Exclusion of private sector, by law, from the research and creation phase of hybrid seeds, inadequate R&D facilities, limited number of seed quality testing centers, and seed promotion and sale points. Also, it was recognized that hybrid seeds holds a very small market share as most of the farmers avoid using these seeds due to uncertainty about their performance under the field situations.

To help in achieving diffusion of these three technologies in the country, a number of enabling measures have been suggested, for example, allocation of dedicated development budget, access to appropriate subsidy, grants, or soft loans to the farmers, building and strengthening policy and regulatory environment, technical training and capacity building of relevant field staff and institutions among a long list of enabling measures.

CHAPTER-1 BACKGROUND & INTRODUCTION

1.1. Background

Technology Needs Assessment (TNA) is one of the foremost critical steps towards identifying and assessing climate change adaptation challenges within the United Nations Framework Convention on Climate Change's (UNFCCC) technology mechanism on technology development and transfer. For a climate-vulnerable country such as Pakistan, TNA has an added significance for aligning its adaptation needs and opportunities with goals and objectives of its sustainable development programs.

In Pakistan, the project on Technology Needs Assessment (TNA) was initiated in June 2015 in collaboration with UNEP-DTU Partnership, Asian Institute of Technology (AIT) and Climate Technology Centre & Network (CTCN) as a part of the Switch Asia regional program.

The purpose of the TNA project is to assist Pakistan in identification of its priority adaptation sectors, followed by prioritization of technologies in these sectors. This will form the basis for development of environmentally sound technology projects and programs to facilitate transfer and diffusion of these priority technologies in accordance with Article 4.5 of UNFCCC. The main objectives of the project are to:

1. Identify and prioritize, through country driven participatory processes, the technologies that can contribute to mitigation and adaptation goals of the participating countries while meeting their national sustainable development goals and priorities;
2. Identify barriers hindering the acquisition, deployment and diffusion of prioritized technologies; and
3. Develop Technology Action Plans (TAP) specifying activities, and enabling framework to overcome the barriers and facilitate the transfer, adoption and diffusion of selected technologies in the priority areas with national relevance.

This TNA project also aims to build capacity of Pakistan to effectively meet the obligations under the UNFCCC to adapt and protect livelihoods of the communities, and to reduce vulnerability of priority sectors exposed to the adverse impacts of climate change.

TNA project's implementation is phased out in three stages as indicated in Figure 1.1. In the first stage two sectors—water resources and agriculture—were identified as economically important and vulnerable sectors to climate change. Later, after extensive consultation with experts and other stakeholders, following technologies were prioritized in these two sectors.

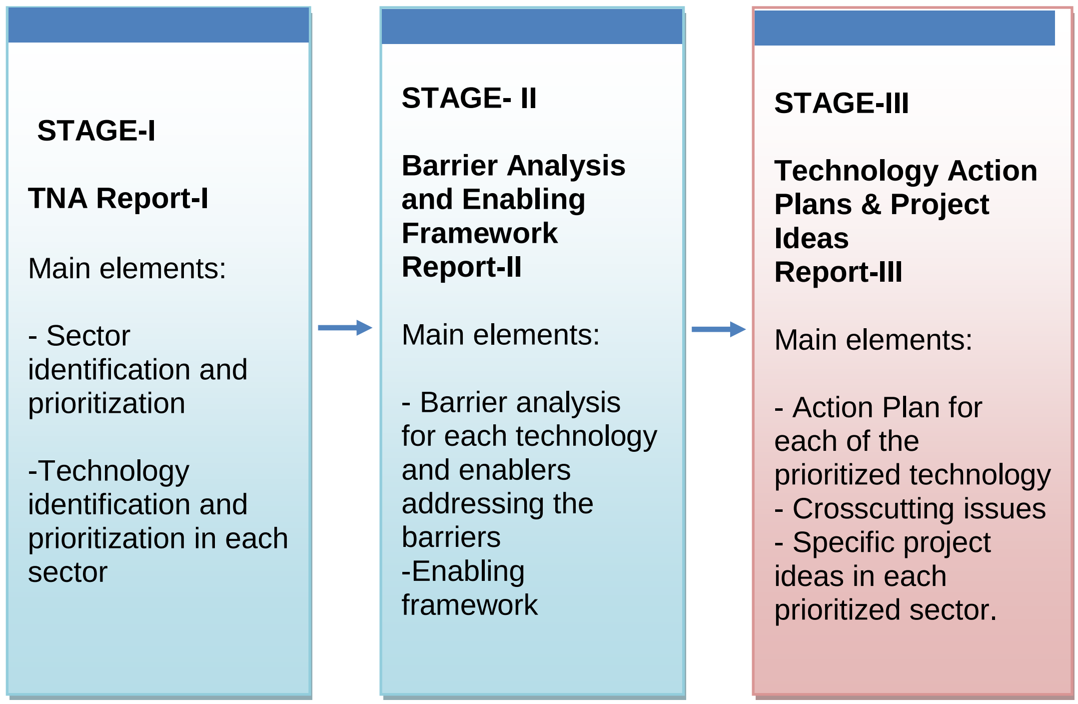
The prioritized technologies identified through TNA process for water sector of Pakistan are:

1. Surface rainwater harvesting
2. Groundwater recharge
3. Urban stormwater management

Likewise, priority adaptation technologies identified for agriculture sector of Pakistan are:

1. High efficiency irrigation systems for irrigated and rain-fed areas
2. Drought tolerant crop varieties
3. Climate monitoring and forecasting—early warning system

Figure: 1.1 Different stages of TNA project implementation followed in Pakistan



Source: Adapted from UNEP Riso Centre Flyer. March, 2014: What are the technology needs of developing countries.

1.2 Methodology

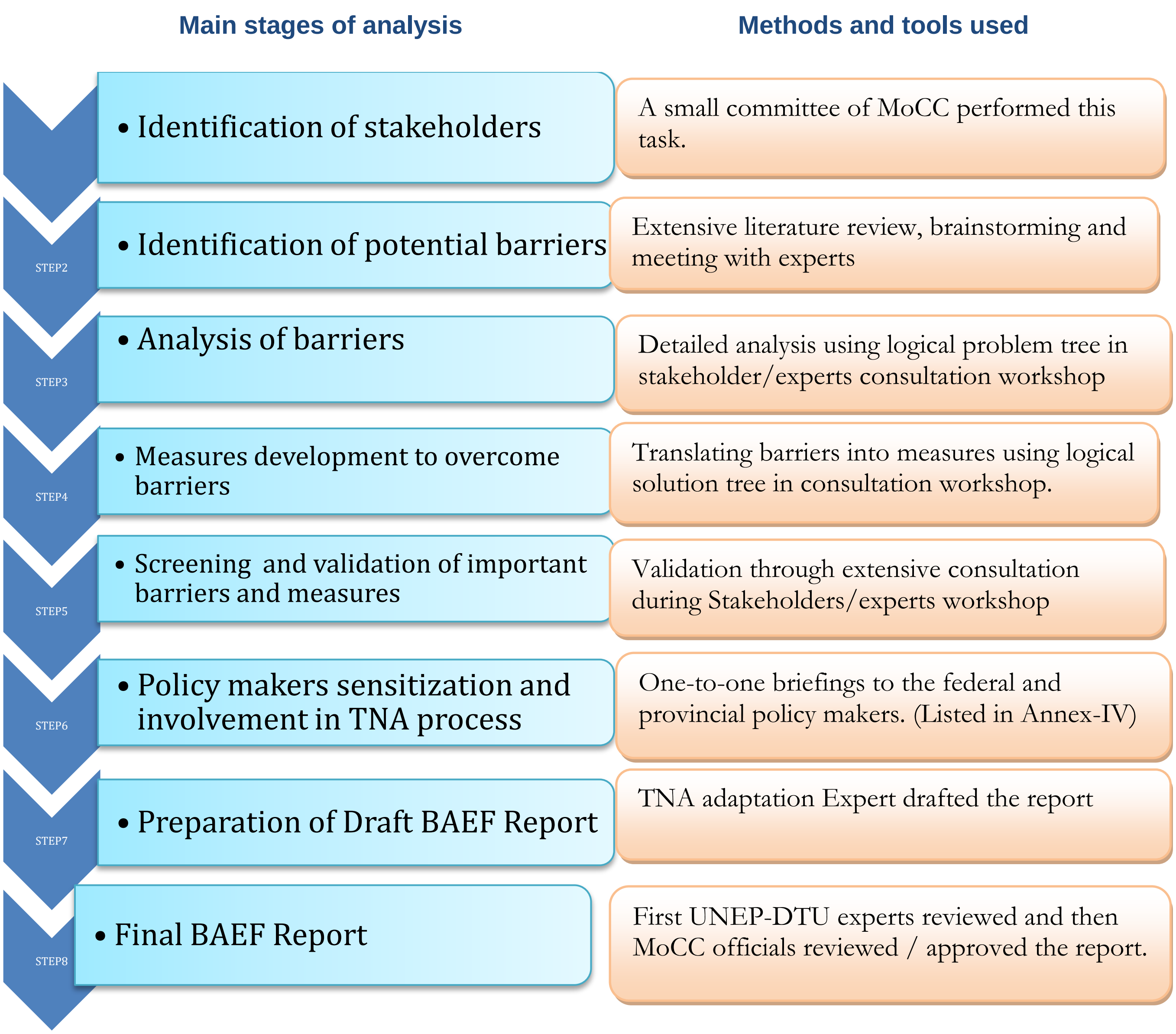
This report is the output of the second phase of the TNA process that covers barrier analysis on transfer, and diffusion of the prioritized adaptation technologies in the selected sectors. In addition, the enabling framework and measures for overcoming barriers are discussed and addressed. For each of the six technologies identified for the water and agriculture sectors, a systematic approach of describing and analyzing technology barriers, and identification of measures and enabling framework was adopted. The process included:

1. Identify preliminary targets for the technology development and diffusion at sectoral scale.
2. Describe technology properties and its potential adaptation benefits, categorize technology either as a market or a public good and briefly elaborate on its current status in the country.
3. Identify measures for overcoming the barriers, possible linkage between different technology barriers within a sector and outline a technology enabling framework that

would help to overcome barriers and create a supporting environment for the development and successful diffusion of the selected technologies.

Brief account of methodology followed in this second phase of TNA process, “Barrier Analysis and Enabling Framework”, is given in Figure.1.2 and explained as under:

Figure: 1.2 Methodology followed in conducting TNA barrier analysis and enabling framework



1. Ministry of Climate Change initially helped through a small search committee in identification and involvement of wide range of stakeholders which include experts from water and agriculture sectors, officials from relevant ministries and departments, farmers, representatives of NGOs, representatives of suppliers and manufacturers, and officials of some international donor agencies in consultation process. A list of these stakeholders along with their contacts is given at Annex-II.
2. Literature review: As a first step a team of experts listed down potential economic and financial and non-financial barriers to the diffusion of each prioritized technology in Pakistan through expert opinion and extensive literature review. Later non-financial barrier category was further broken down into many other barrier categories including policy, legal and regulatory, institutional and organizational capacity, technical, information and awareness etc.
3. Screening and short listing of key barriers, particularly where the potential barriers list was long, to select most essential ones through expanded stakeholders consultation process using 'Logical Problem Analysis' through preparation of 'Problem-Solution Trees and 'Market Mapping' tools for relevant technologies. Additionally, interviews with farmer, suppliers and manufacturers were also used to firm up the key barriers. Further efforts were mainly focused on creating and developing essential measures to overcome the key barriers and in developing enabling framework for development and diffusion of priority climate change technologies in selected sectors to ensure that Pakistan follow the path of climate resilient development.
4. Ensured the full use of TNA barrier analysis guidelines (e.g. Boldt et al., 2012), resources, information and templates provided by specialists of UNEP-DTU Partnership during and after regional capacity building workshops.
5. Ensured that the TNA outcomes are closely aligned with country's sustainable needs.
6. We tried our best to ensure that the whole process of Pakistan's TNA, particularly the technology barrier identification and analysis largely remained country driven and participatory in nature.

1.2.1 Sensitization of policy makers

For ensuring the political ownership of TNA process in the country and to ensure the easy follow up later in the implementation of TNA prioritized technologies, special one on one detailed meetings and briefing sessions were arranged with relevant federal and provincial policy makers (List of policy makers involved and sensitized in this process is given at Annex-IV).

1.2.2 Third phase of TAP and project ideas

After the completion of above two TNA phases, the work on the final Phase-III Technology Action Plan (TAP) and Project Ideas' will be initiated in accordance with the UNEP DTU guidelines.

CHAPTER-2 WATER SECTOR

2.1 Preliminary Targets for Technology Transfer and Diffusion in Water Sector

The existing water resources in Pakistan are under substantial stress due to rapidly growing population size, fast rate of urbanization and subsequent unplanned land use changes. The per capita surface water availability stood at 1,036 cubic meters per year (m^3/yr) in 2012 and is estimated to drop to about 860 m^3 by year 2025 representing acute water shortage condition (WAPDA, 2014). The water sector in Pakistan carries a multi-user profile that meets the demands of water for agriculture and industry sectors, and various other domestic purposes. The irrigated agriculture sector is the largest user of water with the irrigated land base at 53.60 percent of the total cultivable area of 85.81 million acres (ma). The agriculture based economy demands for a sustainable management and conservation of existing and potential water resources in order to achieve a climate resilient growth in the face of climate change which, according to recent climate models projections for the country, indicate increasing uncertainty in temporal and spatial frequency of rainfall across the country (Pakistan Meteorological Department, 2015).

Technological development and innovation could play a critical role to achieve food and water security targets of the country considering uncertain climatic conditions cast by climate change by the end of this century. Pakistan Vision 2025 as a focal policy roadmap document for the country stresses on investing in proven methods and technologies to minimize wastage of water and to promote its conservation in order to achieve goal of water security by the year 2025 (GoP, 2013).

During the first phase of Technology Needs Assessment (TNA) in the country, with consensus from CC Adaptation Expert Working Group members and other important stakeholders, a set of six adaptation technologies were identified and finally three technologies were prioritized through multi-criteria assessment process based on their importance in reducing vulnerability of communities and individuals to the severe impacts of climate change. The prioritized technologies were:

1. Rainwater harvesting (surface run-off)
2. Groundwater (aquifer) recharge
3. Urban stormwater management

Pakistan has experience with all of the above three technologies which are available and in use at various levels, but with certain issues and challenges related to their easy deployment and quick spread. To ensure sustainability of these technologies, the TNA project during this second phase of barrier analysis and enabling framework sets some preliminary targets for the transfer and diffusion of these above mentioned technologies in water sector which are as below:

1. To construct 1000 community and public-run surface rainwater harvesting reservoirs each with a capacity between 15000- 50,000 m^3 by 2025
2. Modernize and upgrade urban stormwater drainage infrastructures of 10 major towns by 2022
3. Introduce and set standards for low impact development (LID) infrastructure in 10 major cities/towns as an approach for urban stormwater management by 2022

4. Construct groundwater recharge systems in Baluchistan and in other dry areas to improve ground (aquifer) water situation

To achieve these preliminary targets of transfer and diffusion of technologies in water sector, the relevant stakeholders and players have to get involved and play active role in the successful implementation of technologies. The important stakeholders include water sector policy makers, experts, relevant ministries of Food Security and Research, Water and Power, Climate Change and its connecting departments at federal and counterpart ministries and departments at provincial level besides National and Provincial Commission on Status of Women (as women and girls being the important stakeholders in this debate). Other players include technology dealers, technicians, and experts in water and irrigation sector. The implementers include NGOs and CBOs focusing on water issues, advocacy groups of women, youth and community leaders active at local and national levels.

2.2. Barrier Analysis and Possible Enabling Measures for Surface Rainwater Harvesting Technology

2.2.1 General description of surface rainwater harvesting technology

In many water-stressed areas, small and medium scale runoff collection infrastructure can contribute greatly to the availability of freshwater for human consumption. This is particularly true in arid and semi-arid regions where the little rainfall received is usually very intense and often seasonal (Elliot et al., 2011). In such situations, water runoff can be abundant for brief periods and non-existent rest of the year, as such the use of this technology can be helpful to ensure that adequate water is available during the dry season.

Rainwater harvesting from ground surfaces is basically a collection, diversion and storing of rainwater to supplement other formal setup of water collection and distribution system for a community for its later use during dry periods. Rainwater collected from ground surface is typically used for non-potable purposes, including irrigation, livestock and general domestic use.

The technology addresses two broad categories for rainwater harvesting; a) collecting rainfall from ground surfaces utilizing ‘micro-catchment’ to divert or slow runoff for storage purposes and; b) floodwater harvesting which is collecting flows from a river, stream, or other natural watercourses. This technique includes an earthen or other structure to dam the watercourse and form a small reservoir.

The technology offers many benefits during seasonal dry periods and droughts especially in the face of climate change that is projected to increase the variability and intensity of rainfall in the long run. Rainwater collection helps to stabilize the depleting groundwater level while the storage infrastructure can reduce land erosion and flood inflow to major rivers. It acts as a convenient source of stored water that could enhance agricultural productivity, decrease travel time for rural women to remote water resources that would result in better health and time for social activities.

2.2.1.1 Technology status in Pakistan

Surface runoff rainwater harvesting (RWH) is widely practiced in arid and semi-arid areas of Pakistan and specifically in rainfed areas from the last many decades as an important measure to control desertification in dry land areas while ensuring water availability for irrigation, livestock and domestic purposes to the concerned communities. PCRWR (2014), as the focal scientific council on water research in the country, reports construction of around 185 rainwater harvesting structures that includes earthen ponds, check and retention dams, dikes, and ditches, in the provinces of Balochistan and Sindh (PCRWR, 2014). However, the numbers of RWH structures are insufficient to meet the growing demand of water by burgeoning population even in the presence of water storage structures that directly depends on the Indus river system. According to WAPDA (2014), there are presently three major storage reservoirs (Tarbela, Mangla, and Chasma) in the country and 32 small and medium dams are approved for construction mainly for hydropower generation and irrigation purposes. The current water storage capacity of water reservoirs is much lower than required as three major reservoirs have lost 28 percent of their capacity due to siltation (WAPDA, 2014).

Pakistan has the world's largest indigenous rainwater harvesting system commonly called as the spate irrigation system. The system irrigates around 0.3 million hectare (mha) of cultivated land in the country while the potential area to bring under this system is estimated to be around 6.935 mha (Ahmed and Steenbergen, 2010). The system thrives on flood water generated from hill-torrents which is diverted to the command area through natural, earthen, and weir-regulated structures. In some areas of Pakistan, where the spate irrigation system is technically advanced, the high flow of floodwater is regulated through diverting it to water storage tanks through well-established system of canal networks. The stored water is distributed out to the water users operating inside the command area as per agreed water entitlements between the government and water-use association.

2.2.1.2. Technology category and market characteristics

The surface rainwater harvesting technology can be categorized as a non-market public good when established at a community level and requires state level support to develop and manage the system. The technology option in this report is community or State-managed surface rainwater harvesting system and thus considered as a non-market public good.

2.2.2 Identification of barriers for surface rainwater harvesting technology

Preliminary barrier Identification:

As an initial step, a desk study of important policy papers and other relevant documents was conducted, supplemented by interviews with experts, key stakeholders and workshop brainstorming. A list of potential barriers to the development, transfer and diffusion of RWH technology, in Pakistan was prepared and categorized into two broad main categories of economic and financial barriers, and non-financial barriers. The non-financial barriers were further segregated down into policy, legal and regulatory barriers, technical barriers, institutional and organizational capacity barriers, social, cultural and behavioural barriers, information and awareness barriers. In random order, the identified barriers included the following:

1- High cost of capital
2- Poor technology design
3- Lack of approved water and agriculture policies
4- Insufficient legal and regulatory framework for rainwater harvesting systems
5- Poor inter-departmental interaction and coordination
6- Lack of incentives for community ownership and participation
7- Uncertain frequency of rain and irregular water flows in water conveyance systems
8- Frequent siltation of water storage structures
9- Low preference to research and training

10- Inadequate information on societal benefits of technology
11- Lack of awareness among general masses
12- Limited institutional capacity and management skills of government departments
13- Inequitable distribution of the harvested rainwater among water users
14- Lack of monitoring of floodwater flows
15- Strong focus on the Indus Basin Irrigation System compared to other alternative irrigation systems
16- Conflicted land tenure
17- Health issues arising from water-borne vectors

Screening and prioritization of identified barriers
After the compilation of the list, it was presented to the participants of the technology barrier analysis workshop to screen the list and to identify the essential barriers—that need to be addressed for technology transfer and diffusion to occur—as well as the non-essential barriers that were to be ignored (For the list of workshop participants, see Annex II). The barrier analysis tools such as starter problem and solution trees were used to expedite process of prioritization of barriers (see Annex-1.3-1.4 for the analysis tools). Through consensus among participants, the final list of barriers were achieved and discussed below in brief.

2.2.2.1 Economic and financial barriers

a. As the technology is identified as a public good, so its development, operation and maintenance etc. thus far remains under the public sector domain. Having an easy access to finance for a government entity, such as a ministry dealing with rainwater harvesting technology, however, generally proves difficult due to insufficient resources such as low program budget compared to high cost of feasibility studies including cost-benefit analysis, financial analysis, or environmental impact assessments to gather sufficient information for a sound decision-making purposes. Additionally, reconstruction of head works or water conveyance structures after each flood also adds to the challenge of keeping the management budget at low.
b. In case of donor funding, where international funding institutions such as the World Bank are financing for such projects, there is a lingering amount of uncertainty on the continuity and success of project once the project is over and most of the project staff is either terminated or re-assigned to other projects. This causes technology ownership issues at the community level.
c. Due to an inherent risk of low rainfall or high floods associated with rainwater harvesting technology, there is a high possibility of crop failures or low crop returns for the farming households that would add to the economic and financial burden of technology management.

2.2.2.2 Non-financial barriers

Policy, legal and regulatory

a. Pakistan lack approved water and agriculture policies that would otherwise provide a clear directive to the growing demands and challenges of water and agriculture sectors through a sustainable management of water resources, specifically in the face of climate change. The draft policies pay a strong attention to Indus Basin Irrigation System (IBIS) in the context of food and water security in the country. Consequently, traditional rainwater harvesting systems, specifically operating in the arid and semi-arid areas of the country, grabs marginal consideration within a policy and regulatory dialogue.

b. Poor understanding of existing water rights and rules, specifically in the indigenous rainwater harvesting systems. This creates a barrier in a good comprehension of possible impacts of external interventions on existing water distribution and maintenance rules and practices.
c. Inequitable distribution of water among water users at the community level is an important element of this aspect of barrier. It is difficult to measure water availability in the system in volumetric terms due to unpredictability of rains and place-based design of the system that currently bears no control or regulation on flow to different branch channels.
d. Limited external support to community level water managers. Wherever it is available, is mostly limited to the provision of heavy machinery such as bulldozer to the user community to repair damaged water conveyance structure after a heavy rainwater flow. One of the largest drawback of bulldozer program identified is the vacuum created in service provision when they go out of service and not replaced (Steenbergen et al., 2010)

Technical

a. Frequent siltation of rainwater storage structures is a major technical design issue. The heavy load of siltation also raises the elevation of the irrigation plots each year and thus making it increasingly difficult for the flood water to enter the plots. This diminishes the overall system efficiency.
b. High labor demand especially with some technical skill to reconstruct temporary diversion weirs and intake structures.
c. Inadequate capacity and local skills to identify the suitable rain catchments, as well as suitable sites for construction of water reservoirs
d. Weak capacity of research institutions to assist local communities in identifying the suitable technologies and suitable sites for water intake structures
e. Limited capacity of communities, especially women, both in terms of know-how and material resources to sustainably maintain and manage the technology.

Social, cultural and behavioral

a. A great variation in land tenure structures exist at the community levels with limited understanding among technology developers and practitioners. This creates a challenge for them to secure a land for the construction of water storage structures and reservoirs to manage these structures and distribute benefits equitably among water users. A conflict in land tenure may reflect complexity of the management of risk associated with the technology that increases inequalities and inequitable access to resources among various social groups and members.
b. The tradition of community-run-systems is limited, scattered and mostly neglected in the country. Therefore the involvement and participation of community members in the decision-making processes related to technology development and implementation largely remains ignored. This explains the lack of community ownership for such projects and programs.
c. General perception that the technology is suitable only for water scarce areas.

Information and awareness

a. Limited knowledge and awareness about the potential benefits of surface rainwater harvesting technology
b. Limited awareness of issues related to climate change and technological solutions

2.2.3 Identified measures

This section discusses the measures needed to overcome the barriers to the implementation of surface rainwater harvesting technology in Pakistan. The main methodology employed for the identification of appropriate measures was the development of problem and solution trees through stakeholder participation, besides the detailed analysis of current national practices in the relevant field (Annex 1.4). The series of discussions during the barrier analysis workshop led to the identification of some key measures needed to overcome and eliminate the barriers identified above.

2.2.3.1 Economic and financial measures

a. To offset the high initial cost of construction of water channels, diversions and water reservoirs, government should reduce local taxes on construction material. For a short-term, the federal government currently has exempted sales tax on brick and crushed stone for 3 years (up to 30 June, 2018) and has reduced custom duty on import of construction machinery up to 10%, yet a raise in other taxes including withholding tax on renting of machinery and equipment etc. in the long-term may outdo the benefits of these tax exemptions (Federal Board of Revenue, 2016). A uniform and stable tax policy with focus on preferred technologies in water and agriculture sectors will be an important measure to ensure food and water security in the country.
b. The federal, provincial and local annual development funds and international donors grants may be used for subsidizing the initial construction of large and medium sized reservoirs.
c. Introduce and expand social safety nets for poor households in the farm of low mark-up loans, easy access to inputs of extension services, credits, and marketing for their crops and livestock products.

2.2.3.2 Non- financial measures

The existing non-financial technology management practices are predominantly reactionary due to the limited understanding of technical, socio-economic, and institutional aspects of the technology management and diffusion. For overcoming non-financial barriers to the implementation of technology following measures need to be taken:

Policy, legal and regulatory

a. Approve and implement agriculture and water policies with support from all the key stakeholders in the society. The policies should focus on the marginalized segment of population by linking up the technology development and diffusion with poverty alleviation programs and interventions. The visibility of indigenous rainwater harvesting systems in the country may improve through supporting inclusion of indigenous knowledge in the design and transfer of the technology.
b. Create and strengthen local farmer or water user organizations that are accountable to most farmers and enforce water rights and distribution rules along with local government institutions within the accepted social structures of the concerned communities. It is important that the right to devise or modify their own rules is respected by external authorities. This allows for a high level of flexibility to adjust to unforeseen circumstances, rapid changes in legislations that provide farmer’s organizations with legal recognition and authority to practice conflict resolution mechanisms.

Technical

a. Increase financial support to relevant R&D institutions for enhancing their capacity to undertake pre-feasibility studies, including site selection before construction.
b. Ensure the availability of necessary technical (construction and maintenance) expertise at local level to assure sustainability of technology.

Information and awareness

a. Effective educational programs need to be undertaken at local level to overcome socio-cultural barriers and to raise communities awareness about advantages of technology. Ministries of Education and Climate Change at the federal and provincial levels can undertake this with the support of local NGOs.
b. Run awareness campaign on the impact of climate change on water resources by involving all the relevant stakeholders from both of the public and private sectors including water managers and users, policy and decision makers, journalists, educators, etc.

Social, cultural and behavioural

a. Understand socio-economic context in which farmers or water users operates in order to ensure sustainable improvement in the technology design and its successful transfer in the later stages. This analysis should be performed earliest at the time of design of projects with in-depth consultation with community members. This practice will help the technology developers and managers to address specific needs and requirement of different segments of community groups specifically underprivileged groups including women. This will in turn improve the ownership of technology at various stages of societal representation.

2.3. Barrier Analysis and Possible Enabling Measures for Groundwater Recharge Technology

2.3.1 General description of groundwater recharge technology

Groundwater is the world's "most mined" resource due to its on-demand accessibility and reliability. Artificial groundwater recharge is a planned activity designed to increase the natural replenishment or percolation of surface water into the ground aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction. The primary objective of this technology is to preserve or enhance groundwater resources. It also serves other beneficial purposes such as conservation or disposal of flood water, control of saltwater intrusion, storage of water to reduce pumping and piping cost and water quality improvement (Asano, 1985). The technology has also application in wastewater disposal and treatment, crop development, stream flow augmentation and prevention of land subsidence (Oaksford, 1985).

The groundwater recharge techniques are confined to areas with aquifers, so the selection of recharge method is mostly site specific and needs extensive hydro-geological study before the final selection of a potential site and a technique. This technical requirement raises a question about the cost effectiveness of a wider-scale replication of a successful recharge technique to other locations.

2.3.1.1 Groundwater governance status in Pakistan

In Pakistan, about 10 percent of the total groundwater exploitation (4 $x10^9$ m^3) is used to meet domestic and industrial requirements while the rest is utilized for the irrigation purposes

(Qureshi et al. 2009). In most populous urban areas, especially in the province of Punjab, about 90 percent of population relies on extracted groundwater for their daily domestic needs. In Balochistan's case, the size of water consumer reaches up to 40 percent and groundwater is the only steady and reliable source of water for a full year.

Groundwater resource is depleting fast in the country with degrading quality due to its excessive mining both inside and outside of the Indus Basin Irrigation System (IBIS). Inside IBIS, even though the average cost of irrigating with groundwater is 30 times higher than that of surface irrigation, but farmers having access to groundwater attain 50–100% higher crop yields as compared to those fully dependent on canal water (Shah 2007; World Bank 2007). Thus easy availability of inexpensive drilling technologies allow even low-income farmer to access groundwater to increase its crop production and improve livelihood, but on the other hand it is contributing to fast depleting of water aquifers

Experiences with full-scale artificial recharge operations in the country are almost non-existent and as a consequence, cost information from such operation is either fully missing or incomplete. The technology is mostly adopted in the Province of Balochistan with no constant perennial surface water source. The most common recharge techniques employed are construction of check dams, delay action dams, and earthen ponds while bore hole technique is very recently utilized as a test project in one or two locations in the province.

Groundwater development and management: Over the last three decades, the government of Pakistan has tried to manage and recharge groundwater level, either through direct management by introducing regulation and laws or indirectly through controlling energy pricing. However, enforcing laws, installing licensing, permit systems and establishing tradable property rights thus far have proved ineffective due to political pressures (Qureshi et al. 2009).

Large-scale extraction and use of groundwater in Pakistan started during early 60s under “Salinity Control and Reclamation Projects (SCARPs)” to tackle the twin issue of salinity and water logging in most parts of Punjab and Sindh. Under this public sector program, 16,700 public tube wells covering an area of 2.6 mha were installed to lower down groundwater table and the pumped water was discharged into the existing canal system to increase irrigation supplies (Qureshi et al. 2008). The success of SCARP led to explosive growth of private tubewells incentivized through the subsidized electricity by the government and introduction of locally made diesel tube wells.

In 1980s, a licensing system was introduced by the government to restrict installation of private tubewells in critical areas where groundwater level was dropping down fast. The national groundwater rules were drafted under Provincial Irrigation and Drainage Authority (PIDA) Act in 1999-2000 and included in Canal Act of 2006. Balochistan government approved Balochistan Groundwater Rights Administration Ordinance in 2001. The initial groundwater regulatory framework for Punjab was prepared in mid 1990s with the assistance of the World Bank that finally led to the preparation, review, and approval of a groundwater regulatory framework (GWRF) during 2005-2007. A groundwater-monitoring cell was setup in the Directorate of Land Reclamation in Punjab Irrigation and Drainage Authority (PIDA) to augment the monitoring network of WAPDA which is active since 2003. The regulatory framework further led to establishment a “Groundwater Working Group” under the Planning and Development Department with representation from all the public provincial agencies dealing in water including Irrigation and Agriculture departments, Public Health Engineering Department (PHED), Water and Sanitation Authority (WASA), Environmental Protection Department (EPD) and professionals from other institutions and groundwater users groups.

Currently, about 0.8 million small capacity private tubewells are working in the country, out of which more than 90 percent are used for agriculture, and meeting more than 50 percent of the total crop water requirements. Groundwater abstraction from 1965 to 2002 has increased from 9×10^9 m^3 to 45×10^9 m^3 (WB, 2007). Approximately 70 percent of the private tubewells are present in the canal command areas where groundwater is used for irrigation both in isolation and in conjunction with the canal water, ensuring the productivity of major crops such as wheat, cotton, rice and sugarcane.

In Punjab province, groundwater abstraction exceeds recharge level. The water quality is deteriorating due to intrusion of water from saline groundwater zone into the over pumped fresh groundwater zones, This deterioration is more extensive in the head reach areas of the canal system where rice is grown. There is higher reliance on this source specifically in tail ends of the distributaries and watercourses where surface water supplies are erratic and scarce.

In case of Sindh province, growth of private tubewells in the province is less intensive compared to Punjab due to relative generous supply of surface water and more saline nature of the groundwater in the larger parts of the province.

In Balochistan province**,** groundwater is the only reliable and easily accessible source of water used for irrigation and various domestic purposes. In larger parts of the province, groundwater is accessed through Karezes[1] and open dugwells supported by generous subsidies on electricity rates in the past.

2.3.1.2. Technology category and market characteristics

The groundwater recharge technology can be categorized as a non-market public good when established at a community level and requires state level support to develop and manage the system. The technology option in this report is community or state managed technology and thus considered as a non-market public good.

2.3.2 Identification of barriers for the groundwater recharge technology

As a first step, a team of experts identified a list of potential barriers to the diffusion of groundwater recharge technology in Pakistan through literature review supplemented by expert opinions. The list is as follows:

1. Lack of approved water policy
2. Lack of technical expertise
3. Limited funding
4. High capital cost
5. Conflicting policies such as low subsidy rate on the renewable energy
6. Political interest and interference
7. Hydrogeological uncertainty
8. Lack of reliable groundwater related data
9. Low institutional capacity

[1] Karez is an indigenous underground irrigation tunnel bored horizontally in to rock slopes so that water from deep within the earth runs out on the surface and utilized for irrigation purposes.

10. Weak coordination among public departments relevant to the technology
11. Absence or low participation of ground water users' in decision making processes
12. Limited information on groundwater rights and distribution rules
13. Difficulty in assigning property rights
14. Untargeted financial and economic incentives for water users and managers
15. Lack of land use planning and policy

The final screening and prioritization of the above mentioned identified-barriers to the diffusion of this technology were undertaken through extensive consultation and brainstorming sessions with stakeholders at the barrier analysis workshop. The barrier analysis tools such as starter problem and solution trees were used and found helpful in getting the elements of the groundwater recharge technology challenges (see Annex-1.5-1.6 for the analysis tools). Key identified barriers are briefly discussed below.

2.3.2.1 Economic and financial barriers

a. **High initial investment and maintenance cost**
Check and delay action dams are the most commonly deployed groundwater recharge techniques specifically in the province of Balochistan where the groundwater represent the only constant and easily accessible water resource. An important barrier to successful replication of this technology is high cost of dam construction and maintenance to prevent quick siltation, which reduces the infiltration capacity of water down to the ground level. Likewise, feasibility studies for choosing a suitable site for dam construction are also costly. The important root causes are high cost of construction material and labor to undertake construction in cost effective manner. Also there are low tax reduction incentives to supplies of these materials and other resources.

b. **Poorly targeted financial and economic incentives**
The government offers heavy subsidies to the agriculture and energy sectors with goal to achieve higher agricultural productivity, mostly, at the cost of high groundwater extraction rates. One good example is highly subsidized cheap electricity offered to farmers with 70 percent subsidy on electric tariffs where federal government shares 40 percent and WAPDA 30 percent of the total subsidy. This has encouraged over-pumping over the decades, as the electricity charges bore no relation to consumption. The most serious distortion of market mechanisms observed in this case is the low recovery of electricity charges. For the period 1988-1992, the recovery rate noted was only 47 percent for WAPDA and the average outstanding bill for each tubewell was 80,150 PKR (3,000 USD) (Steenbergen et al., 2015).
Agriculture sector that contributes 21 percent yearly in GDP, contribute less than 1 percent in taxes. Currently, the federal government is offering up to I million PKR interest free loans on the installation of new solar tubewells which will definitely add more to the burden of dwindling groundwater resources in the country.

2.3.2.2 Non financial barriers

Policy, legal and regulatory
Policy instruments play an important role in hindering or facilitating the diffusion and transfer of the groundwater technology. Three policy instruments were broadly identified by the barrier analysis group members and the literature survey: Regulatory or command-and-control policy instruments such as ownership and property rights; economic policy instruments making use of

financial (dis-) incentives such as taxes and subsidies (which are discussed above as a barrier under economic and financial barrier group); and voluntary/advisory policy instruments that motivate voluntary action.

a. Regulatory policy barriers:

i. Disaggregated and unclear ownership rights to water and land are major barrier. This implies that owner of surface land is the owner of water under it. Therefore, households with water boring facility can easily escape regular water fee or taxation. The land tenure structure also considers whether land is owner-cultivated, under sharecropping or fixed-renting. The research shows that in owner-cultivated and fixed renting land tenure areas, groundwater extraction could be more vigorous than sharecropping system and could be a potential barrier to groundwater recharge efforts (Nasim and Helfand, 2015).

ii. Difficulty in assigning effective property rights that includes rights to resource access, withdrawal, management, exclusion and alienation. Parts of this barrier arise from unclear administrative responsibilities among various management authorities operating at various levels of governance and bureaucratic inertia.

iii. Conflicting policies in agriculture and water sector are another major barrier to sustainable groundwater management and recharge initiatives. Energy pricing policies have also been used to indirectly manage groundwater resources

b. Voluntary or advisory policy barriers:

i. Poorly organized groundwater user groups and their passive participation in regulating groundwater resource are identified as another major barrier to this technology transfer. The formation and operation of strong water user organizations in part depends on decentralized decision-making processes in the public sector that certainly comes with political and social trade-offs. The groundwater governance system in the country strongly follows top-down approach.

ii. There is an absence of a single groundwater management body authorized to implement policies (specifically licensing policy) that attempt to manage resources in a long-term sustainable way. A critical sub-element of this barrier is the presence of large groundwater user base in the country that according to an estimate reaches up to .1.0 million (Ahmad and Ali, 2011).

Information and awareness

a Reliability and adequacy of information on groundwater quantity and quality is quite low and scattered. There is reasonably reliable hydro-geological information available for the Indus basin, but it’s still inadequate outside this region especially for areas lacking extensive and contiguous aquifers. Limited information is available on groundwater quality and, where present, it is collected mainly in the context of groundwater salinity. Groundwater profile quality information is completely lacking (e.g. information regarding depth to the interface of fresh and brackish groundwater) that make it a challenge to move towards sustainable management practices such as installation of sustainable skimming wells.

b Conflicting information exist on water and salt-balances in groundwater, irrigation system, and basin health by different government agencies involved in water management and as a consequence this generates lack of consensus on already developed groundwater budget and management plans.

Technical

a. Defining the exact hydrological boundary of a ground water resource is extremely challenging, that makes it complicated to specify and set both the technical and social boundary of a resource.
b. Designing a suitable groundwater recharge system requires a multitude of technical skills, experts and resources to meet the demands of both hydrological and social structures. There is generally lack of technical staff both in public sector and in the community where the technology is developed and maintained.

Political

a. Effective management of tubewells specifically in highly critical areas is a major issue. The question of closing down tubewells in such areas brings up the possible involvement of political forces. This makes it a big challenge for enforcement authorities to device a criteria and strongly adhering to it without caving in under political pressure. This possible scenario registers some important questions such as which of the tubewells should be closed down? What compensation should be offered and how specifically when providing alternative source of water is not a simple solution.

2.3.3 Identified measures

A sustainable management of groundwater resource demands a complex, hybrid governance systems that would have the potential to address all the important barriers mentioned above. Any set of technology transfer and diffusion efforts would meet substantial challenges and even failure in the long run if technology barriers were not considered and duly solved to create an enabling environment for the successful utilization of groundwater recharge technology by the resource users.

2.3.3.1 Economic and financial measures:

a. To reduce the high cost of capital, the government should keep taxes on construction material low. Also, donor funding can also be helpful in this regard.
b. Promote conjunctive use of surface canal and/or runoff water and groundwater to manage water quality and cost. In the canal command areas of Pakistan, the unmanaged conjunctive use of these two water resources are generating issues of waterlogging at the head-end of canal due to excessive availability of water to the farmers, while causing salinity issues for tail-ends farmers due to less available water which forces them to switch to excessive use of bad quality groundwater. To manage the conjunctive use of waters, the canal department needs to regulate the flow match with the crop requirement while educating farmers about proper mixing ratios of water and avoiding the risk of secondary salinization.
c. The government should provide subsidies on the use of efficient irrigation technologies to achieve real water saving. There is also need of incentives to reduce geochemical leaching in order to control groundwater pollution. For this purpose, subsidies on fertilizers and pesticides need to be re-targeted.
d. -Levy fee directly for water abstraction that would vary according to area, volume, source and location. The use of remote-sensing technology to map crop distribution and actual evapotranspiration can be of real help in supervising the groundwater resources.
e. -Introducing market based system for effective regulation: A groundwater permit system already exist and functional. Building on this system, a permit market could be developed in Indus Basin area with close to 800,000 groundwater users, where farmers trade their allotted permits for their benefits. To reduce the transaction cost of the

system, a strong regulatory framework that facilitates trading of permits, needs to be set up. This market needs to be regulated by a combination of a central authority and community-based institutions. Local institutions, with strong oversight from a central authority, could significantly reduce transaction cost in trading the permits (Nasim and Helfand, 2015).

2.3.3.2. Non-financial measures

Policy, legal and regulatory measures

a. Regulatory groundwater policy:

i. Implement clear and effective water, land rule, and property rights. Land surface zoning can be used a policy instrument to protect quality of groundwater and control abstraction. The Punjab province has mapped up critical areas with very low groundwater levels, however, provinces needs to review its existing cropping patterns for areas where hydrological conditions suggest that additional groundwater resources are insufficient to support intensive agriculture. Separate strategies should be developed for large commercial farmers and for small poor farmers who are totally dependent on groundwater for protecting their livelihoods. Cropped areas for different crops should be fixed on the basis of the country's food requirements and the availability of water resources.

ii. Another precautionary measure could be aquifer and land use planning that involve long-term groundwater planning through participatory decision-making.

b. Voluntary or advisory policy:

i. Traditional local practices and indigenous knowledge should be considered when favoring a participatory decision-making process that encourages active involvement of water user groups.

ii. Integrate strong conflict resolution mechanisms in groundwater governance system in order to resolve regulatory and advisory policy issues at the community level.

Information and awareness

a. Develop and maintain a comprehensive database of information on groundwater users, various types of uses, groundwater abstraction quantity, aquifer conditions, water table depth and groundwater quality. This information is central in moving from resource development to resource management paradigm through understanding areas where groundwater resources are underdeveloped and where these are overdeveloped. This information should be backed up by the information on socio-economic dynamics of these regions. The data must be open sourced, centrally placed to avoid the duplication of efforts by different groundwater monitoring agencies and ensure high quality.

Technical

a. Strengthen R & D departments and activities to undertake detailed hydrogeological studies by providing them with easily access-able and reliable funding throughout the year. The aim should be to train departmental staff in necessary skills required in the sustainable management of the water resources.

2.4 Barrier Analysis and Possible Enabling Measures for Urban Stormwater Management Technology

2.4.1 General description of urban stormwater management technology

Managing stormwater or surface runoff is one of the biggest and most expensive challenges that the urban cities face in general. It is estimated that in an event of a rainfall, only 10 percent of rainwater flows along the surface while the rest is either infiltrated in to the porous ground recharging the groundwater or returns to the atmosphere through evapotranspiration. In urbanized areas like cities, hard impervious surfaces such as parking lots, rooftops, and roads make up a larger part of rainwater receiving structures. With limited area available to absorb rainwater, subsequently this water follows quickly into sewer and ditches. The sewer systems overflow when run out of their capacity and therefore pose the instant challenge of inland flooding which in turn could inundate housing and work places, damage the transportation infrastructure, and act as the potential breeding ground for the water-born vectors if the stagnant water stays for a longer period of time.

In Pakistan, combined sewer and stormwater systems predominates that convey domestic and industrial wastewaters and stormwater runoff through a single pipe system. Due to unavailability of wastewater treatment facilities even in the big cities of the country, the poor, and unhygienic condition of wastewater generally ruin the high quality of stormwater and therefore rendering it unfit as a supplemental source of water for irrigation purposes, groundwater recharge etc. Due to various demographic and economic factors such as burgeoning growth of population size in cities, high rate of migration from rural areas to urban, and rapidly changing land use patterns have further put the twin systems of storm and sewerage water under a high pressure. In many of the major cities of Pakistan, the system is in grave condition and in some highly populated segments of the city it is even on the verge of collapse. This fact is evident from the frequent instances of flash flooding in the major cities during the monsoon rainfall.

Managing this twin system is tough and challenging. To separate the two systems is very costly, and normally out of the budget reach of local government administration who is responsible for water and sanitation services at community scale. Unfortunately, no estimated cost is available for the separation of twin systems and the sole management of stormwater at the city scale in Pakistan, but according to United States Environmental Protection Agency, funding needed, for stormwater management and projects to correct sewers that overflow, totals 106 USD over the next 20 years (Copeland, 2016).

Climate change emerges as a promising threat to urban stormwater management systems around the world. According to new climate models' projections for Pakistan, the climatic changes will very likely modify both frequency and intensity of rainfall by the end of this century that potentially translates in to frequent instances of urban flooding. Despite the scale of threat, stormwater management is not a high priority on the national policy radar therefore it fails to capture strong support and visibility from the government agencies involved in natural resource development and management.

Consequently, stormwater management choices are tough because it is inextricably linked to other public services; for example, good storm drain is essential for basic sanitation and decent transportation. Whereas a good drain system needs proper solid waste management, so ultimately it requires comprehensive land use planning and management.

Considering the high cost of technology, along with its low visibility on the national and local policy making radar, the Adaptation Technology Expert Group suggested looking for alternative low cost options to support storm water management which are currently supported by city government and in practice in other parts of the world. In this context, 'green infrastructure' technologies were identified as a useful alternative to the traditional stormwater management systems that can complement or supplement conventional stormwater infrastructure.

Green infrastructure is also known as Low Impact Development (LID) and is defined as “infrastructure that use natural landscape, instead of engineering structures, to capture and treat rainwater where it falls” (ibid). This include green rooftops, trees and tree boxes, rain gardens, vegetated swales, pocket wetlands, infiltration planters, curb extensions, permeable pavements, reforestation, and protection and enhancement of riparian buffers and floodplains. LIDs provide many supplemental benefits along with stormwater management, for example, controlling urban heat island effect and various vector born diseases, groundwater recharge, species protection, and enhancing aesthetic beauty of a city though urban forestry.

2.4.1.1 Technology category and market characteristics

Traditional stormwater management system is a non-market publically provided good due to a wide scale of efforts it requires from the state and local governments to develop effective strategies and techniques. Green infrastructures or LIDs are however could be treated as both public and market goods depending on who designs and funds the LID initiatives.

2.4.2 Identification of barriers to urban stormwater management technology

The identification process for the potential barriers to the diffusion and transfer of urban stormwater management technology in Pakistan followed the same steps adopted for the groundwater recharge and surface rainwater harvesting technologies. A long list of barriers was prepared during the barrier identification workshop, it was screened further and filtered to key barriers on the basis of many important variable that included cost of technology, the degree of willingness to adopt and replicate, having supplemental benefits for the technology adopters etc. The barrier analysis tools such as starter problem and solution trees were constructed to find key barriers (Annex-1.7-1.8). The barriers identified were:

1. High capital cost of investment
2. Lack of coordination and cooperation among public departments both horizontally and vertically in existing governance structure
3. Absence of water and land use planning policies
4. Enforcement challenges of state regulations
5. Inadequate technical expertise
6. Unpredictability of rainfall frequency and intensity in the future
7. Poor knowledge about the stormwater capacity of cities and districts
8. Inadequate information on regional hydrological systems
9. Lack of information on performance and cost-effectiveness of low impact development (LID) infrastructure
10. Public perception of LIDs
11. Lack of guidelines and standards for stormwater management
12. Lack of funding for demonstration projects
13. Limited information and education level of builders and developers on new designs of conventional and green infrastructures
14. Lack of incentives for developers and consumers of green infrastructure

The key identified barriers are discussed below.

2.4.2.1 Economic and financial barriers

a. Huge amount of investment and O&M cost is needed for undertaking construction or repair of a citywide existing stormwater drainage infrastructure. This barrier has two important aspects: lack of funding to implement projects, and uncertainty over costs as well as cost-effectiveness. At the local government level, municipalities either do not have capacity or legal authority, to develop, increase, and enforce stormwater fees that would generate revenue for them to implement LID projects.

b. There is a perception among private and public developers and lenders that LIDs can be as expensive as conventional infrastructures. This perception comes from the poor understanding about LIDs: cost to design, construct, maintain and insufficient economic analysis of environmental and social benefits of green infrastructures.

2.4.2.1 Non financial barriers

Stormwater management issues are very complicated, especially in the area of cooperation and coordination among relevant agencies, communities and other district level government departments. Important non-financial barriers identified are described briefly here:

Policy, legal and regulatory

a. Absence of concrete and comprehensive land use and water policies at the national level with actionable strategies at the local government scale. The rapid changes in land use patterns alter the natural surface drainage system and therefore compromising the stormwater management capacity of the natural and built environments. Furthermore, current urban land use regulations are not compatible with climate change projections.
b. Absence of or poorly developed local ordinances; building codes; health codes; drainage codes; and parking spaces. The existing municipal codes and ordinances favor grey infrastructure over LIDs.
c. Weak enforcement of the existing urban planning codes and regulations: An important element of this barrier is the fragmented efforts among local governments. The density of communities the municipalities serve and their capacities vary greatly which create a big challenge to resource managers to control stormwater runoff in their area of responsibility.

Social, cultural and behavioral

a. Limited community support to municipalities managing stormwater drain systems. This barrier arises because the community run systems are limited and also due to ignoring variation in uniqueness and circumstances of individual communities by municipalities**.**

Technical

a. Inadequate technical expertise of local and city governments to design and deploy effective project designs at the community scale.
b. Poor knowledge about the stormwater capacity of each city, district and community, and other required hydro-geological information needed to design an effective system.

Information and awareness

a. Limited information on cost-effectiveness of green infrastructure at the international and national level.
b. Absence of data and information on the negative consequences of climate change at the regional scale.
c. Need of information on the potential benefits of stormwater collection and use by the communities.

2.4.2 Identified measures

The following measures were considered important to overcome the barriers.

2.4.3.1 Economic and financial measures

a. Allocate adequate development budget to local governments for the design, development, construction and subsequent operation and maintenance of the urban stormwater infrastructure.
b. Explore and compete for the donor funding opportunities particularly international climate adaptation financing for the diffusion and transfer of green infrastructure. The economic benefits of this green infrastructure technology is received from the combination of the decreased cost of damages resulting from flooding and the reduced cost of constructing stormwater management and drainage infrastructure.
c. Provide incentives to developers and consumers of LIDs to encourage market to create a space for green infrastructure tools, equipment, and initiatives so the technology could move from a public good status to market good through indulging private investors in public-private partnerships or stand-alone private projects. Exemption from some taxes and fees for developers and some bonus subsidies to consumer group for at least a period of 3 years of technology promotion.

2.4.3.2 Non-financial measures

Policy and regulatory

a. Design, and approve a land use planning, and water policies with clear directives beneficial utilization of surface rainwater harvesting including stormwater.
b. Increase coordination and cooperation among various districts, and cities for managing stormwater by forming a central authority or a forum for continuous multijurisdictional communication, planning, and monitoring related to stormwater.
c. Prepare and implement local ordinances that deal with LIDs.

Technical

a. Strengthen R&D activities at both state and local government levels. Ensure a dedicate source of funding for the program managers in order to conduct staff training, and purchase of any other necessary equipment etc. Introduce remote sensing and GIS techniques to monitor and evaluate the performance of currently operational stormwater systems.

These measures promise many societal benefits along with control of urban flooding. It includes reduction in pollutants loading to drinking water sources, prevention of water-borne vectors. Reforestation and green roof practices not help in reducing energy costs for the buildings but also heat island effects. Green infrastructures also improve urban aesthetics, increase property values, and provide wildlife habitat and recreational space for urban residents.

2.5 Common barriers Identified in Water Sector

This section looks at different barriers common to surface rainwater harvesting techniques, groundwater recharge and urban stormwater management. These three prioritized technologies in water sector serve the common goals of irrigation, flood protection and groundwater recharge in the country. Rainwater harvesting is the oldest technology that capture and store rainwater in storage structures, ranging from small ponds to earthen and concrete dams mostly for the irrigation purposes for rural communities. In the last three decades, after a multiple drought experiences in various parts of the country, there is a gradual shift in water sector's paradigm in the country from "water for agriculture expansion only" to "integrated water resource conservation and management", and so water storage structures are built and maintained with dual purposes of irrigation and groundwater recharge purposes. However, the later is a top priority in arid and semi-arid settlements only such as in province of Balochistan and Potohar region where groundwater is the only reliable and easily available source of water for the individuals and communities. Compared to these two technologies mentioned above, urban stormwater management, specifically the green infrastructure, is an area of research and practice that awaits attention by policy and decision makers and consumers alike. The practice is currently limited to repair and expansion of combined sewer systems in the cities.

The three technologies share many common barriers in the context of similarity in their development and use, therefore it is imperative to take a holistic approach towards finding barrier linkages in order to find potentially more efficient approaches and opportunities to address their combined effect. The table 2.1 shows the key common barriers identified for the three technologies in the water sector of Pakistan.

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Table 2.1 Common barriers identified in different prioritized technologies in water sector

Common barriers in Water sector technologies	
Barrier Category	**Barriers**
Economic & Financial	High capital and maintenance cost
	Limited financial allocation to local governments
	Inadequate loan and donor funding
Policy, legal and regulatory	Lack of sound comprehensive cross-sectoral policies for resource protection, development and management
Information & awareness	Limited information and awareness about the existence and usefulness of the technology
Institutional & organizational capacity	Limited institutional capacities specially at local level in integrating climate change risks in development planning
	Limited human skills and maintenance specially at local level

The above-mentioned barriers are common and inter-linked in water sector technologies. Therefore, overcoming these barriers would immensely help in adoption and diffusion of all three water sector technologies.

2.6. Enabling Framework for Overcoming the Barriers in the Water Sector

A key component of the enabling framework for overcoming the barriers to the diffusion of prioritized technologies in the water sector is the operationalization of the existing national climate change policy and its implementation framework recommendations. The next step should include the increased budgetary allocation for increasing the resilience of the vulnerable communities from the impact of climate change on water resources. So that the diffusion of above mentioned prioritized technologies can be facilitated through the mobilization of external donor agencies, and getting access to international climate finance funds specifically GCF and adaptation fund. For that to happen we may need to devise effective technology based adaptation projects that would promise to deliver the potential benefits of these technologies to the resource managers, users and other beneficiaries alike.

The next important component of sustainable water sector management in Pakistan is the need to ensure that social, economic and environmental aspects of water are integrated into sectoral policies and plans. While these plans and programs should be taking guidance from the cross-cutting themes of water access, equity and hazards.

Based on this theme, the prioritized technologies' implementing strategy needs to be focusing on alternative water resources, ground water sustainability and hydro-disaster risk reduction in the form of flash floods specifically inundating and damaging infrastructure and risking human lives in the urban centers. Further, though a number of measures are proposed to improve diffusion of water sector prioritized technologies, but it is important to address the most fundamental, practical and urgent ones first.

In this category, we easily can place institutional capacities' enhancement, strengthening laws and regulations, ensuring climate informed –decision making and planning, promoting research and technology awareness, and implementing pilot demonstration projects. In addition ensuring the required investment will continue to be the fundamental enabling factor across all water sector technologies implementation.

Based on above discussion, barriers and measure may cover these 5 broad issues:

1. Ensuring appropriate financial mechanism to support implementation
2. Mainstreaming climate change considerations into relevant sectoral polices, plans and strategies
3. Strengthening research, training and technology awareness-raising among stakeholders
4. Strengthening institutional capacities at national and sub-national levels
5. Designing and implementing practical pilot demonstration projects

A brief account of important enabling measures needed to diffuse water sector prioritized technologies is given in Table 2.2.

Table: 2.2. Key measures identified for three technologies in water sector

Key measures identified
Economic & financial
a. Ensure the availability of sufficient local development funding from National as well as International funding sources for the diffusion of this technology.

Policy, legal and regulatory
a. Approve pending water policy with special attention to water conservation and sustainable ground water management. b. Define administrative boundary of groundwater aquifers and authorize a single groundwater management body in each province. c. Recognize role and authority of water user organization and/or other indigenous administrative set up in formal decision making processes. d. Resolve ownership right to water and land and property rights through improved policy coordination
Information and awareness
a. Prepare extensive information and awareness material about the existence and usefulness of water sector technologies and disseminate them through workshops and training sessions.
Technical- Institutional and organisational capacity
a. Invest in technical capacity building of R & D and local government institutions b. Ensure the local training and availability of construction and maintenance staff.

Key water sector measures and enabling framework
The key enabling measures needed to ensure diffusion of above mentioned prioritized water sector technologies and to achieve the preliminary technology transfer and diffusion targets are as follow:

a. **Financing:** High capital cost is a key issue in all three water sector technologies. So, we need to ensure that the national development planning process give required priority to the diffusion of these technologies in the country. Further, as national development funds are limited 'Economic Affairs Division' should made every effort to obtain project specific grants /soft loans from international donor agencies particularly from international climate financing mechanism such as 'Adaptation Fund', 'Green Climate Fund' etc..

b. **R&D Institutional capacity**: Need to ensure that sufficient financial resources are allocated in annual budget to R&D Institutions to enhance their technical capacity. So, they can undertake feasibilities studies to select most suitable sites for surface rainwater harvesting, groundwater recharge based on hydro-geological conditions. Further, for designing the most appropriate urban stormwater drainage system based on future climate projection also require R&D institutional capacity.

c. **Operation and maintenance capacity:** To ensure the sustainability of all three water sector technologies sufficient financial resources need to make available for enhancing the technical capacity of R&D and other line departments. Further, special training programs be undertaken to train local technicians in operation and maintenance of these technologies.

CHAPTER-3 AGRICULTURE SECTOR

3.1 Preliminary Targets for Technology Transfer and Diffusion in Agriculture Sector

Agriculture sector in Pakistan is the backbone of the country's economic growth and development. In 2015, the sector's contribution to national export reached to around 60 percent of the total export. The recent climate change projections for agriculture sector indicate increase in temperature, changes in rainfall patterns and changes in wind and solar radiation patterns that will adversely affect crop productivity with a looming threat to the national food security gains.

The 'Vision 2025' (GoP, 2013) document as a guiding policy framework identifies several issues and challenges to achieve sustainable development through food and water security. One of the most important challenges to the growth of sector is the slow rate of technological innovation due to limited adoption of progressive farming techniques. Hence, to cope with the severe impacts of climate change, the agriculture sector needs to adopt environmentally sound technologies to move towards climate resilient development pathway.

Keeping in view the above stated projected climate change impacts on agriculture sector the TNA project in its phase-I identified and prioritized the following three climate change adaptation technologies in agriculture sector:

1. High efficiency irrigation systems
2. Drought tolerant crop varieties
3. Climate monitoring and forecasting- early warning system

The above mentioned technologies in agriculture sector are mainly prioritized as an adaptation measure to reduce the vulnerability of population linked with or dependent on agriculture sector to the impact of climate change. However, it is emphasized from the outset that all the above three technologies are available and used in the country at various levels, and the only issue is that these technologies are not being used and implemented widely and sustainable enough to bring sustainable benefits to the agriculture sector.

The preliminary targets identified under TNA project for the transfer and diffusion of these technologies in agriculture sector are:

1. Installation of drip/sprinkler irrigation system on around five million hectares of agriculture farmlands in arid and semi-arid areas by 2020;
2. Develop and promote use of drought tolerant wheat and rice seeds varieties that can grow in dry conditions by 2025;
3. To provide training to farmers on efficient irrigation techniques and water management;
4. Up gradation of existing agriculture R&D centers in each province;
5. Up-gradation and modernization of climate monitoring and forecasting system in the country by 2020.

3.2 Barrier Analysis and Possible Enabling Measures for High Efficiency Irrigation Systems (Drip and Sprinkler)

3.2.1 General description of technology

In the light of projected water scarcity due to ensuing climate change threats, efficient use of water is extremely important. High efficiency irrigation systems (HEIS) including drip and sprinkler irrigation techniques are the best-known water saving technologies for irrigation purposes.

The technology is useful in addressing the growing demand for scarce water resources and has shown positive effects on yield, income and food security. Further, fertilizers and agricultural chemicals can also be applied more efficiently through these irrigation technologies.
Drip irrigation is a method in which water is supplied to crops at “specific point” usually at the base of the plant. This method uses a network of pipes ending with small emitters to give water to the plant roots. Drip is used best for a wide range of orchards, vegetables, and cotton crop. Whereas, sprinkler (or overhead) irrigation is a method of distributing water in pipes under pressure, and spraying it into the air so that it breaks up into small water droplets and falls to the ground like natural rainfall. The system caters for both small and large-scale applications and comes in hand-move systems and mechanically operated ones. The system is suited to most row, field, and tree crops that are grown closely such as cereals, wheat, pulses, cotton, vegetables, and fruits. As pressurized irrigation systems have better uniformity & higher application efficiency; higher crop yields can be obtained with these methods.

Installation of this technology requires:
1- Pumps or pressurized water systems which take water from the source and provide pressure for delivery into pipe systems. Pressure varies from 2-3 bars to more than 10 bars;
2- Filtration system;
3- Nutrients application system;
4- Pipes (including main pipe line and tubes);
5- Control valves and safety valves;
6- Drip emitters or mini-sprinklers and their variances;
7- Monitoring plant water need through tensiometer or through programs addressing irrigation quantity and frequency provided by technicians.

The technology provides many adaptation benefits: with projected decline in rainfall and fresh water availability, HEIS technology provides efficient use of water supply especially in arid and semi-arid drought prone areas or those with seasonal rainfall. It reduces demand for water by reducing water evaporation losses. Drip irrigation system lowers probability of onset of disease such as fungus through liquid fertilization and less leaching of nutrients from the root zone. The technology is highly adaptable to various topographies, and soil characteristics (including saline and sandy soils) except heavy clay soils. The technology works in conjunction with other on-going schemes such as rainwater harvesting to better adapt to climate change stress.

3.2.1.1 Technology status in Pakistan

The high efficiency irrigation systems were introduced in Pakistan in early 80s by the public research institutes with the financial support from the international donors such as FAO, ADB and World Bank (Ashraf, 2012). According to WAPDA Vision 2025 (2002), 3.493 MA lands were targeted to bring under drip and sprinkler irrigation systems.

Pakistan has the world's largest contiguous Indus Basin irrigation system (IBIS), the irrigation efficiency of the system, however, is highly compromised due to high amount of water losses at the different levels of water conveyance system including canals, watercourses and field. The yearly water losses for instance, according to water balance sheet for Punjab province, reaches up to 45 million acre foot (MAF) out of 90 MAF of total available water to crops (Punjab Agriculture Department, 2015).

The early HEIS pilot projects have demonstrated a high rate of failure specifically outside IBIS zone. The failure have been identified and associated with high installation and maintenance costs due to use of imported materials, lack of technical support and inappropriate system designs which did not meet the local requirements. In the last one-decade, HEIS have been modified to meet requirements, and manufactured within the country except few essential parts which are imported. Likewise, government has shown substantial support in the form of subsidy, which along with technical support from the provincial agriculture departments to the farmers have resulted in widespread adoption of this technology specifically in the province of Punjab.

Punjab government aims to install HEIS on 120,000 acres with support from World Bank. Punjab government currently is offering cost sharing arrangement in province between government and the beneficiary farmers whereby, government is providing 60 percent subsidy on total scheme cost while the beneficiary farmers contribute the remaining 40 percent of the cost. In addition to this, the government is also providing 10,000 PKR per acre of scheme area for construction of water storage pond, if needed, on the basis of site-specific technical requirements (Government of Punjab, 2016).

3.2.1.2 Technology category and market characteristics

Depending on the scale of application, the drip and sprinkler irrigation technology options considered in this report are systems owned by farmers thus can be categorized as a market consumer good. A market map (Annex-1.1) is produced to show the various working elements of the technology market and how their interconnectivity affects the technology diffusion and success at the field level.

Market characteristics for medium scale irrigation systems identified are:

1. Farmers can adopt drip and sprinkle irrigation if subsidized.
2. Most parts of the equipment can be manufactured locally, except few imported parts of pumps and timers.
3. Awareness raising about the usefulness of the technology needs to be undertaken mainly by relevant government institutions and can be supplemented by civil society organizations.

3.2.2 Identification of barriers for high efficiency irrigation system

The barrier identification process for the diffusion of drip and sprinkler technologies is essentially based on literature reviews, interviews with sector experts, consultation and brainstorming sessions with stakeholders including technology market suppliers and with Adaptation Expert Working Group at the workshop. The identified barrier and measures were analyzed using the market mapping, starter problem and solution trees presented in Annex-1.9- 1.10. The identified barriers are divided into two main categories- economic/financial barriers & non-financial barriers. Non-financial barriers are further divided into eight sub-categories: policy/regulatory, technical, Social, cultural and behavioral barriers, institutional capacity barriers, information and awareness barriers, human skill barriers, environment barrier and market failure barriers.

Here is the list of generalized potential barriers to diffusion and transfer of high efficiency irrigation systems:

1. High cost of set up and maintenance and operation process
2. Under-developed, weak supply chain
3. Absence of approve water and agriculture policies
4. Weak water pricing system
5. Water and property right conflict
6. High cost of energy to run the system
7. Low preference for resource conservation technologies
8. Technical capacity of government institutions and agencies
9. Low technical capacity of consumer group
10. Absence of cost effectives of technology at field level and in different climate regions
11. Risk of soil degradation due to salinity buildup
12. High maintenance requirement
13. Not suitable for every soil type
14. Communication gap between technology developers, suppliers and consumer
15. Lack of product certification and quality assurance procedures
16. Poor economic viability of technology for small land holders

The barriers prioritized through stakeholder consensus are described below.

3.2.2.1 Economic and financial barriers

The high initial investment required for purchase of different technology units, transport and installation is a major financial barrier to technology diffusion. As such the major financial barriers identified through the above-mentioned processes are as under:

a. High initial cost of building small to medium sized drip and sprinkler irrigation systems.
b. High maintenance and operation cost specifically in case of drip irrigation technology with a lifetime of around 7 years.

3.2.2.2 Non financial barriers

The non-financial barriers identified, are grouped under different categories described below:

Market failure and imperfection

a. As a market good, HEIS faces several market challenges that are major obstacles in the deployment and successful replication of this technology. The local market for HEIS is under-developed, small and have a weak supply chain. Currently, the Agriculture department of Punjab government has 22 pre-qualified registered supply and service companies, which are responsible for installation of drip and sprinkler irrigation systems on turn-key basis and for provision of post installation support for at least two years. However, out of 22, only five (5) companies are active and providing required services to the farming community. Various elements of this barrier were further diagnosed with poorly articulated demand, insufficient number of competitors, economies of scale achieved only at high investment level, and uncertain financial situation in the country.

Policy, legal and regulatory

a. Absence of approved water and agriculture policies and weak institutional framework with respect to water management in the agriculture sector.
b. Current irrigation water pricing is not encouraging water saving. So, there is a lack of clear economic incentive for saving water due to inefficient pricing of canal water.

*Abiyana (*the price farmers pay for water), fluctuates between 85 PKR per cropped acre in Punjab to 250 PKR per acre for non-food crops in Khyber Pakhtunkhwa (Iqbal and Iqbal, 2015). Abiyana recovery rate is 60 percent nationally and is still declining rapidly. Overall, the irrigation system recovers only 24 percent of the annual cost of overhaul and maintenance and requires an annual subsidy of 5.5 billion PKR.

c. Water and property rights conflict in case of constructing water storage tanks or small reservoir for a small community.
d. Absence of local standards for equipment quality: The locally manufactured HEIS parts suffer from design and quality malfunction that on one hand badly affect the technology performance in the long run and on the other discourages farmers to adopt this technology.

Technical

High efficiency irrigation systems face many serious technical challenges that are listed below:

a. Extensive maintenance needs due to frequent clogging of emitters.
b. Uneven water distribution on unleveled plots, causing over or under irrigation to some plants.
c. Limited repair and maintenance technical knowhow.
d. Need for access to a reliable daily water supply.
e. Inadequate water quality for drip and mini sprinkler irrigation.
f. High cost of water for those small scale farmers using potable water source.
g. Power supply for pumping to lift water and pressurized system to ensure uniform distribution of water requires additional investment.
h. Fluctuating low flow rate in irrigation canals and non-equitable water delivery schedules in irrigation canal and that required for HEIS systems (in case water is delivered under gravity) requiring additional cost to invest in intermediate storage system.
i. High cost of lifting water in groundwater irrigated areas reducing economic viability of system.
j. Lack of scientific data or proper socio- economic analysis of technology at national level.
k. Limited research data quantifying the real water saving and water productivity of MI on various crops and different field conditions (data is available only for experimental farms, for limited number of crops and system types and for a few locations).
l. Sprinkler not economically viable for small landholders due to its high cost of installation and maintenance.
m. Technical expertise to consider the soil type, field size, slope and field characteristics.
n. Drip irrigation not suitable for all crops due to different crop spacing and height soil types / topography and slopes.
o. Need for well-trained local technicians for sustainable operation and maintenance of these systems.
p. Micro irrigation system needs to be disconnected before land preparation for crop cultivation.
q. Risk of soil degradation due to a gradual salinity build up in the soil profile.

Social, cultural and behavioral barriers

a. Resistance of farmers to change, perception of complexity, and perceived negative consequences (risk) – loss of investment (time, effort, money) if crops fail or if there is no market.
b. Preference to other irrigation techniques such as flood irrigation methods.
c. Farmers lack technical knowhow in managing and maintaining irrigation systems.

d. May require shifting to high value cash crops for economic viability requiring farmer to adopt new cropping patterns.
e. Land tenure: farmer who lease lands require owner authorization for investing in installation and maintenance technology.
f. Fear of theft and vandalism of system.

Institutional capacity barriers

a. Limited research & development institutional capacity to undertake practical experiments and pilot projects for demonstration to farmers.
b. Limited good knowledge and practical experience which is necessary to install and operationalize such water saving systems, as each system needs to be site specific for optimal use.
c. Weak collaboration and communication between extension, research and end user.

Information and awareness barriers

a. Inadequate awareness about the existence and usefulness of the technology.
b. Absence of communication between technology producer and user.
c. Absence of knowledge base on successful case studies undertaken locally to demonstrate impact of HEIS systems on water use efficiency (water saving is dependent on local climate).
d. Inadequate access to training services and information.

3.2.3 Identified measures

This section discusses the measures needed to overcome the barriers identified in the previous section to the implementation of efficient irrigation technologies in Pakistan. The main methodology employed for the identification of appropriate measures is the development of problem and solution trees (Annex-1.9-1.10) through the stakeholders' participation, besides the detailed analysis of national and international current practices in the relevant field. Finally, the discussion during the stakeholders workshop based on solution tree resulted in identification of the key identified measures needed for the diffusion of drip and sprinkler irrigation technologies in the country.

The measures prioritized through stakeholder consensus are described below.

3.2.3.1.1 Economic and financial measures

a. Provision of low interest or interest free loans for purchase and installation of equipment.
b. Provision of special grants or subsidy on initial cost of installation to promote the use of these water saving technologies.
c. Provision of liberal tax rebate or tax incentives.
d. Reduction of import duties on parts needs import.
e. Financial disincentives to encourage optimal use of water using water efficient irrigation system.
f. Review water pricing so as it reflects its long-term marginal cost taking care not under value crop production and to consider cost of making the water available in the field and for use.

3.2.3.1.2 Non-financial measures

Policy, legal and regulatory

a. Government may develop liberal subsidy policy to promote drip and sprinkler technologies in the country.
b. Set up standard for HEIS equipment parts.
c. Government should fit this technology as the part of a larger investment in horticultural production to improve production and market access and thus increase investment in promotion of efficient micro-irrigation system.

Technical

a. Assessment of the actual cropped areas that can be brought under drip systems in catchment areas which would benefit from them in terms of water productivity improvements.
b. Training of water users and service providers in design, installation, operation and maintenance,
c. Training of farmers on how to use real-time climate and soil-based information to determine crop water requirement and irrigation water management and irrigation scheduling (when and how much to apply).
d. Development of practical guidelines for micro-irrigation system design and management
e. Organize farmers' exposure trip on demonstration site to expose farmers to the MI technology and provide them with all the information of the products, suppliers, cost and economic benefit.

Social, cultural and behavioral

a. Educate the farmers about the financial benefits of the use of these technologies. Education should be in a way that it highlights how the technology is going to contribute towards the well-being/ empowerment of women water users/managers.
b. Reduce perception of risk through demonstration plots, and identification or creation of markets.

Institutional capacity

a. Government may provide necessary financial support to its R&D and other relevant institutions to undertake needed research and pilot demonstration projects.
b. Government relevant institutions may undertake active information and awareness campaigns about the usefulness of such technologies.
c. R&D institutions may be strengthened and tasked to prepare country's long-term water and climate scenarios.

Information and awareness

a. Farmer be educated to shift to high value cash crops and change cropping patterns and practices which are amendable to drip/sprinkle irrigation technology to get maximum benefit of the use of technology.

Human Skills

a. Government may provide financial support to its relevant institutions for arranging the creation of skilled technicians workforce well trained in installation and maintained of these technologies.
b. Simultaneously farmers may also be adequately trained for day-to-day operation and minor repairs of these systems.

Market support

a. Manufacturers, suppliers, importers may be provided tax incentives and low interest credits for encouraging business investment in these technologies.
b. Develop, implement and regulate product standard
c. Market may be supported to have adequate suppliers at the local level and marketing structure should be within farmer's easy reach.

3.3 Barrier Analysis and Possible Enabling Measures for Drought Tolerant Crops Varieties

3.3.1 General description of technology

Development of new improved crop varieties enhances their resistance to water and heat stresses resulting from climate change. Drought is the principal constraint on crop production in dry land areas specifically impacting the lives of poor. Drought tolerance crop variety is an important management strategy for efficient water use and better crop yield in the areas with limited or unpredicted water supply. So improved crop varieties that can resist these stresses, can help to ensure food security despite climate change uncertainties.

The technology employs both conventional breeding and genetic engineering techniques and tools to create stress-tolerant wheat varieties. The participatory plant breeding offers a more active role to farmer by offering them observer plant performance in the field while attempting to select the plant traits for better drought tolerance. Genetic engineering involves the use of molecular markers to better understand the genetic basis of drought tolerance and to select more efficiently for this trait. Both techniques though take considerable time in development of a new crop variety and its field-testing procedures.

The technology provides efficient use of available crop water especially in drought prone areas or those with seasonal rainfall; reduces high demand of water by minimized evaporation losses from the crop.

3.3.1.1 Technology status in Pakistan

Drought tolerant crop varieties are rather a less researched area due to relatively low priority put to dry land agriculture. Out of 22 mha of cultivated lands in Pakistan, about 5 mha is rainfed, and the rest is irrigated areas. However in the past few decades, some prolonged occurrences of drought in the dryland areas and deteriorating condition of canal networks has forced the policy makers to pay attention to rainfed agriculture and drought tolerant crop varieties.

Pakistan has many varieties of locally available drought tolerant crops that are developed for both irrigated and rainfed areas of the country and some are widely adopted by the farmers. In case of wheat, for example, Chakwal-50, GA-2002, Inqilab-91, Dharabi-11, NRL-2017 are some examples of drought tolerant varieties that have been developed in the past and currently in use by the farmers. Most of the drought tolerant wheat varieties have displayed pest resistant with good grain yield and high bread-making (chapatti) quality in field trials. The performance and cost effectiveness of these varieties at the farm level rather remains a researchable area because monitoring and evaluation of the performance of technology at the farm level is limited.

The seed industry in Pakistan is supported through Seed Act, 1976 which provides a regulatory mechanism for controlling the quality of seeds through setting up important institutional infrastructure, such as National and Provincial Seed Councils, and Federal Seed Certification and Registration Department (FSC&RD). The FSC&RD is responsible for controlling quality of seeds, certification, standardization of seed quality, information dissemination on genetic suitability and adaptability of crop seed varieties, and publishing a list of registered seed varieties. The Seed Councils play an advisory role on development, operation and regulation of seed industry through ensuring investment in seed industry, approve and/or sanction seed standards and regulate inter-provincial seed movement (Hussain, 2011).

3.3.1.2.1 Technology category and market characteristics

Drought tolerant crop varieties technology falls under category of both market and non-market good. As initial stage of research and patenting of drought tolerant seeds production is normally done by state research institutions, therefore, at this stage the crop variety is a non-market public good. But the next stage makes this technology a market good because it involves a complex demand and supply chain for drought tolerant seed sale and distribution. It involves commercial and private institutions working under market influence and forces (As shown in market map Annex 1.2).

3.3.2 Identification of barriers for the technology

Research on inducing resistance to climatic stresses including drought, temperature, pest etc. in crops and other valuable cash crops is a long process. Pakistan has many research institutes particularly focusing on enhancing this trait of plants either through genetic engineering or conventional breeding experiments. There were many barriers in development and deployment of this technology at the base scale identified through literature review, expert opinions, and interaction with farming community.

During the stakeholder consultation workshop, the problem solution tree tools were also used to screen and validate the identified barriers and measures (Problem solution trees given in Annex 1.11-1.12).

The list generated below shows an initial list of potential barriers to this technology:

1. Inadequate financial resources for research and development
2. Lack of technical expertise, equipment, physical infrastructure for genetic manipulation of crops.
3. Difficulty in access to good quality seeds.
4. Poor seed storage facilities.
5. Limited number of seed testing labs for ensuring quality of seeds.
6. Limited number of registered and certified seed supplier in the market
7. Poor credit facilities.
8. Low seed demand.
9. Delayed release of varieties.
10. Inefficient seed production, distribution and delivery system.
11. Small market size and supplier chain: uncertainty in demand side of the chain.
12. Inefficient / poorly equipped seed testing labs to confirm the quality of seed.
13. New pest issues.
14. Inappropriate communication/ extension approaches.
15. Insufficient data sharing and collaboration among research institutions so high chances of project multiplication.
16. Lack of strong legislation and regulatory framework to control seed market.
17. Inadequate patenting of research findings and disagreement of intellectual property rights.

A brief summary of key barriers and their enabling measures is presented below.

3.3.2.1 Economic and financial barriers

a. The main economic and financial barriers to the diffusion and adoption of technology are inadequate financial resources available to the research institutions to undertake research to produce crop varieties that better suit the local environment, set up new research laboratories, develop human resources, and knowledge transfer to the technology user groups.
b. Generally the rainfed areas of the country express high poverty rate, where farmers are small landholders with limited access to easily available water resources. Rainwater harvesting and use of groundwater ensure the constant supply of water for agriculture. The land is poor in nutrients and so thus is high the demand for fertilizer and other land preparation machinery. These factors on one hand increases the average cost of crop production for the farmer compared to its counterparts in the irrigated land areas of the country, and on the other hand, discourages taking risk in the form of switching to new crop varieties such as drought tolerant ones.
c. Drought tolerant crop verities are more expensive in the market than other non-drought tolerant seeds due to poor price market regulation by the government. Even though, agriculture sector is the most heavily subsidized sector in Pakistan, unfortunately, the subsidies and tax relaxation policies are poorly targeted towards small household farmers specifically in the rainfed areas. Similarly, the high cost of seed testing and quality assurance is another significant area of economic barrier.

3.3.2.2.1 Non-financial barriers

Market failure and imperfection

Compared to other agricultural products, seed market in Pakistan is small and holds both private and government sectors. In case of Punjab, 30 percent of the seeds comes from private sector, 30 percent from government research institutions, and the remaining 40 percent is farmer's own seeds which they grow each year and save some for the next year.

a. Weak seed supply chain and distribution mechanism: Difficulty in access to good variety of seeds especially for the farmers in remote areas is a crucial barrier in diffusion. The main element of this barrier is the small size of the drought tolerant seed market with a very limited number of registered seed suppliers to meet the demands of the farming community. Moreover, there are many fake brands with low quality seeds circulating in the markets.
b. Unregulated seed pricing: Good quality, certified seeds are rather expensive to buy for the farmers. In some cases, local seed companies import low quality, cheaper, but untested seeds and distribute under the popular brand names. Low price initially put these untested seeds in high demand among farming community but as the farmers fail to achieve their production targets after the cultivation, the seed variety gradually loses its creditability along with market demand. This quality control issue eventually is one of the major causes of small, distorted seed market
c. The seed supply chain is inefficient, slow, and lack capacity to meet the market demand. For seed suppliers, the storage of seeds is a major issue as there are insufficient seed storage houses available.

Policy, legal and regulatory

The Seed ACT of 1976 did not identify and acknowledge the direct participation, investment and individual property rights to plant breeders and research organizations from private sector. To amend, the National Assembly passed “Seed (Amendment) Bill” in 2015, and National Assembly Standing Committee on National Food Security and Research passed “the Plant Breeder’s Rights Bill” in August 2016 which is awaiting now to laid before the National Assembly.

The bills have faced strong opposition from the farming community, social activist groups and legislators. Seed Amendment Act, 2015 has made it mandatory for farmers to buy seeds from a licensed company or its agent every time they have to cultivate a new crop. The law has imposed fines and even imprisonment on farmers for preserving, selling and exchanging seeds (Ilyas, 2015). According to a expert statistics, in case of Punjab alone, 40 percent of seeds in use by the farmers come from their own previous years’ stock of harvested crops. The bill clearly challenges the traditional system of seed storage and usage by small landholding farmers.

Similarly, the “Plant Breeder’s Rights Bill” grants Intellectual Property Rights (IPRs) protection to plant breeders and allow introduction of genetically modified (GM) varieties by private investment companies for the first time in the history of the country (Sher, 2016). Farmers and environmentalists have reservation on safety of genetically modified varieties and monopolization of seed market by the international private seed companies.

The 18^{th} Amendment in 1976 Constitution, enacted in 2010, has raised some serious legal challenges for these two seed laws. The Plant Breeder’s Rights Bill still awaits approval from the National Assembly to come into force. After the Amendment, the subject of agriculture is devolved to the provinces and only they have the power to pass or modify any agriculture related acts or laws. This fact put the current legal status and authority of both of the seed laws in question and so is the right of direct investment granted to the private sector in the seed market. On the regulatory front, after the Amendment, the authority and power of the Federal Seed Certification and Registration Department remains uncertain.

Technical

a. There is lack of strong research institutions that specializes in genetic manipulation and experimentation. Most of the laboratories are outdated with inadequate manpower and technical skills. The seed quality testing laboratories at the provincial scale suffers the similar fate.

Information & Awareness

a. There is also lack of information and awareness among technology developers and users about the international treaties and protocols that would be useful in understanding in IPRs protocols. Due to non-availability of information on potential benefits of the use of drought resistant seeds varieties, farmers are unwilling to try it in field as they perceived them as low yielding, late maturing and labor increasing. Also there are concerns about storability i.e. if varieties are more prone to pest attacks.

3.3.3 Identified measures

Considering the continued need for research and also to strengthen the under-developed market situation for this technology, there are many possible measures, which can remedy the current technology stagnant situation. These measures are discussed below:

3.3.3.1 Economic and financial measures

a) To overcome key economic and financial barriers discussed above, the provincial governments needs to allocate a dedicated fund for the drought-sensitive areas and promote drought tolerant crop varieties through agriculture extension services and programs. The domestic funds need to be supplemented by international sources such as International Centre for Agricultural Research in Dry Areas (ICARDA) and Food and Agriculture Organization of the United Nations (FAO) etc. to ensure dedicated funding for the up gradation of research institutes and seed testing labs.
b) Release soft credits and loans to farmers for ensuring farming community's ability to afford drought tolerant seed varieties. Specifically the network and reach of poverty reduction funds and programs such as Benazir Income Support Program could be expanded to include small landholding farmers from rainfed areas.
c) Reduce taxes on research instruments, equipment and other necessary tools used for development of good breed of drought tolerant crops. Encourage use of resource conservation techniques and technologies such as laser land leveling, rainwater harvesting, efficient irrigation techniques so to reduce the cost of land preparation, cultivation and crop management and complement the use of drought tolerant hybrids.
d) Build and improve public-private partnership in seed supply chain so it can meet the seed market needs and demands.

3.3.3.2.1 Non-financial measures

Market failure and imperfection/ Regulatory, legal and legislative

a. In order to build a diverse, expanding, stable and profitable seed market including one for drought tolerant crops and other similar crop varieties, the most crucial step is for federal and provincial governments to have carefully review the existing acts, laws such as Seed Amendment Act, 2015 and Plant Breeder's Rights Bill, 2016. It is very important to address and resolve the reservations of key stakeholders on private investment and protection of small landholding farmers' right before the final approval of the bills and its implementation.
b. Build and improve public, private and public-private sectors to strengthen the market. In private sector, the large transnational seed companies have extensive and well-resourced research capacity, extensive network of technology suppliers, and can easily transfer adapted germplasm from one country to another. Build public-private partnership, and this would lead to an efficient and sustained seed distribution system.

Technical/ Information and awareness

a. Strengthen institutional capacity of agriculture research organizations in terms of building research infrastructure, human resources, and knowledge transfer.
b. Seed quality testing labs may be established in agricultural areas and appropriately equipped to provide required seed quality testing service to the farming communities.
c. Agricultural extension services may be geared to disseminate appropriate knowledge and awareness about the availability and potential benefit of the use of drought resistant seeds varieties.

3.4 Barrier Analysis and Possible Enabling Measures for Climate Monitoring and Forecasting-Early Earning System

3.4.1 General description of the technology- Climate monitoring and forecasting - early warning system technologies

The purpose of the weather forecasting and early warning system technology is to detect and forecast the extreme climatic events with sufficient lead time so that the public can be alerted in advance to take appropriate response to minimize the impact of the climate related hazards and to save the losses to the life, property and crops.

However, the accurate and reliable predictions of day to day weather, and particularly future impacts of climate change are largely handicapped by high level of uncertainty associated with non-availability of accurate and reliable data. As such, due to the complexity of global climate and weather systems, regular measurement of specific variables provided by climate monitoring and early warning systems are particularly indispensable for countries like Pakistan where the frequency and intensity of extreme and erratic weather patterns is increasing due to climate change. This measurement is also essentials facilitate disaster preparedness and adaptation planning in the country.

With dense climate monitoring and effective prediction and early warning communication system in place, this technology increases the effectiveness of vulnerability monitoring, allowing individuals (farmers) and community to prepare for hazards. It also enables early identification of at-risk population in disaster prone areas and provides decision makers with the information for effective adaptation planning and its mainstreaming in national development goals.

3.4.1.1.1 Technology status in Pakistan

Pakistan Meteorological Department is the national institution responsible for early warning system for floods, drought, heat wave, and cyclonic storms, of which flood-warning system is the most mature and sophisticated one. After the floods of 2010, the Department has installed a flood alert and management information system- a comprehensive system that serves multipurpose ranging from flood alert, flood control and management.

The present climate monitoring, forecasting and early warning system operative in the country desirably needs and upgrades are given as under:

1. Expansion of existing climate monitoring stations.
2. International cooperation, data exchange nationally and internationally.
3. Availability and use of real-time high resolution satellite imagery.
4. Development and use of weather forecasting models.
5. Installation and up-gradation of weather surveillance radar Systems.
6. Improvement in early warning dissemination system.

3.4.1.2. Technology Category and Market Characteristics

The Climate monitoring, forecasting and early warning technology can be categorized as a non-market public good when established at state-level. The technology option being considered in this report is a state-run and state-provided climate monitoring and early warning service which is a non-market public good.

3.4.2 Identification of barriers

The barrier identification to the diffusion of technology essentially based on literature reviews, interviews with sector experts, consultation and brainstorming sessions with stakeholders and with Adaptation Expert Working Group at the workshop. The identified barriers and measures were analyzed using the starter problem and solution trees presented in Annex-1.13 to 1.14. The identified barriers are divided into two main categories- economic/financial barriers & non-financial barriers. Non-financial barriers are further divided into five subcategories - policy/regulatory barriers, capacity/information barriers, technology barriers, social and environmental barriers. The barriers prioritized through stakeholder consensus are described below.

3.4.2.1 Economic and financial barriers

There is hardly any economic barrier to the diffusion of technology as the technology is a public good and not market-based. However, high initial investment cost and inadequate government financial support is major financial barrier to technology diffusion. As such the key financial barriers identified through the above-mentioned process are as under:

a. High initial investment cost of building a dense climate monitoring network, setting-up an advanced forecasting and efficient early warning system.
b. High operational and maintenance cost of such an advance forecasting and early warning system.

3.4.2.2 Non-financial barriers

a. Limited expertise to develop and run advanced numerical forecasting models.
b. Limited capacity to interpret satellite high-resolution imagery and forecast model output at local level.
c. Absence of dense climate monitoring station network.
d. Limited research in the area of weather and climate change science.
e. Absence of any university offering degree courses in field of meteorology or climate sciences.
f. Limited real-time climate and rivers flow observational data availability.
g. Absence of free data exchange among national users organizations.
h. Limited cooperation among relevant government agencies such as meteorology department, disaster management, agriculture, irrigation and water management authorities at federal and provincial level.

3.4.3 Identified measures

In order to overcome the above identified barriers and to promote technology diffusion, the adoption of following measures are recommended.

3.4.3.1 Economic & financial measures

a. Allocating increased needed financial resources for the modernization, expansion, and up-gradation of climate monitoring, forecasting, and early warning system in the country.
b. Ensure needed budgetary provision for regular operation and maintenance cost of system.

3.4.3.2 Non-financial measures

a. Create close cooperation with relevant international institutions for sharing knowledge, data and satellite products etc.

b. Enhance research and technical capacities of relevant national institutions for the development and application of global climate models and their output and products.
c. Ensure the development of effective early warning communication and dissemination system.
d. Ensure community and local institutions' involvement in the use and dissemination of forecast and early warnings for reducing the losses emanating from climate related disasters.
e. Promote easy data exchange and research outcomes among relevant stakeholders.

3.5 Common barriers identified in agriculture sector

This section looks at the barriers common to different prioritized technologies in agriculture sector such as drip/ sprinkler high efficiency irrigation techniques, drought tolerant crop varieties and climate monitoring and forecasting- early warning system. Specifically the barriers identified in Table 3.1 are common and inter-linked with three technologies; overcoming one barrier for a technology would translate into resolving some challenges in other technologies, that would eventually lead to rapid and more sustained adoption and diffusion of all these technologies in the agriculture sector of Pakistan.

Table 3.1 Common barriers identified for different prioritized technologies in agriculture sector

Barrier Category	Barriers
Economic & Financial	High capital, operation and maintenance costs
	Low incentives in the form of short term subsidy or soft loans
Information & awareness	a. Limited information and awareness about the existence and usefulness of the technology b. Limited communication among technology developer, supplier, and users
Institutional and organizational capacity	Limited institutional capacity
	Limited R&D capacity
	Limited human skills and training in designing and installation of systems
Market imperfections	Small underdeveloped market. Weak supply chain and distribution mechanism

The above-mentioned barriers are common and inter-linked in agriculture sector technologies. Therefore, overcoming these barriers would immensely help in adoption and diffusion of all three prioritized agriculture sector technologies.

3.6 Enabling framework for overcoming the barriers in the agriculture sector

Agriculture is the backbone of Pakistan's economy. But hardly any agriculture development strategy and plans has taken into account the future tendencies and challenges posed to food security in the long run. Bearing in mind that climate change is threatening the food security because it can exacerbate the scarcity of water resources through high evaporation regimes and reduced and erratic rainfall.

The following section explores the specific measures needed to enable the country to overcome the identified barriers of prioritized agriculture technologies. The literature review and interviews with technology experts and users show that creating and strengthening the enabling environment for support of agriculture technology depends on many key elements which are tied with policy and regulatory framework, market imperfections and other institutional and organizational capacity building measures. The most crucial elements identified through this participatory, research based process have been:

1- Policy and regulation
2- Public agricultural research and
3- Enterprises development

1- Policy and regulatory frameworks are important which act as a guide to avoid technology externalities faced by end-user. A key component of the enabling framework for overcoming the barriers to the diffusion of prioritized technologies in the agriculture sector should be the earliest adoption of draft national agriculture policy and the enhanced operationalization of the existing national climate change policy and its implementation framework's agriculture and water related recommendations. This policy measure must be supported by an increased budgetary allocation for the diffusion of above-mentioned prioritized technologies through the facilitation and mobilization of national budgetary resources including external donor agencies.

Likewise, strong regulatory environment is crucial in handling market imperfection and failure specifically in case of technology innovation benefits from patents and intellectual property rights; for example, new crop varieties can be produced at optimal level with some type of plant variety protection in place. In case of poorly or underdeveloped markets for a technology, high transaction cost generally limits the development and spread of technology. Examples related to agricultural technology include the cost of acquiring information about new technology, poor quality control by inexperienced or fraudulent enterprises, various types of importers, input dealers, and other intermediaries who deliver technology to farmers. A strong regulatory structure to handle the high transaction costs is important that will offer adequate protection to farmers against environmental externalities of technology along with transaction costs.

2-The public research institutions are facing acute challenge of decline in funding either by government or donor supports. Private companies generally do not invest in research, which generate information on techniques that cannot be privately marketed. Hence investment in public research is necessary and it is equally importance that agricultural research institutions improve their industry-based links that would boost their learning and ability to interact with private enterprises. In the context of technology innovation, it is crucial that agricultural research institutes become well aware of intellectual property rights and establish such policies to protect them while closely working with private enterprises that are able to deliver their technologies to farmers.

3-Participation of private entities in development and diffusion of pro-poor environmentally sensitive technology is highly acknowledged. Capacity of local private sector is a defining element in delivery of successful technology to end-user both for private and public agricultural technology. This includes private manufacturing firms for various efficient irrigation systems, seed companies, building developers and contractors.

Ensuring the required investment is the fundamental enabling factor across all agriculture sector technologies implementation. All the enabling measures can benefit from fundamental measures such as training, human and institutional capacities enhancement, strengthening laws and regulations, setting of appropriate policies (incentives or disincentives), ensuring climate informed –decision making and planning, promoting research and technology awareness, and implementing pilot demonstration projects.

Therefore, the proposed enabling framework basically can be divided into following broad categories:

a) Ensuring appropriate financial mechanism to support development and diffusion of agriculture prioritized technologies to offset the high capital and operation and maintenance cost. For agriculture sector technologies also 'Economic Affairs Division' should made efforts to obtain grants/ soft loans from international donors particularly from international climate financing sources.
b) Mainstreaming climate change considerations into relevant sectoral polices, plans and strategies.
c) Ensuring that sufficient financial resources are available to R&D institutions for strengthening and undertaking research, training and technology awareness raising activities among stakeholders.
d) Strengthening operation and maintenance institutional capacities at national and sub-national levels. Special training to train local technicians in operation and maintenance of agriculture prioritized technologies.
e) Implementation of practical pilot demonstration projects.

For a sustainable technology transfer, a suitable enabling environment can initiate a paradigm shift from project based, short time-framed site development to skill development in technology end users which are mainly farming community. Engagement of farmer for skill development and imparting knowledge to them will develop technology ownership that is important to up scale the technology at wider scale. The enabling factors also require that all stakeholders should be involved in planning, designing, and implementation not only at demonstration site but also other knowledge sharing and training programs for each technology. A brief account of identified barriers and measures needed to diffuse each prioritized technologies in agriculture sector is given in Table 3.2.

Table 3.2. Key technology barriers and measures for agriculture sector of Pakistan

Technology barriers	**Measures**
High efficiency irrigation system	
1. High initial cost of technology installation, and O & M 2. Underdeveloped supply chains, small market size and weak market information	1. Provide financial assistance in the form of subsidy, low taxes, and soft loans to technology users 2. Improve trade policies, provide incentives to develop demand and supply sides
3. Lack of collaboration and communication between technology developer, manager and user communities 4. High level of expertise required in design	3. Improve access to technology information 4. Train farmers and other users including agriculture extension staff

and installation of system	
Drought tolerant crop varieties	
1. High initial finances required for genetic manipulation or crop breeding experiments to produce desirable seed varieties 2. Small and under-developed market for such crop varieties; high competition among local variety and imported varieties 3. Limited numbers of seed testing and certification centers	1.Provision of credits and loans to farmers and ensuring access on terms of farming community 2. Establish functional market, improve information 3. Increase number of testing facilities and also the number of skilled staff
Climate monitoring and forecasting- early warning system	
1. High cost of installation, O&M 2. Absence of dense climate monitoring station network 3. Limited research in the area of weather and climate change science 4. Absence of free data exchange among national users organizations	1 & 2. Allocating increased needed financial resources for the modernization, expansion, and up-gradation of climate monitoring, forecasting, and early warning systems in the country 3. Provide funding to R&D institutions and build their capacity 4. Improve coordination and collaboration among national, regional and international organizations and R&D agencies for data and products sharing, and improved relationship with other users organizations

Acknowledgments: *The technical team of this TNA project want to put on record the contributions of particularly two individuals Mr. Imran Khan Head of TNA Technical Support Unit MoCC and Ms. Masooma Hassan Climate Change Expert for their deep professional involvement without which the timely completion of this report may not have been easy.*

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Annex I: Market Mapping and Problem-Solution Trees

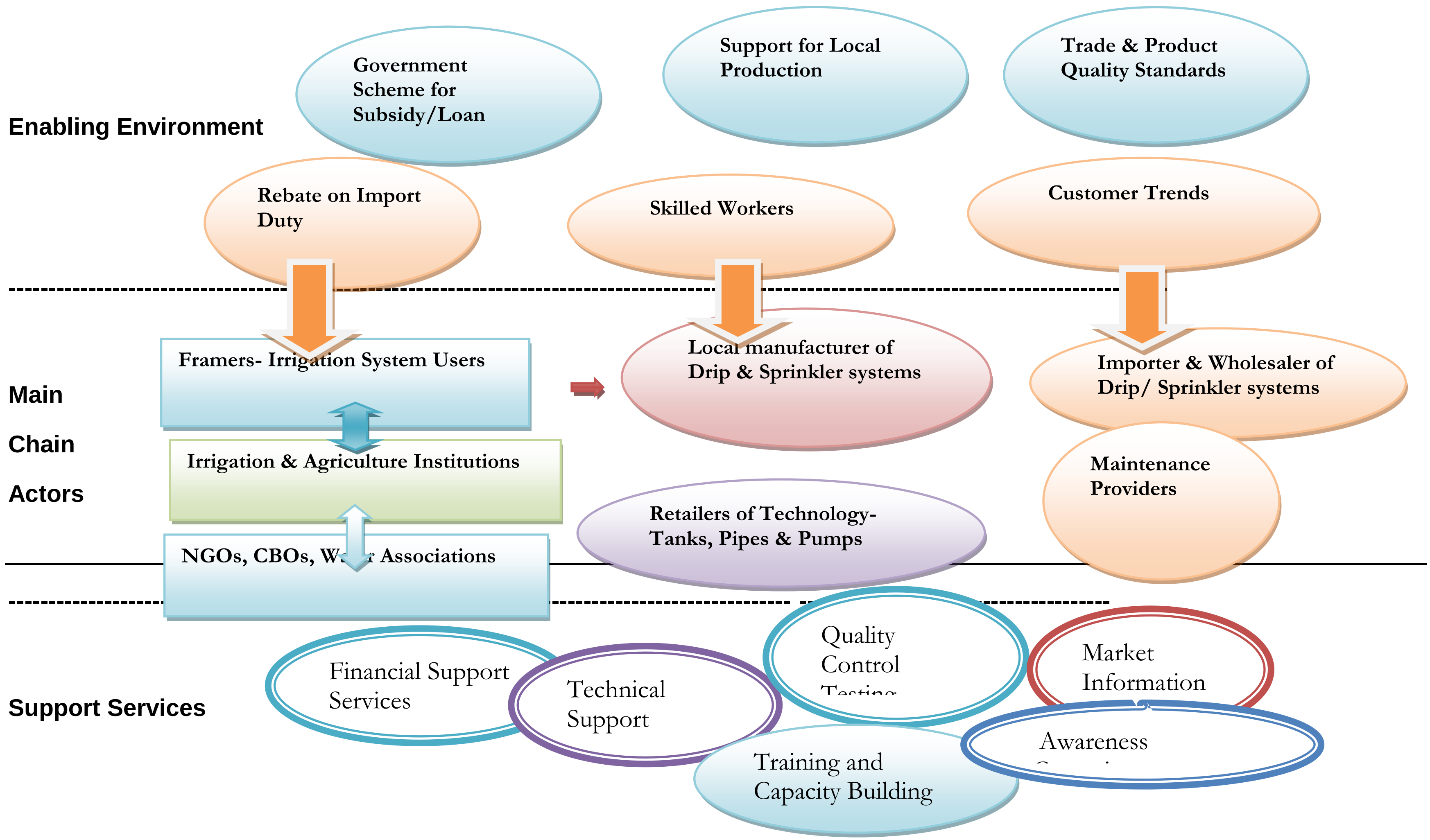
Market Mapping: Market mapping is only applied to technologies which are identified as the market consumer goods such as high efficiency irrigation systems and drought tolerant crop varieties.

During the market mapping exercise, the stakeholders helped to identify market chains and discussed its different components and their inter-linkages. The construction of such maps has helped to communicate the institutional and commercial environment in which a specific technology developer, user and a manager operates and impact the technology demand and supply chains through holding or releasing the required information.

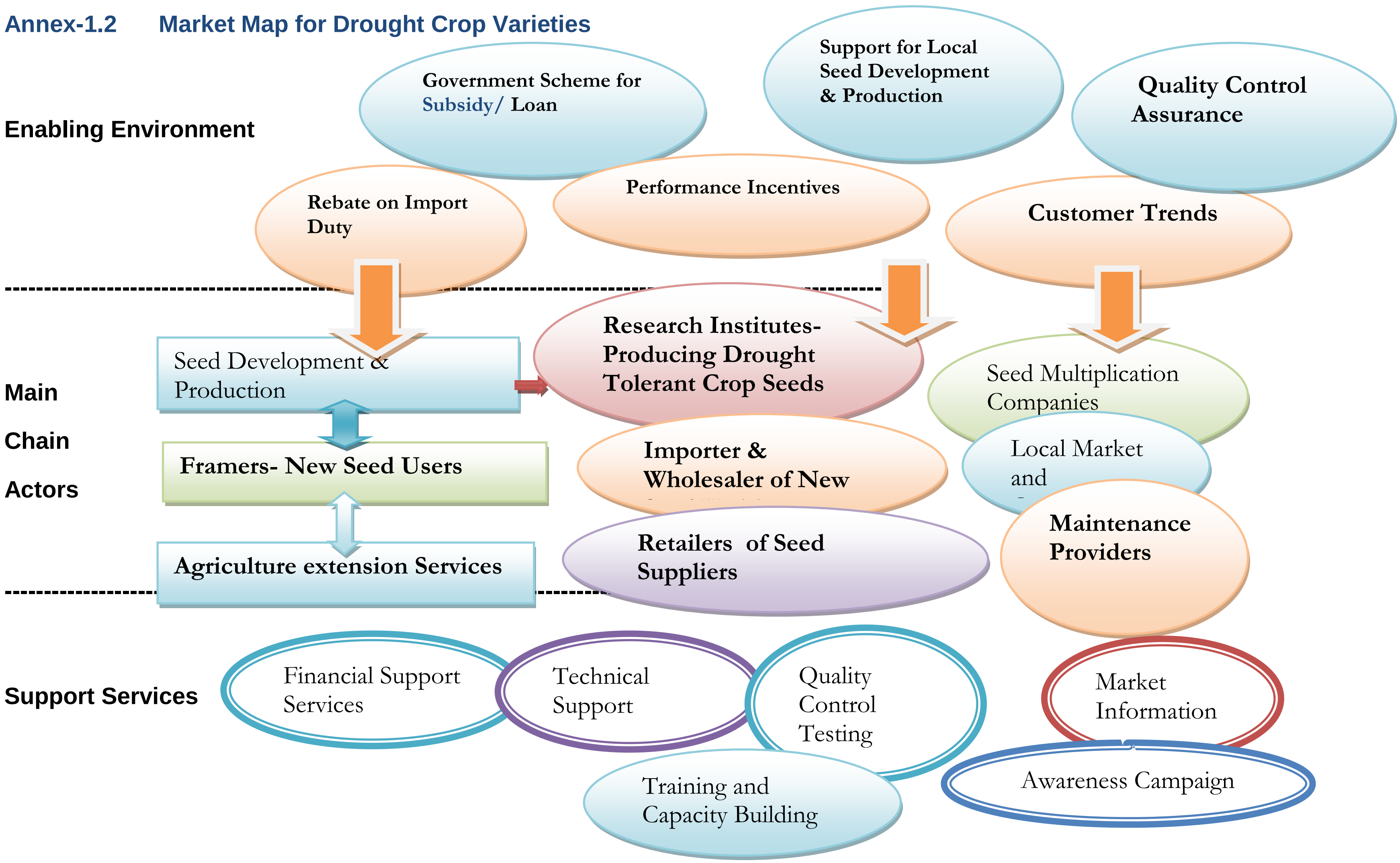
The main market mapping elements considered are: enabling environment- legal, organizational, market chain developers, wholesaler, retailer and consumer etc. For example, the market chain for drought tolerant crop varieties includes- seeds developer, producer, extension services, whole sellers, retailers, and farmers/consumers. The specific market maps for the two markets technologies are given as Annex 1.1 and Annex 1.2.

Problem and Solution Trees: The problem and solutions trees for each technology were prepared and used by experts to identify and analyze the barriers and to find measures to overcome the identified obstacles to the diffusion of each technology. Problem/Solution trees for all the six prioritized adaptation technologies are presented in Annex 1.3 to Annex 1.14.

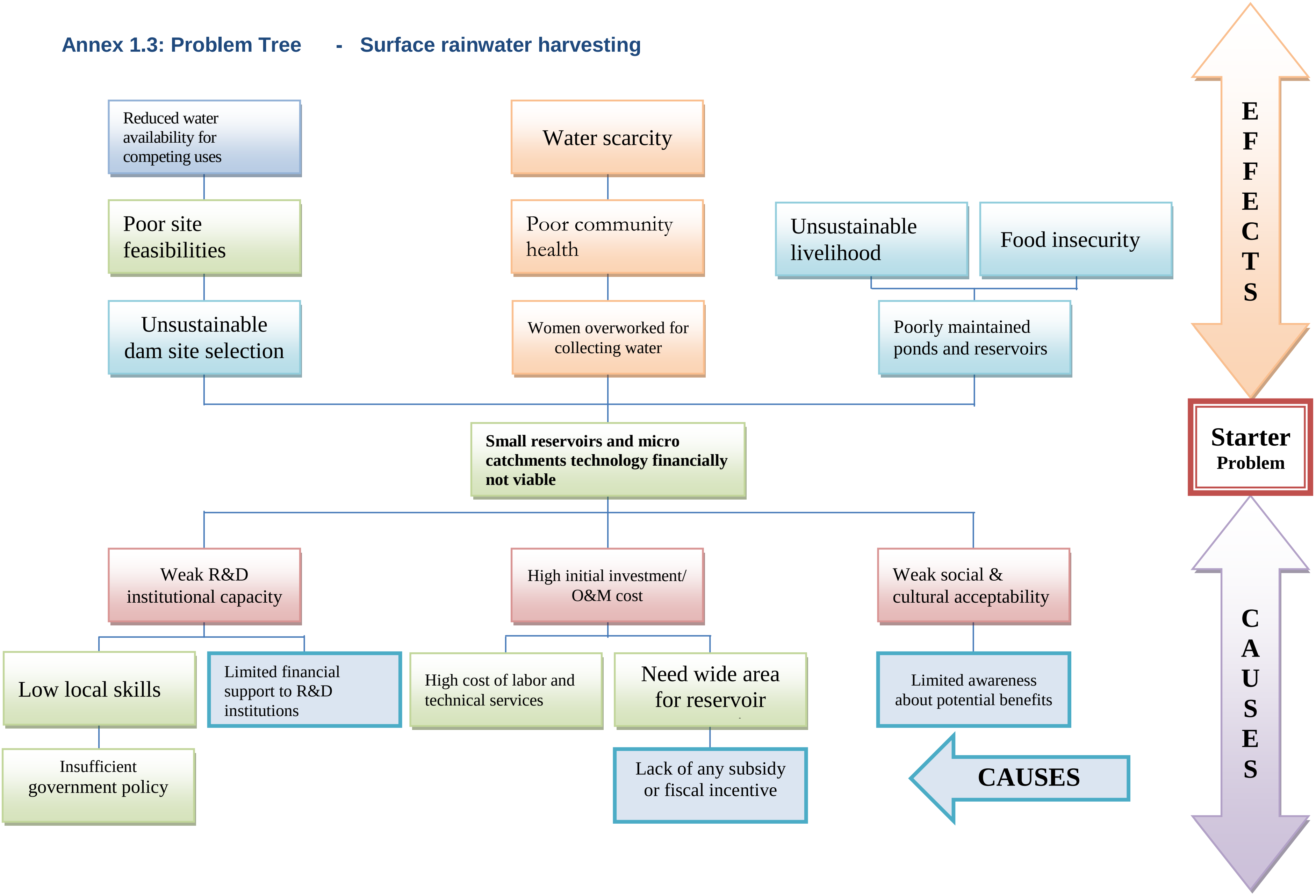
Annex-1.1 Market Map for drip & Sprinkler irrigation system



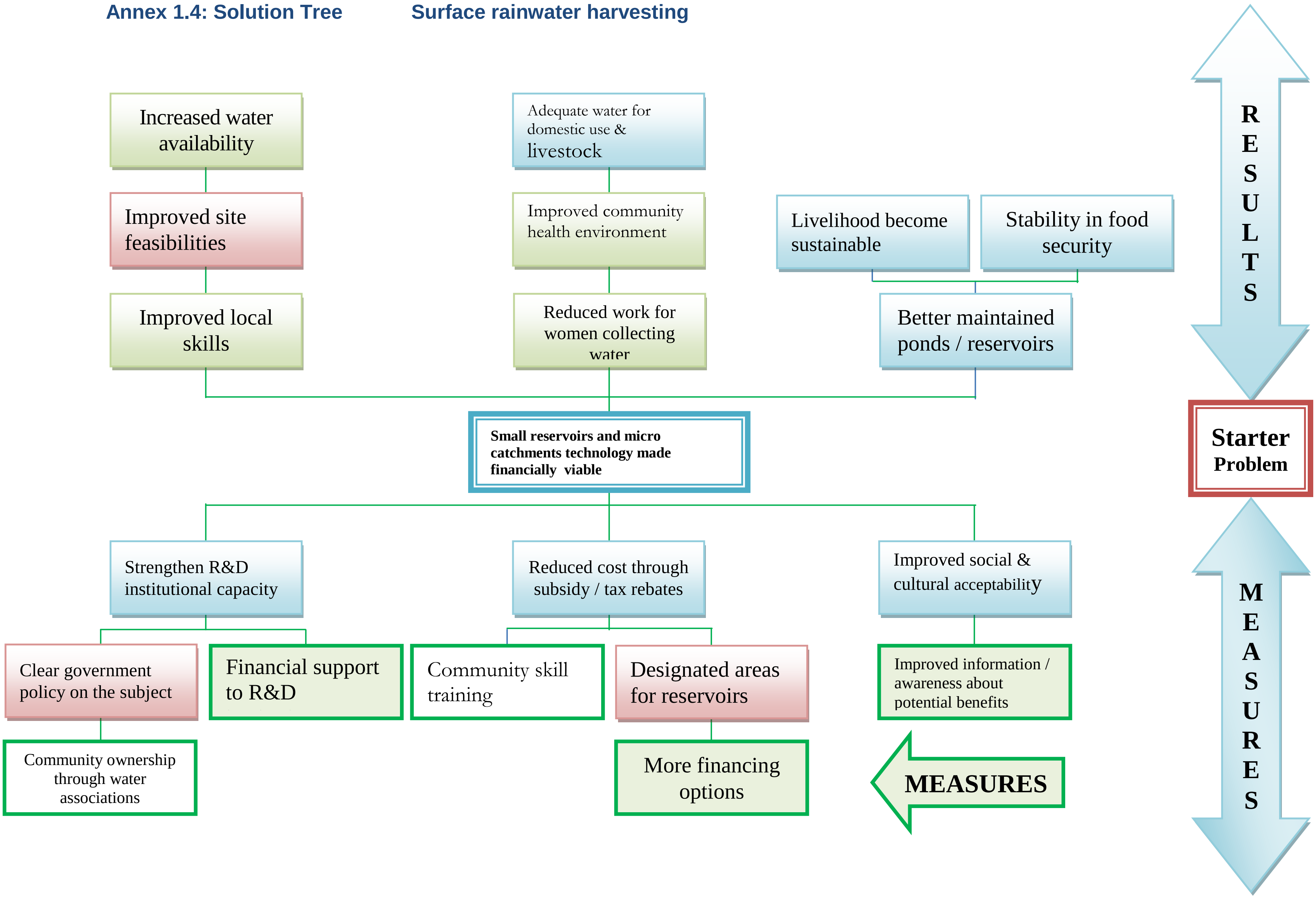
Annex-1.2 Market Map for Drought Crop Varieties



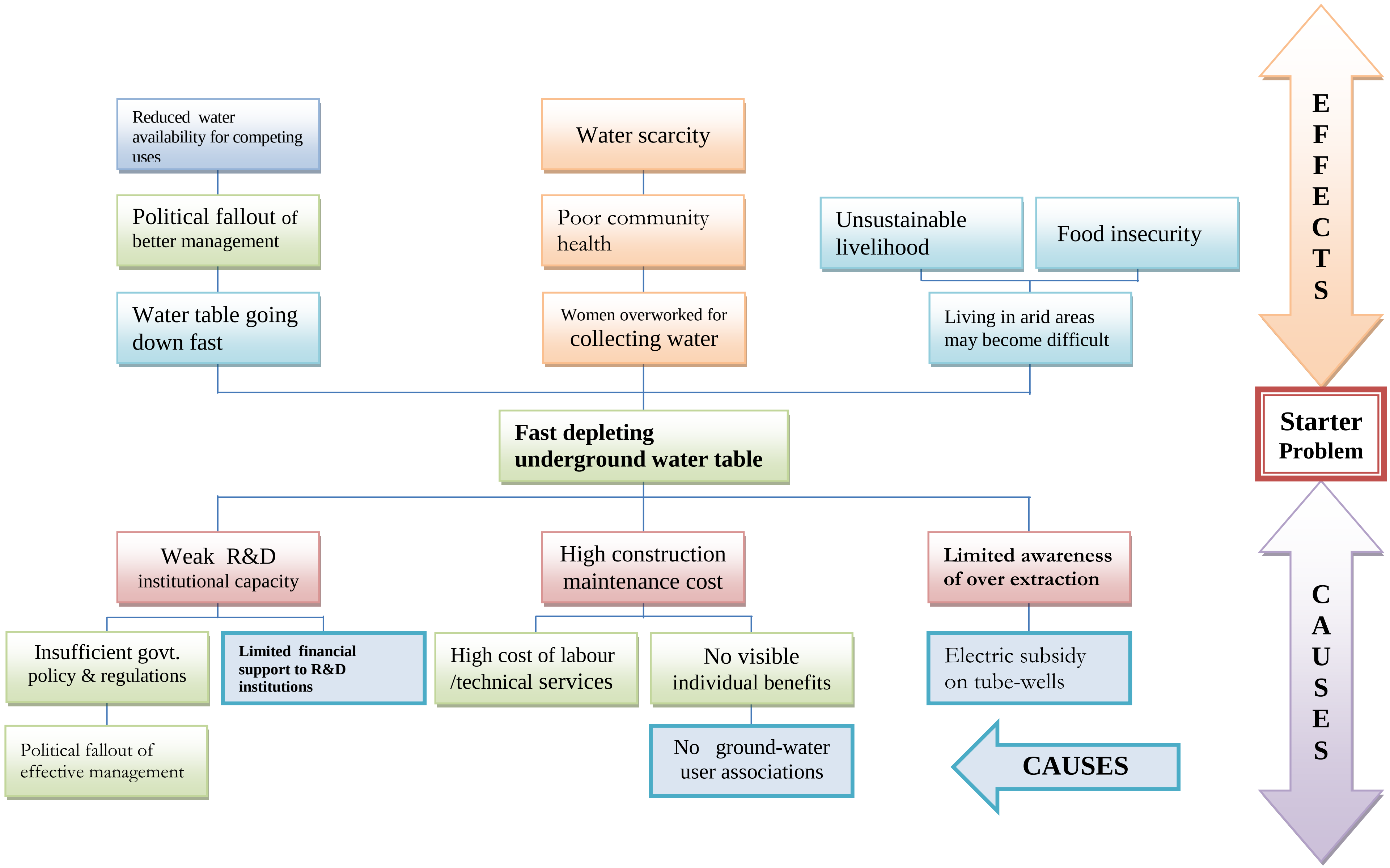
Annex 1.3: Problem Tree - Surface rainwater harvesting



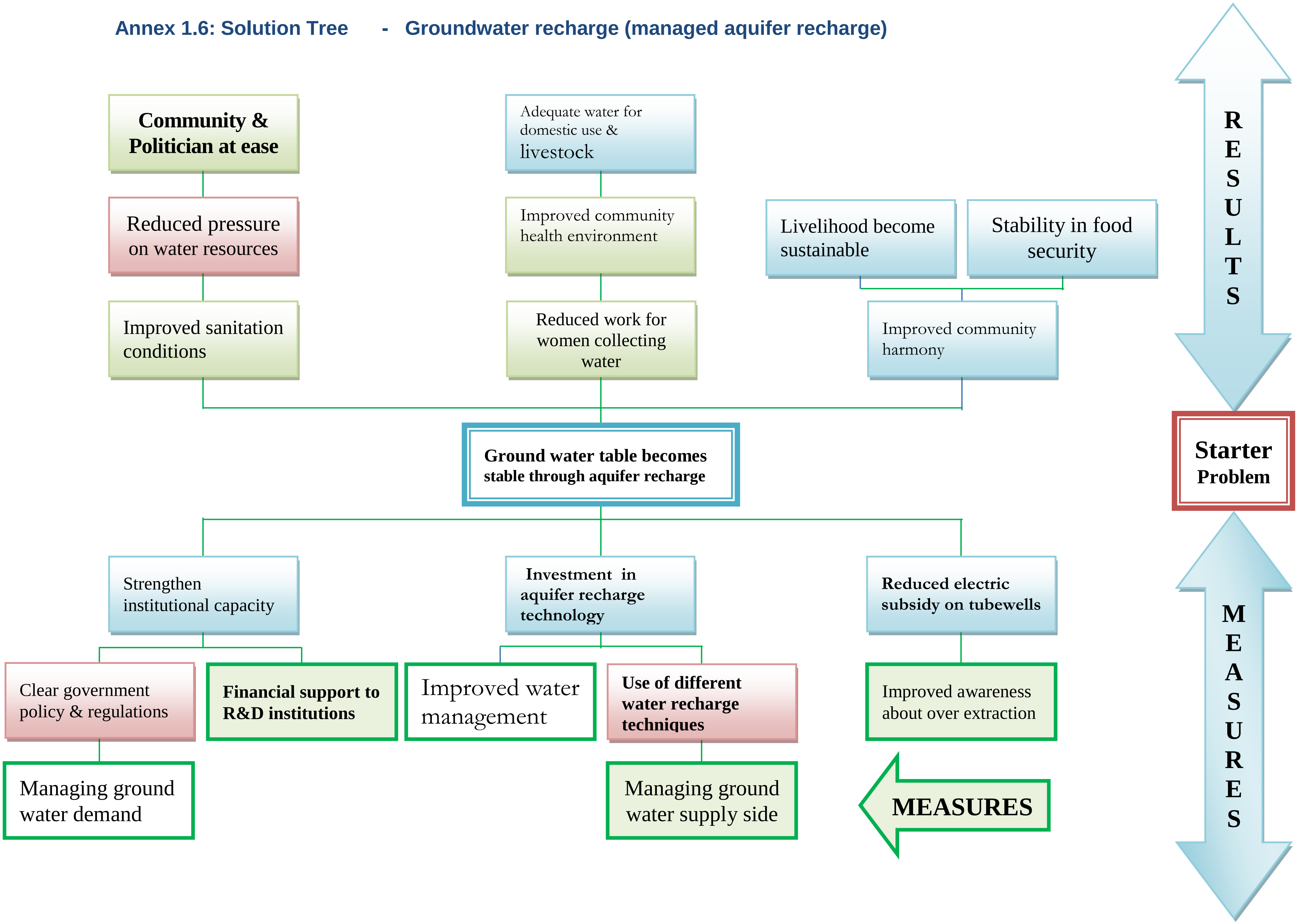
Annex 1.4: Solution Tree Surface rainwater harvesting



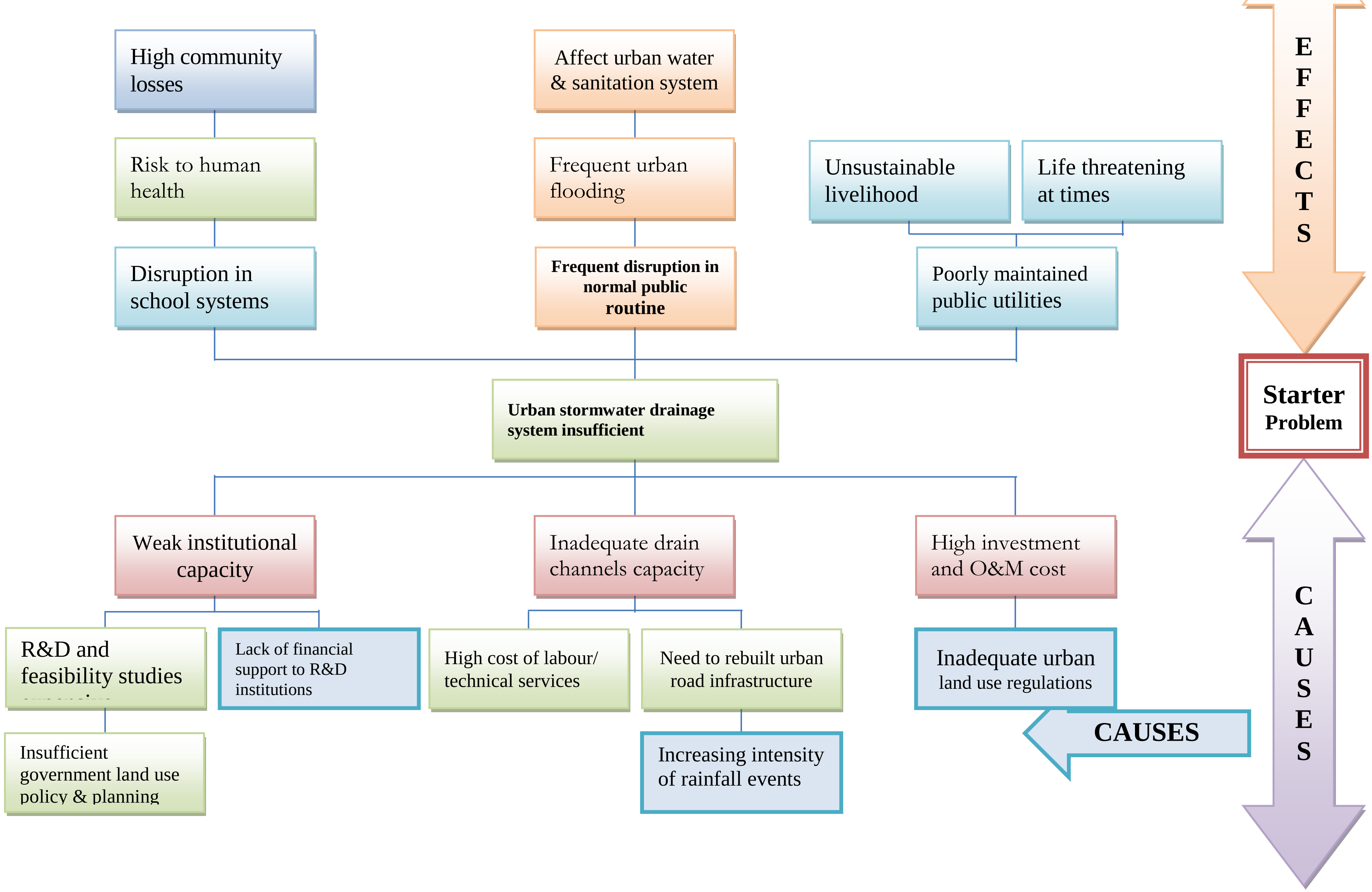
Annex 1.5: Problem Tree - Ground water recharge (managed aquifer recharge)



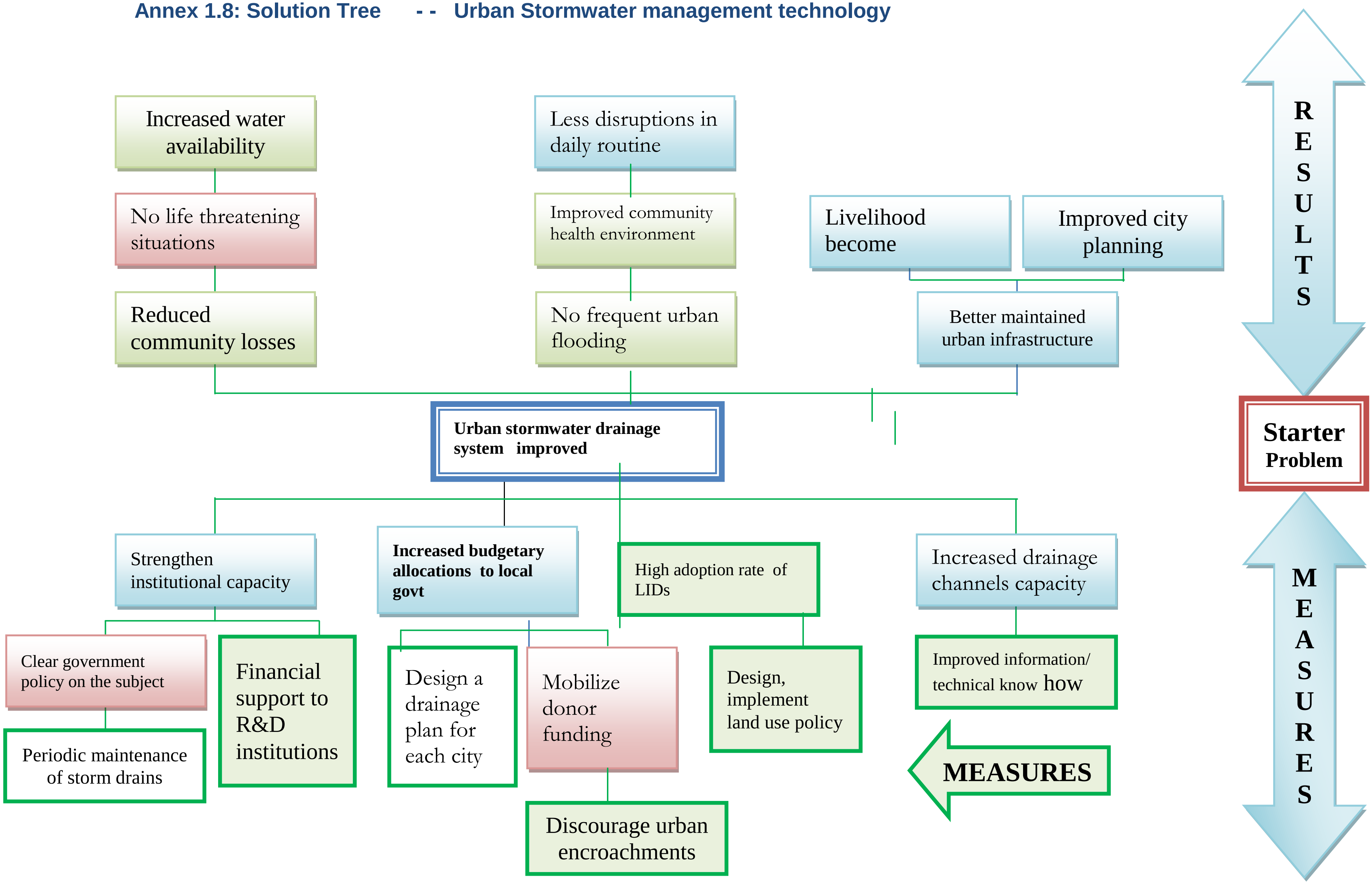
Annex 1.6: Solution Tree - Groundwater recharge (managed aquifer recharge)



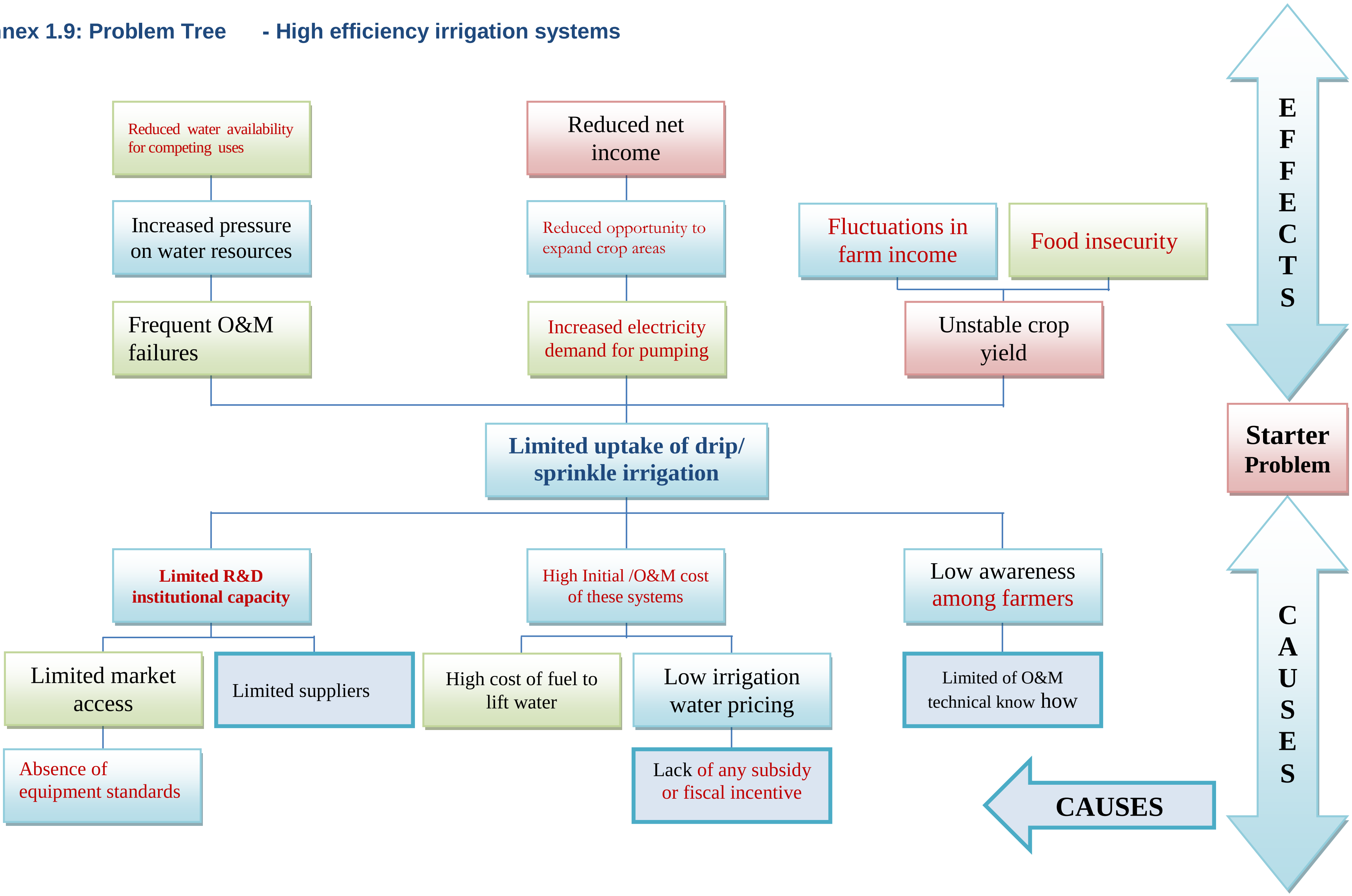
1. Annex 1.7: Problem Tree - Urban Storm drainage infrastructure technology



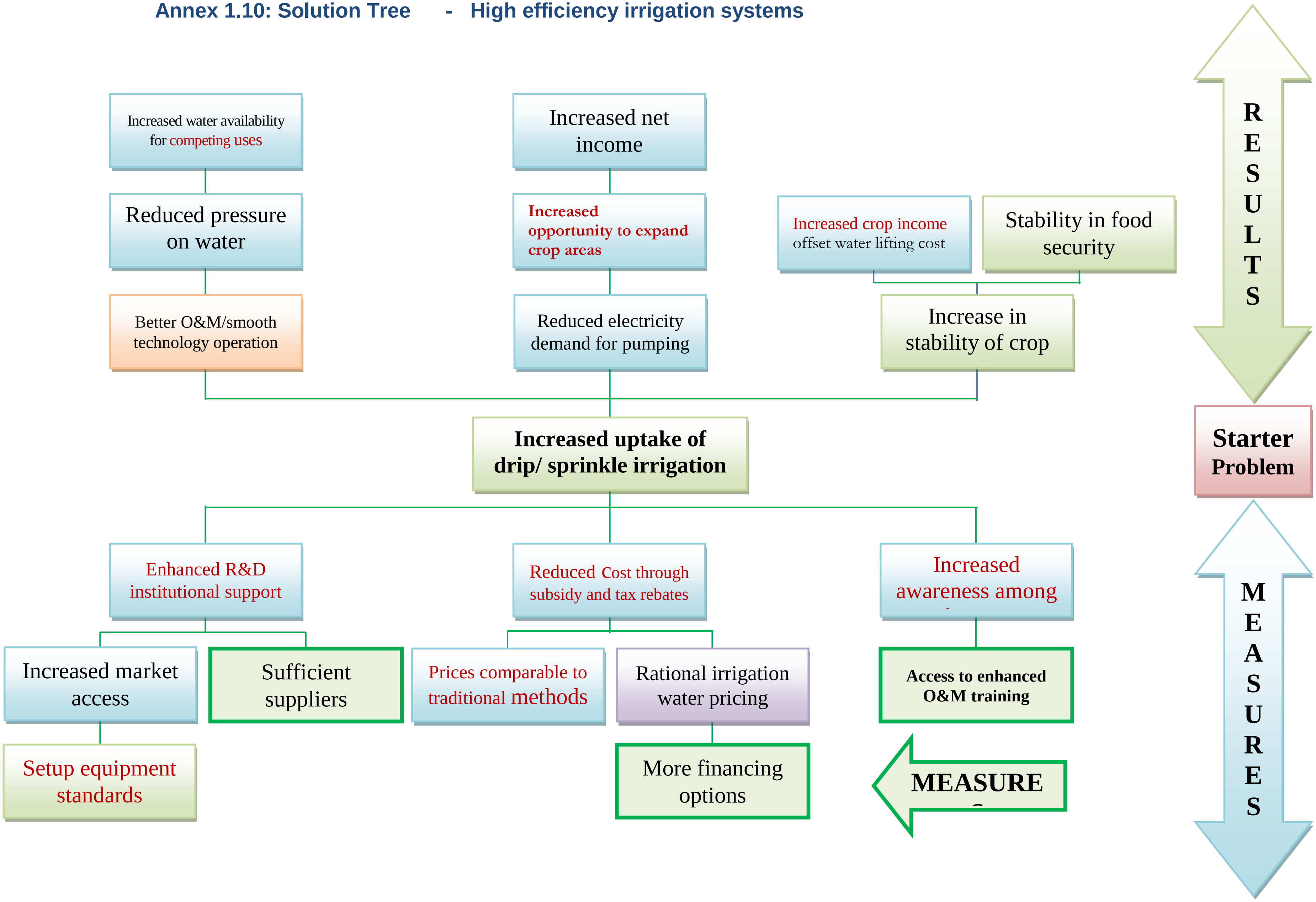
Annex 1.8: Solution Tree -- Urban Stormwater management technology



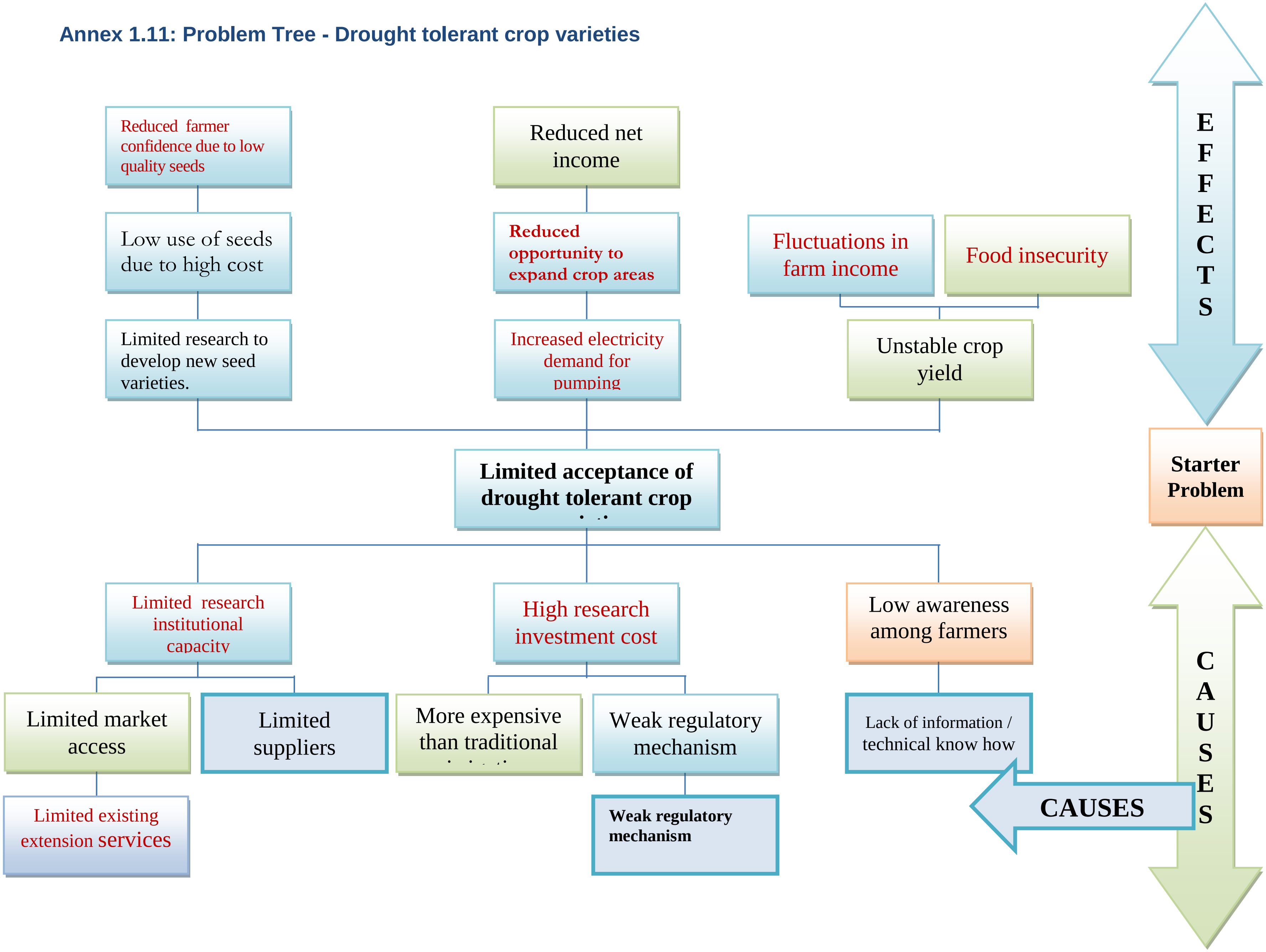
Annex 1.9: Problem Tree - High efficiency irrigation systems



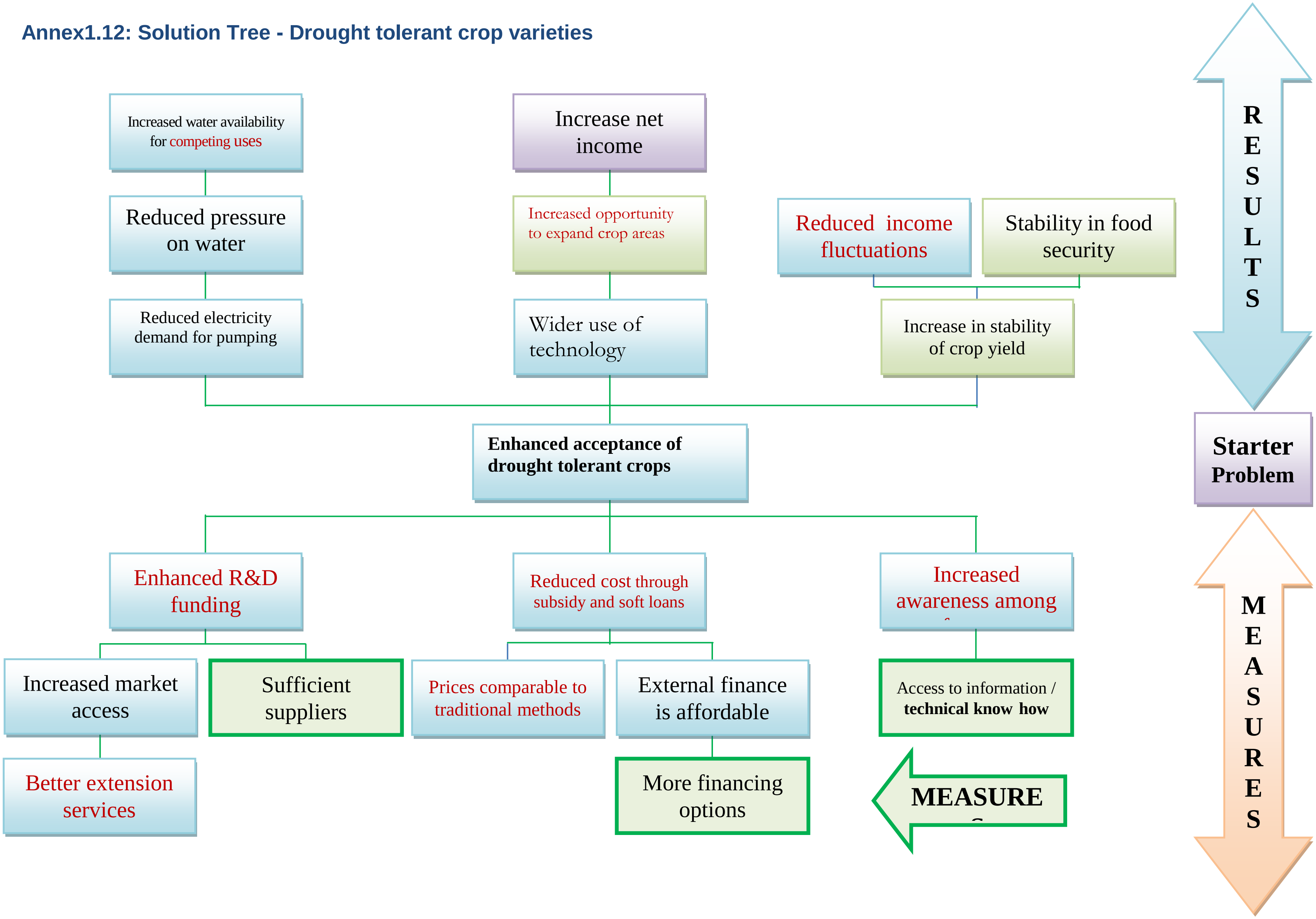
Annex 1.10: Solution Tree - High efficiency irrigation systems



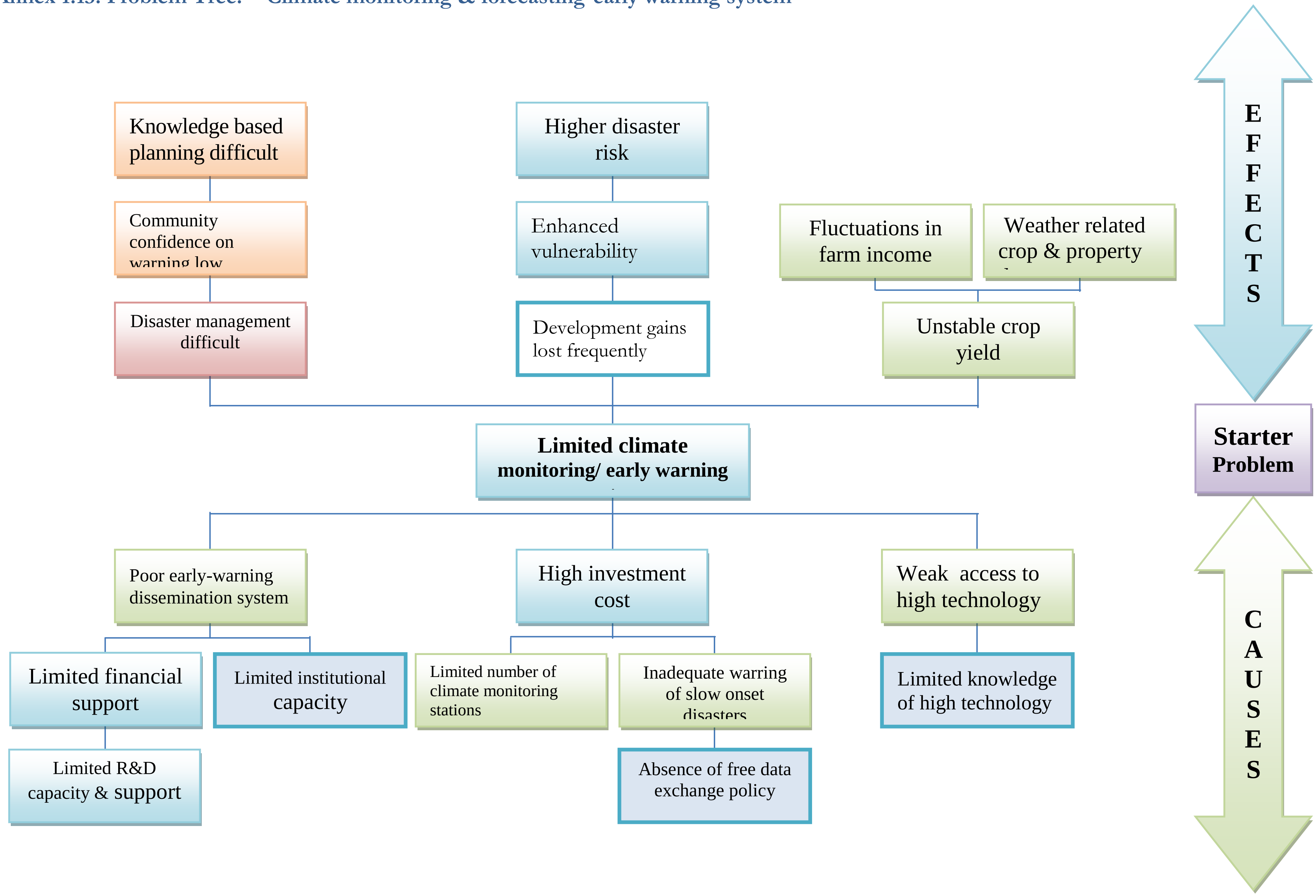
Annex 1.11: Problem Tree - Drought tolerant crop varieties



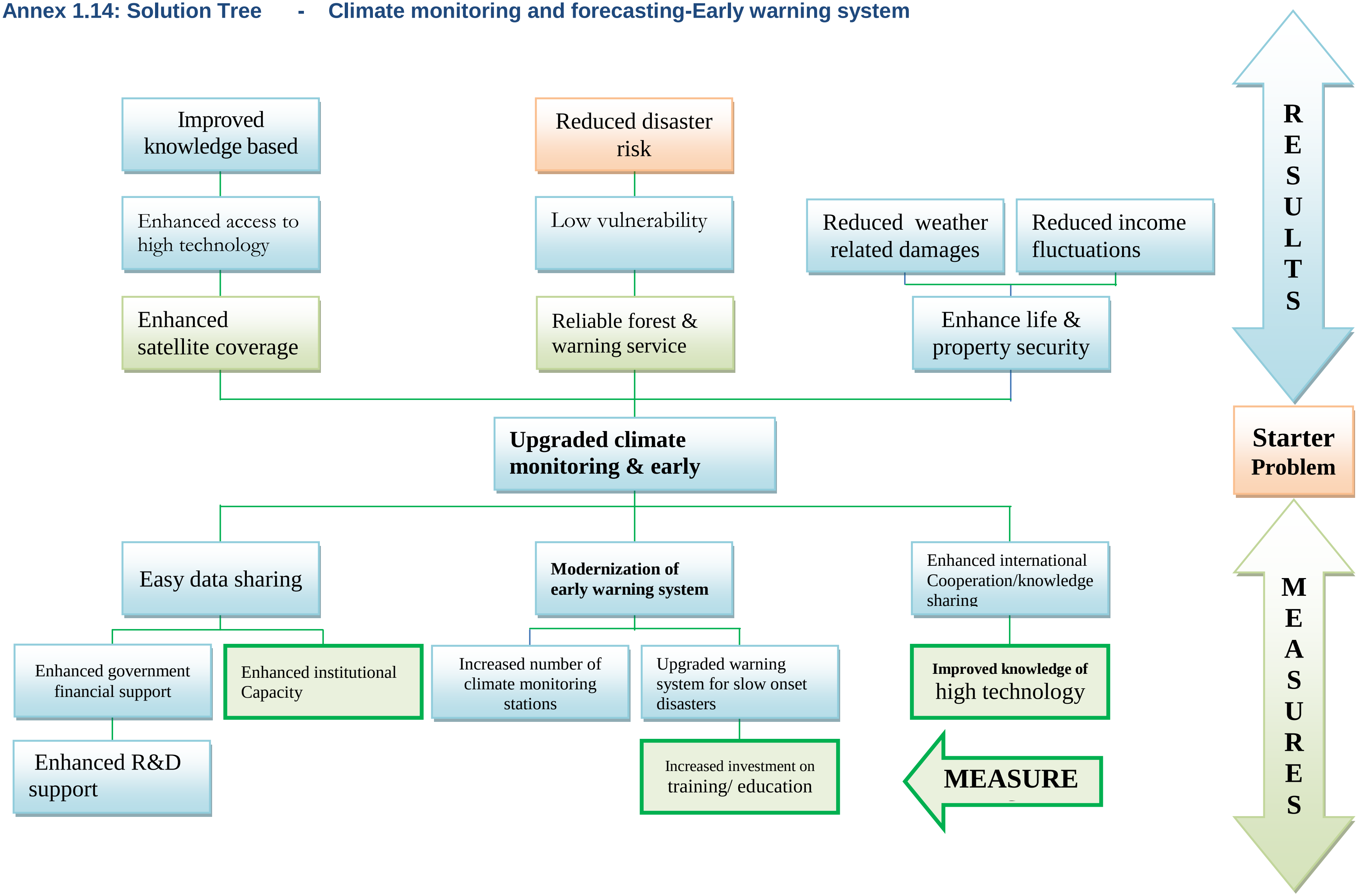
Annex1.12: Solution Tree - Drought tolerant crop varieties



Annex 1.13: Problem Tree: - Climate monitoring & forecasting-early warning system



Annex 1.14: Solution Tree - Climate monitoring and forecasting-Early warning system



Annex II. List of stakeholders involved in TNA process

Sr. No	Name	Organization/ Contact	Type of Consultation
1	Mr. Arshad Laghari Member National Assembly	Chairman, Parliament Standing Committee on Water Resources	One to one
2	Mr. Junnaid Iqbal Chaudhry Member National Assembly	Member, Parliament Standing Committee on Water Resources	One to one
3	Mr. Afzal Hussain Tarar Progressive Farmer & Fromer Member National Assembly	H- , Bird wood Road, Lahore	One to One
4	Mr. Raiz Ahmed Khan	Former Federal Secretary, Ministry of Water & Power	One to one
5	Mr. Irfan Tariq Director General	Ministry of Climate Change, Islamabad	One to one & round table discussion
6	Mr. Seerat Asghar Jaura, Federal Secretary, Food Security	Ministry of Food Security & Research	One to one
7	Dr. Arshad M Khan	Former Executive Director Global Change Impact Study Centre (GCISC), drarshadmkhan@yahoo.co.uk	Round table discussion
8	Dr. Muhammed Hanif	Director, Pakistan Meteorological Department hanifwxc@hotmail.com	Round table discussion
9	Mr. Javed Ali Khan	Former DG Environment dg.moenv@gmail.com	Round table discussion
10	Ms. Hina Lotia,	LEAD Pakistan hlotia@lead.org.pk	Round table discussion
11	Dr. Arshad Ali,	Director, Land Resources Research institute National Agriculture Research Centre (NARC), Islamabad	Round table discussion
12	Dr. Moshin Iqbal	Former Member Agriculture, Global Change Impact Study Centre (GCISC) drmoshiniqbal@gmail.com	Round table discussion
13	Mr. Munir Shaikh,	Former Member Climate Science, Global Change Impact Study Centre (GCISC) mmunirsheikh@yahoo.com	Round table discussion
14	Dr. Ashfaq Ahmed	Professor, Agriculture	Round table

	Chattha,	University, Faisalabad aachattha1@yahoo.com	discussion
15	Mr. Ghazanfar Ali,	Former Member Water Section, , Global Change Impact Study Centre (GCISC), ghazanfaar.ali@gmail.com	Round table discussion
16	Dr. Shahina Tariq	Chairman, Head of Department of Meteorology, COMSATS University, shahinatariq@comsats.edu.pk	Round table discussion
17	Dr. Akram Kahlown,	Former Chairman Pakistan Council Research on Water Resources (PCRWR) kahlown@hotmail.com	Round table discussion & One to one interview
18	Mr. Sajjad Yaldram, ,	Dy. Secretary, Ministry of Climate Change yaldramsajjad@yahoo.com	Round table discussion
19	Ms. Masooma Hasan	Environmental Policy and Planning Professional maychid999@gmail.com|	Round table discussion
20	Mr. Muhammad Akram Anjum,	Chief Meteorologist, Pakistan Meteorological Department akram58pmd@gmail.com	Round table discussion
21	Dr. Mohammad Azeem Khan,	Director General, National Agriculture Research Centre (NARC) azparc@yahoo.com	Round table discussion
22	Dr. Inayatullah Chaudhry	Agriculture Department ci@drinayat.com	Round table discussion
23	Dr. Aurangzeb Khan	Director General, Climate Change AJK Planning Department auranzeb_nrm@yahoo.com	Round table discussion
24	Shehzad Hasan Shigri,	Director Environmental Protection Agency, Gilgit-Baltistan shigri_shahzad@yahoo.com	Round table discussion
25	Dr. Qamar uz Zaman Chaudhry	Climate Change Adaptation Expert & Lead Author Pakistan Nation Climate Change Policy. dgmetpak@hotmail.com	Round table discussion
26	Dr. Ashfaq Ahmad Sheikh	Director General, PCRWR. ashfaq-sheikh@hotmail.com	Round table discussion
27	Dr. Abdul Majeed	Project Lead, Pakistan Centre for Advance Studies in Energy, IUCN, Islamabad, abdul.majeed@iucn.org	Round table discussion
28	M.Bashir Khan	Chief Foreign Aid, Agriculture P&DD AJK	Round table discussion

		directorajkepa@gmail.com	
29	Dr. Amjad Virk	Former Project Director SLMP Ministry of Climate Change amjad.virk@slmp.org.pk	Round table discussion
30	Dr. Jawad Ali	Director, Climate Change Centre, University of Agriculture, Peshawar jawad@helvetas.org.pk	Round table discussion
31	Mr. Asad Maken ,	Climate Change Unit, UNDP, Islamabad asad.maken@undp.org	Round table discussion
32	Mr. Mian Shaukat Shafi,	Asian Development Bank(ADB), Islamabad mshafi@adb.org	Round table discussion
33	Dr. M. Zia-ur-Rahman Hashmi,	Head, Water Resources & Glaciology Section, Global Change Impact Study Centre (GCISC), E-mail: ziahashmi77@gmail.com	Round table discussion
34	Ms. Javeria Afzal,	Advisor DRR & Climate Change, Oxfam Novib, Islamabad javeria.afzal@oxfamnovib-pakistan.org	Round table discussion
35	Mr. Muhammad Arif Goheer	Head, Agriculture & Coordination Sections, Global Change Impact Study Centre (GCISC), E-mail: arifgoheer@gmail.com	Round table discussion
36	Dr. Arshad Ali	Director Land Resources Research Institute, National Agriculture Research Centre (NARC). (arshadalinarc@gmail.com	One to one
37	Dr. Munir Ahmed	Director Climate Change, Alternate Energy and Water Resources Institute, National Agriculture Research Centre (NARC), (munir.wrri@gmail.com	Round table discussion
38	Muhammad Zubair	Deputy Director General, Water and Soil Conservation Unit Planning and Development Department, Government of Khyber Pakhtunkhwa	Round table discussion
39	Dr. Mahmood-ul-Hassan.	Senior Scientific Officer, Land Resources Research Institute, National Agriculture Research Centre (NARC), Islamabad	Round table discussion

		(mmh@comsats.net.pk)	
40	Mr. Khadim Hussain	Supplier, Micro Drip (Pvt) Ltd F-178/3, Kehkashan, Block 5, Clifton, Karachi-Pakistan	One to one interview
41	Ms. Nazima Shaheen	AcitonAid Pakistan. House 42A, Orchard Scheme, Murree Road, Islamabad Nazima.shaheen@actionaid.org	Round table discussion
42	Engr. Khurram Khaliq Khan	Procurement Consultant, World Bank, Islamabad kkkhaliq@yahoo.com	Round table discussion
43	Nasir Iqbal Ansari	Agribusiness Consultant, Fauji Foundation nasiriqbalansari@hotmail.com	Round table discussion
44	Tahawwar Ahmed	Consultant NDMA tahawwar@hotmail.com	Round table discussion
45	Ms. Faiqa Aziz	Ministry of Climate Change Faiqaaziz14@gmail.com	Round table discussion
46	Tayyab Shehzad	Consultant- Ministry of Climate Change tshahzad68@yahoo.com	Round table discussion

Annex III. Policy Factsheets

Annex III-1 Agriculture Sector

Policy Name	Agriculture and Food Security Policy
Name of Field	Agriculture
Date Effective	In draft
Date Promulgated	Still in draft
Unit	Agriculture
Country	Pakistan
Year	Still in drat
Policy Status	Under review
Agency	Ministry of National Food Security and Research
Funding	
Related Policies	Vision 2030; National Climate Change Policy
Stated Objective	To achieve sustainable growth in the productivity of major crops as well as the promotion of high value agriculture including horticulture, fisheries and livestock
Policy Type	No list is provided classifying policies
Policy Target	No list provided
URL	http://www.mnfsr.gov.pk/
Legal References	Policy is still in draft
Description	"The Policy sets out a vision and goal for agriculture and food security, along with a set of policy directions. This would help the provinces that have, after the 18th Amendment, overall responsibility for agriculture and rural development, to articulate their own polices and strategies, as well as formulate investment plans for both the public and private sectors. It includes a set of actions related to Federal and inter-provincial issues in agriculture and food security related to international and domestic coordination, upstream and strategic research. It also covers minimum standards for food safety, seed certification, and pest and animal health surveillance. Finally, it makes proposals for a series of federally funded flagship programs to address critical issues that need a national approach and political backing to be successful"

Annex-III.2 Draft National Water Policy

Policy Name	National Water Policy
Name of Field	Water
Date Effective	In draft since 2002
Date promulgated	Still in draft
Unit	Water resources
Country	Pakistan
Year	Still in draft
Policy Status	In draft
Agency	Ministry of Water and Power
Related Policies	National Water Supply and Sanitation Policy ()
Stated Objective	To develop potential water resources while efficiently manage and conserve the existing resources
Policy Target	No list is provided
URL	http://waterinfo.net.pk/sites/default/files/knowledge/National percent20Water percent20Policy percent20 percent28Draft percent29.PDF
Legal references	WAPDA Act, 1958, Environmental Protection Act, 1997, and Indus River System Authority (IRSA) Act, 1992
Description	The policy aims to contribute to food security and poverty reduction by fostering sustainable increase in productivity of water through optimal supply and better management of water resources. The policy wants to achieve efficient management and conservation of existing water resources, and optimal development of potential resources in order to manage conflicting water rights and inequitable water distribution among water users in canal command areas, groundwater mining in low recharge areas so to ensure safe and acceptable quality of water, minimize salt buildup and other environmental hazards in irrigated areas. The policy also emphasizes on institutional reforms to make managing organizations more dynamic and responsive.

Annex III.3 National Climate Change Policy (2012)

Policy Name	National Climate Change Policy
Name of Field	Climate Changes/ climate resilient development
Date Effective	September 2012
Date promulgated	February 2013
Unit	Climate Change
Country	Pakistan
Policy Status	On going
Agency	Ministry of Climate Change
Funding	GoP, International climate financing sources
Related Policies	Vision 2013, Draft National Agriculture and Food Security Policy, Draft Water Policy, Draft National Sustainable Development Strategy (2013), National Environment Policy (2005),
Stated Objective	To pursue sustained economic growth by addressing climate change challenges faced by the country through integration and mainstreaming of climate change policy in other cross-sectoral policies
Policy Type	Climate change and development
Policy Target	Policy and decision makers at national and provincial levels in various related ministries and organizations, development partners, NGOs, CBOs, and other stakeholders
URL	http://www.mocc.gov.pk/
Description	The policy addresses climate change mitigation and adaptation challenges and needs of economically and socially vulnerable sectors of the country. It aims to steer Pakistan towards climate resilient development through devising comprehensive sets of adaptation and mitigation measures for climate vulnerable sectors with sets of key activities to achieve the goal. This includes capacity building of concerned institutions, awareness raising, international and regional cooperation, and technology transfer and securing international climate finance systems.

Annex-IV List of policy makers contacted during TNA briefing and sensitization process

S. No	Name	Organization/ Department	Contact
1	Mr. Hashim Tareen	Secretary, Planning and Development, Government of Balochistan	2nd Floor, Block 6, Civil Secretariat, Zarghoon Road, Quetta Phone # 081- 9202425
2	Mr. Saleem Awan	Secretary, Irrigation and Power Department, Government of Balochistan	Civil Secretariat, Zarghoon Road, Quetta Phone # 081- 9201074
3	Mr. Abdul Rehman Buzdar,	Secretary, Agriculture and cooperative Department, Government of Balochistan	Room 19, Top floor, Block 2, Civil Secretariat, Zarghoon Road, Quetta Phone # 081- 920126
4	Mr. Ghulam M. Sabir	Secretary, Forests and Wildlife Department, Government of Balochistan	1st floor, Block 4, Civil Secretariat, Zarghoon Road, Quetta Phone # 081- 9202264
5	Mr. Naseer Kashani,	Additional Secretary (Regulations and Admin) Department of Finance, Government of Balochistan	Civil Secretariat, Zarghoon Road, Quetta Phone # 081-9201272
6	Mr. Iqbal Muhammad Chuhan	Secretary, Environment Department, Government of Punjab	Gate no. 8, Qaddafi Stadium, Ferozepur Road, Lahore
7	Mr Iftikhar Ali Sahoo	Secretary, Planning & Development, Government of Punjab	Civil Secretariat, Lower Mall, Lahore
8	Mr. Muhammad Mehmood	Secretary, Agriculture Department, Government of Punjab	Civil Secretariat, Lower Mall, Lahore
9	Mr. Muhammad Usman Chudhary,	Special secretary, Finance Department, Government of Punjab	Civil Secretariat, Lower Mall, Lahore
10	Mr. Capt.(retd) Saif Aanjum,	Secretary, Irrigation Department, Government of Punjab	Old Anarkali Road, Lahore
11	Mr. Syed Hassan Naqvi,	Additional Secretary, Finance Department, Government of Sindh	Civil Secretariat, No 4-A, Court road, Karachi
12	Mr. Syed Zaheer Haider Shah,	Secretary, Sindh Irrigation, Government of Sindh	Tuglaq House Sharah-kamal-Ata -Turk Karachi
13	Dr. Rahim Samroo, ,	Secretary, Industries and Commerce Department, Government of Sindh	Room no 303, Second Floor, Tuglaq House Sharah-kamal-Ata -Turk Karachi

14	Mr. Mir Ijaz Hussain,	Secretary, Planning & Development, Government of Sindh	Tuglaq House Sharah-kamal-Ata -Turk Karachi
15	Mir. Ijaz Hussain Talpur,	Secretary, Environment, Climate Change & Coastal Development, Government of Sindh	EPA Complex, Plot # FD-2/1, Sector-23, Churangi Korangi, Karachi

Ministry of Climate Change, Government of Pakistan